Australasian Universities Building Education Association Conference

Construction Education: Live the Future

44th AUBEA

https://www.deakin.edu.au/student-life-and-services/events/AUBEA2021

Deakin University CRICOS Provider Code: 00113B

Host University

28 - 29 October 2021
Virtual Conference

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Acknowledgements

The 44th AUBEA International Conference was originally planned to be held in October 2020, but the COVID-19 pandemic challenged its realisation. With the persistence and perseverance of many individuals and organisations, the conference has been made a success in 2021 in the virtual mode. It gives me immense pleasure in acknowledging the support rendered by all those individuals and organisations.

I would like to thank all the authors of the papers and attendees at the conference today. Without your perseverance, we would not have been able to hold the conference.

Next, I would like to thank all the reviewers of the abstracts and the full papers. Your expertise and contributions enabled us to ensure the scientific rigour of the papers in the proceedings. Likewise, support provided by the session chairs at the conference is very much appreciated.

Thank you very much to all the keynote speakers for taking time to address the conference audience despite your busy schedule. The titles of the keynote speeches are timely, and your addresses are laden with important insights for the future direction of the academia in the post COVID era.

I would like to express my gratitude to our sponsors, the Australian Institute of Building (AIB) and the Australian Institute of Quantity Surveyors (AIQS). Their continued support to AUBEA conferences is highly appreciated.

Appreciation is extended to the members of the conference organising committee, Professor Anthony Mills, Dr Nateque Mahmood, Dr Jamal Thaheem, Dr Gayani Karunasena, Dr Abid Hasan and Dr Abdul-Manan Sadick, for their hard work over the course of the conference organisation.

Finally, I am grateful to the members of the event organisers who did the heavy lifting of managing the logistics of the conference organisation whilst the organising committee was busy with the academic/scientific aspects of the conference. Special thanks go to Jess Holmes, Tara Stenhouse, Georgina Fatouros and the other team members of the event organiser.

Yours sincerely,

Professor Imriyas Kamardeen
Chair of the Conference Organising Committee

Acknowledgements

Conference Organising Committee

- Professor Imriyas Kamardeen
- Professor Anthony Mills
- Dr Nateque Mahmood
- Dr Jamal Thaheem
- Dr Gayani Karunasena
- Dr Abdul-Manan Sadick
- Dr Abid Hasan

Scientific Committee

Full papers accepted for publishing in the Conference Proceedings were subject to a blind peer review process. The 2021 Conference Committee gratefully acknowledges the generous work of the reviewers, who provide constructive and invaluable feedback within tight time frames to ensure the high standard of published papers. A full list of scientific committee is published on page xxv.

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Preface

I am delighted to write the preface for the proceeding of the 44th AUBEA Conference hosted by Deakin University. During recent years, AUBEA Conferences have expanded its traditional catchment area of Australasia, to also attract delegates from Asia, Africa, and Europe and this has confirmed AUBEA as a truly global conference. Attending an international event such as the AUBEA Conference has provided an opportunity for academics, industry practitioners and students to build their network whilst exchanging good practices in a prominent event relevant to education in the building and construction management discipline. Due to the unique blend of topics within building/construction education and industry, the AUBEA Annual Conferences have provided a perfect platform to strengthen the nexus between research and learning/teaching whilst being fully informed by the dynamics in our construction industry.

This 44th AUBEA Conference is the first AUBEA Conference conducted entirely online.

The AUBEA Council made a deliberate decision to postpone the conference in 2020 due to COVID-19 and decided to run a fully online AUBEA Conference in 2021. There is no denying that the level of disruptions caused by COVID-19 is unprecedented in the 46 year history of AUBEA. Despite this disruption, it was the joint view of the AUBEA Council and the host committee to continue with the AUBEA tradition to hold the AUBEA Conference in 2021, not only to maintain the tradition and continue the benefits for the wider academic community but also as symbol of our resilience as a mature academic society. I, therefore, would like to commend the perseverance and hard work of the organising committee to make this happen under such challenging circumstances. It is the view of AUBEA Council that AUBEA Conferences will continue in the future, so this AUBEA 2021 conference, in particular, is an important milestone to signal that continuity strongly.

Last but not least, I would like to thank you, our sponsors, and all delegates for attending and supporting AUBEA 2021. I would also like to extend my thanks to the scientific reviewers and other relevant parties that have supported AUBEA 2021. Your strong support has enabled us to host another successful AUBEA Conference. AUBEA Conferences are indeed a celebration of building education, and it is imperative for us to continue. Yes, there have been and still are disruptions due to COVID-19 but our drive and innovativeness will prevail so that we can carry on doing what we do best, which is educating the next generation in building/construction to continue to build a better and sustainable world for all humankind.

Professor Monty Sutrisna
President of AUBEA 2020-2022

Foreword

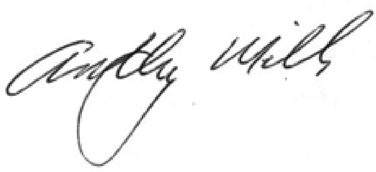
Welcome to Deakin University as we host the 44th Australasian University Building Educators Association Conference (AUBEA 2021). Deakin is one of the oldest providers of built environment education in Australia. We have a long history of built environment education, which dates back to the 1870s via our predecessor The Gordon Institute, in Geelong. The School of Architecture and Built Environment is one of the foundation schools that formed Deakin University in 1974. Over that time, we have been active contributor to AUBEA, and so it is with much pride that we host the conference in 2021.

AUBEA is a membership-based non-profit organisation, established in 1975 to promote and improve teaching and research in building through communication and collaboration. In these most unusual times, this is the first virtual conference of AUBEA's in its 46-year history.

The conference theme of "Live the Future" was identified before the pandemic, but as time has passed it has become more important than ever to reconsider what building education will become in future. The profound changes that are resulting from this global event, has brought new attitudes, behaviours, and ideas, to challenge established norms, and pose new questions about education in the built environment.

To maintain and assure the quality of the conference proceedings, each abstract received was reviewed. The authors received anonymous reviewers' comments on their abstracts and were invited to submit their initial full papers. All the full papers have been peer reviewed with anonymous reviewers' comments before final acceptance to the conference.

On behalf of the organising committee, I would like to express my thanks to Professor Imriyas Kamardeen as chair of the committee. I would like to acknowledge my colleagues, Dr Jamal Thaheem, Dr Nateque Mahmood, Dr Gayani Karunasena, Dr Abid Hasan and Dr Abdul-Manan Sadick, who were also on the organising committee and have been working very hard to make this conference a reality.



Professor Anthony Mills
Chair of Construction Management
School of Architecture & Built Environment
Deakin University

Keynote Speakers

Professor Tony Arnel

Industry Professor, Deakin University

Engaging with Industry in Times of Disruption

Tony Arnel is Industry Professor at Deakin University. He is an expert in the built environment and has been a sustainability advocate for more than three decades. Tony is also the Chair of the Engineering Advisory Board at Deakin University, serves on the board of Forest and Wood Products Australia and is the Immediate Past-President of Energy Efficiency Council

Tony is a Life Fellow of the Australian Institute of Architects and a Fellow of the Australian Institute of Company Directors.

Over his distinguished career, he has worked in a variety of positions in state government, capital city government, the private sector and academia.

For nearly a decade, he was the Global Director of Sustainability at engineering company Norman, Disney and Young, working across the companies worldwide network. Before Norman, Disney and Young, he was the Victorian Building Commissioner for over ten years. He was also a director at the City of Melbourne in the late 90s.

Professor Ron Wakefield

Dean of the School of Property, Construction and Project Management (PCPM), Interim Dean of the School of Global, Urban and Social Studies (GUSS) and, Deputy Pro Vice-Chancellor, International, RMIT University

Preparing Construction Management Students for the Future

Professor Wakefield is currently Professor of Construction, Deputy Pro Vice-Chancellor International, Dean of the School of Property, Construction and Project Management and Interim Dean of the School of Global, Urban and Social Studies at RMIT, Australia. Ron researches and teaches at RMIT in the areas of process simulation and modelling, residential and commercial construction and uses of information technology in construction management. He has degrees in Civil Engineering, including a PhD and BE (Hon 1) from the University of New South Wales and an MSE from Princeton University.

Prior to joining RMIT, Professor Wakefield was the William E. Jamerson Professor of Building Construction in the Department of Building Construction and the Associate Director for Building Technology Research at the Center for Housing Research, Virginia Tech. Ron has over 25 years' experience as an international researcher, consultant and engineer in building construction. He is the Chair of the Board of Tract Consultants, a Director of Launch Housing and JJR Consulting and a co-opted member of the Victorian Building Practitioners Board.

Honorary Professor Norman Faifer

Chartered Builder, Certified Quantity Surveyor, Accredited Adjudicator, Norman A Faifer and Associates

How do Universities add value? Research, teaching, employability skills and fostering social and community values

Norman served his cadetship in building at LU Simon P/L, Builders, retiring after 14 years to set up his own building business trading out some 25 years later. He now practices as an Expert in Building Matters and has appeared in all Victorian jurisdictions and the Federal and Family Courts of Australia in Building matters. He has been appointed by the Family Court as the single Expert Witness and Special Referee in Building matters in cases listed before that Court. He has acted as an Arbitrator in commercial building disputes and has been nominated as Adjudicator in Building and Construction Security of Payment Disputes. Has been appointed as the Expert Determiner (both in binding and non-binding cases) in building and construction disputes.

He is a Life Fellow of the Australian Institute of Building, a Fellow of the Australian Institute of Quantity Surveyors, the Institute of Arbitrators and Mediators, Australia, and the Resolution Institute, a member of the Building Disputes Practitioners Society and has been, through his company, a member of the Master Builders Association of Victoria for over 35 years.

He has lectured in building and construction related topics in the faculties of: Architecture and Building at RMIT, in Engineering at Swinburne, in Architecture, Building and Planning at the University of Melbourne and in Science Engineering and Built Environment at Deakin University. He has given seminar lectures to the Institutes of Quantity Surveying and Arbitrators & Mediators and of course is committed to the Institute of Building which he joined as a student member in 1971.

Professor Margaret Bearman

Professor, Research, Office of DVC (Education), Deakin University

The Future of Higher Education within a Digital World

Margaret Bearman is a Research Professor within the Centre for Research in Assessment and Digital Learning (CRADLE), Deakin University. She holds a first class honours degree in computer science and a PhD in medical education. She is known for her work in assessment design, feedback in clinical environments and digital education. Recognition for her work, includes Program Innovation awards from the Australian Office of Learning and Teaching and Simulation Australasia.

Professor Valerie Francis

Chair in Construction, Faculty of Architecture Building and Planning, The University of Melbourne

Women and Construction Management Education

Valerie Francis is a Professor in Construction Management within the Faculty of Architecture, Building and Construction. She is a civil engineer with over ten years' experience in commercial, industrial, institutional and domestic construction as a senior structural engineer and project manager. Valerie also has a Master's degree in Project Management and a PhD which focused on gender in construction and engineering. She worked as a Research Fellow for five years on two large ARC projects investigating construction efficiency prior to joining the University in 2000.

While she maintains an interest in issues involving construction procurement her current research explores factors affecting organisational effectiveness and employee satisfaction and well-being. Valerie is a recognised expert in the field of work-life balance in the construction industry and to date she has been the sole and joint (with Lingard) recipient almost half a million dollars for research in the area. She is the joint author of "Managing Work-Life Balance in Construction" published by Spon Press in the UK in 2009 and was the Chief Investigator on an ARC grant investigating the effect of different work-life strategies on several "live" construction project.

Valerie research has also investigated issues affecting women's attraction, retention and progression in construction. Her study on professional women's career progression was the largest study of its nature worldwide and it resulted in the development of a career typology for professional women. Her research work has resulted in the publication of a wide number of industry reports and papers in top tier international journals as well as local Australian journals. In 2010 she won the NAWIC Bovis Lend Lease Crystal Vision Award (Victoria) for her thirty years of service to women in engineering and construction. She subsequently awarded the National Crystal Vision Award in 2012. This is awarded every two years by the National Association of Women.

Valerie is also the co-ordinator of the Master of Construction Management and Assistant Dean (Research Facilities).

2021 Conference Themes

Theme 1: Redesigning construction education for the Fourth Industrial Revolution (Industry 4.0)

This theme focuses on defining educational contents that equip construction graduates with the required skills for the jobs of the future, and covers, but is not limited to, the following broad topics:

- curricula that prepare graduates capable of shaping the built environment for individuals and communities to thrive
- improved integration of BIM and Digital Engineering into curricula
- meeting future industry expectations of construction graduates.

Theme 2: Preparing construction graduates for the jobs of the future

This theme emphasises on pedagogical techniques that prepare construction graduates with the required skills for the jobs of the future, and covers, but is not limited to, the following broad topics:

- pedagogical strategies that nurture graduates for the jobs of the future
- construction education to enhance the digital literacy of graduates
- adopting Cloud computing, VR/AR/AI and Gamification in construction teaching and learning
- new and emerging roles in the construction industry.

Theme 3: Innovation and research that makes a difference to our industry

This theme encapsulates research and innovation that is critical to the advancement of the construction industry, and covers, but is not limited to, the following broad topics:

- cutting edge technologies for high performance construction and built environment
- innovative methodologies for enhancing sustainability, quality and resilience in construction
- remodelling processes, productivity and performance of the construction industry.

Theme 4: Value adding to stakeholders and the community

This theme concentrates on industry-focused, applied research that can add value to and enhance industry practices, processes and products, and covers, but is not limited to, the following broad topics:

- best value and best performing products, methods and processes for a sustainable industry and community
- rethinking contracts, ethics, professionalism and diversity for a thriving industry and community
- revamping policies, regulations and codes for a thriving industry and community.

Theme 5: Industry case studies, innovative methods and practices

This theme captures insights from construction industry practitioners' experiences, research and analytic findings, and exemplary case studies. The theme is quite broad and any topic of current interest to construction organisations and industry as a whole can be submitted, including aspects/topics that discuss the expectations of industry from future construction graduates and academia. Similarly, exemplary case studies of the implementation of novel technologies and approaches can be submitted, highlighting insights thereof.

Thursday 28 October

8.30 – 10.50am	**Plenary Session 1** Chair: Prof Anthony Mills		
8.30 – 8.35am	**Welcome to AUBEA** *Prof Imriyas Kamardeen, Deakin University*		
8.35 – 8.45am	**Acknowledgement of Country** *Melinda Kennedy, Wadawurrung, Deakin University*		
8.45 – 8.50	**Council Chair Address** *Prof Monty Sutrisna, Head of School, School of Built Environment, College of Sciences, Massey University*		
8.50 – 9.05am	**Opening Remarks** *Prof Karen Hapgood, Executive Dean, Faculty of Science, Engineering and Built Environment, Deakin University*		
9.05 – 9.10am	**Meet our Sponsors** *Linda Tivendale, Australian Institute of Building*		
9.10 – 9.55am	**How do Universities add value? Research, teaching, employability skills and fostering social and community values** *Hon Prof Norman Faifer, Chartered Builder, Certified Quantity Surveyor, Accredited Adjudicator, Norman A Faifer and Associates*		
9.55 – 10.40am	**Engaging with industry in times of disruption** *Prof Tony Arnel, Industry Professor, Deakin University*		
10.40 – 10.50am	Break		
10.50am – 12.35pm	**Paper Session 1** Chair: Dr Larry Xiancun Hu	**Paper Session 2** Chair: Dr Jamal Thaheem	**Paper Session 3** Chair: Assoc Prof Guillermo Aranda-Mena
10.50 – 11.05am	**Process improvement priorities for BIM related curricula in Australian Universities** *Amer Hijazi and Priyadarshini Das, Western Sydney University*	**Attitude of stakeholders towards the adoption of green building in Ghana: the perspective of construction professionals** *Florence Dadzoe, Department of Construction Technology and Management*	**Building circularity in infrastructure and commercial construction procurement** *Assoc Prof Guillermo Aranda-Mena, RMIT University*
11.05 – 11.20am	**Teaching maths not using newfangled methods –**	**Career Choice, Socio-economic Status of**	**Enhancing employability of project management**

	who would have thunk it could work? *Dr Larry Xiancun Hu, University of Canberra*	**Women in Construction Programs** *Mariam Akinlolu, Mangosuthu University of Technology*	**higher education graduates: should universities adopt an integrated competence approach?** *Luc Bauwmans, Central Queensland University*
11.20 – 11.35am	**Curriculum enhancement through internships for construction, property and project management students: Australia-India experience** *Prof Usha Iyer-Raniga, RMIT University*	**Financial risk maturity model for public-private partnership projects in Ghana: modelling and validation** *Isaac Akomea-Frimpong, Western Sydney University*	**The influence of COVID-19 on health and safety management in construction industry in New Zealand** *Kam Cheng, Ara Institute of Canterbury*
11.35 – 11.50am	**COVID -19 responses at Uni of Adelaide and Uni of Melbourne: impacts affecting Construction and Project Management programs** *Dr Timothy O'Leary, University of Melbourne*	**Digitization of construction claim management: The case of additional cost claims** *Babar Ali, University of Melbourne*	**Are we handling trade wastewater discharge effectively during building construction in Australia?** *Dr Gayani Karunasena, Deakin University*
11.50 – 12.05pm	**Session Q&A**	**Investigating the causes of subcontractors' underutilisation of the security of payment legislation in Australia** *Ali Alkhatatneh, Central Queensland University*	**Adaption of supply chain management theories to Australia-China construction supply chain** *Jinyun Liu, University of Melbourne*
12.05 – 12.20pm		**Starting suicide prevention from home by incorporating social, spatial and biophilic design aspects to house design along with value management quantification** *Neda Abbasi, Central Queensland University*	**Session Q&A**
12.20 – 12.35pm		**Session Q&A**	
12.35 – 12.50pm	Break		
12.50 – 2.35pm	**Paper Session 4** Chair: Argaw Gurmu	**Paper Session 5** Chair: Prof Imriyas Kamardeen	**Paper Session 6** Chair: Dr Nateque Mahmood
12.50 – 1.05pm	**The Value of Price Indices to Construction Decision-makers**	**Drivers for implementing effective waste trading practices in the construction industry.**	**Building occupants and the lack of awareness in energy conservation measures**

	Argaw Gurmu, Deakin University	*Shiyamini Ratnasabapathy, Western Sydney University*	*Laura Almeida, Western Sydney University*
1.05 – 1.20pm	**Construction & Demolition waste management practices in Australia and the UK: A comparison of organizational factors** *Dr Mohammad Tanvi Newaz, The University of Newcastle*	**Early-career project practitioners' views on whether their education prepared them for work in construction: a qualitative study** *Christina M. Scott-Young, RMIT University*	**BIM based cost planning for quantity surveying students: a case of WelTec** *Dr Wallace Enegbuma, Victoria University of Wellington*
1.20 – 1.35pm	**Determining the best intervention times of whole building assets for renewals during the planned period** *Dr Pushpitha Kalutara, Central Queensland University*	**Managing to retain Generation Z in the construction industry** *Assoc Prof Christina Scott-Young, RMIT University*	**Technical challenges for automated indoor construction progress monitoring** *Biyanka Ekanayake, University of Technology Sydney*
1.35 – 1.50pm	**A framework to overcome deskilling in the construction industry by improving existing training systems in Australia** Chalini Kendaragama, Deakin University	**Emerging Risk Management Approaches on Mega Construction Development projects – International Case Studies** *Jery Johnson, RMIT University*	**Agile ways of working in the construction industry** *Pearl Ng, RMIT University*
1.50 – 2.05pm	**A resilience toolkit for construction management graduates** *Mohammad Tanvi Newaz, University of Newcastle*	**Systematic review of risks in Modular Integrated Construction practice** *Ayaz Khan, Griffith University*	**Lesson learned to maintain and widespread implementation of precast concrete building in Malaysian construction industry** *Dr Zul-Atfi Bin Ismail, Universiti Malaysia Perlis*
2.05 – 2.20pm	**Creating the emotionally intelligent home-office** *Assoc Prof Guillermo Aranda-Mena, RMIT University*	**Throw DIRT* enough, and some WIL** stick: A case study on Collaboration between Academia and Industry** *Tayyab Maqsood, RMIT University*	**Plastic Minimisation in Construction: A Pilot Study identifying and quantifying the composition of C&D plastic in construction waste** *Dr Linda Kestle, Unitec Institute of Technology*
2.20 – 2.35pm	**Session Q&A**	**Session Q&A**	**Session Q&A**
2.35 – 2.50pm	Break		

2.50 – 4.35pm	**Paper Session 7** Chair: Dr Linda Kestle	**Paper Session 8** Chair: Prof Anthony Mills	
2.50 – 3.05pm	**Challenges of green building In Nigeria: stakeholders' praserspectives** *Dr Olabode Ogunmakinde, Bond University*	**Modular Prefabricated Classrooms: A New Zealand Study to Investigate Cost and Time Performance Potential** *Wajiha Shahzad, Massey University*	
3.05 – 3.20pm	**How sustainable is NZ construction industry for migrant workers?** *Dr Eziaku Rasheed, Massey University*	**Exploring the grit personality in a construction management program** *Dr Matt Stevens, Western Sydney University*	
3.20 – 3.35pm	**Construction industry inclusive branding: attracting non-traditional talent** *Assoc Prof Christina Scott-Young, RMIT University*	**Constructing pedagogical alignment for a sustainable mindset of future-ready graduates** *Dr Gesa Ruge, Central Queensland University*	
3.35 – 3.50pm	**Improving productivity of construction labour in the Republic of Kiribati** *Dr Rashika Sharma, Unitec Institute of Technology*	**Integrating the 4th industrial revolution in spatial planning curricula: the case of South African tertiary institutions** *Ockert Pretorius, University of Johannesburg*	
3.50 – 4.05pm	**The impact of new international waste policies on the Australian construction and demolition waste stream** *Tayyab Maqsood, RMIT University*	**The use of social media platforms for business branding in construction industry** *Pride Ndlovu, University of the Witwatersrand*	
4.05 – 4.20pm	**Session Q&A**	**Session Q&A**	
4.20 – 4.35pm			

Friday 29 October

9.00 – 10.40am	**Plenary Session 2** Chair: Prof Anthony Mills
9.00 – 9.05am	**Welcome to AUBEA – Day 2** *Prof Imriyas Kamardeen, Deakin University*
9.05 – 9.10am	**Meet our Sponsors** *Grant Warner, CEO, Australian Institute of Quantity Surveyors*

9.10 – 9.55am	**Preparing Construction Management Students for the Future** *Prof Ron Wakefield, Dean of the School of Property, Construction and Project Management (PCPM), Interim Dean of the School of Global, Urban and Social Studies (GUSS) and Deputy Pro Vice-Chancellor, International, RMIT University*		
9.55 – 10.40am	**Women and Construction Management Education** *Prof Valerie Francis, Chair in Construction, University of Melbourne*		
10.40 – 10.55am	Break		
10.55 – 12.40pm	**Paper Session 9** Chair: Dr Tim Law	**Paper Session 10** Chair: Dr Abdul-Manan Sadick	**Paper Session 11** Chair: Dr Olubukola Tokede
10.55 – 11.10am	**Emerging partnership procurement systems and cost management strategies in a cost-reimbursement environment – lessons learned from megaprojects** *Jery Johnson, RMIT University*	**Standardisation of Information Input for Automated Compliance Checking Efficiency** *Dr Wallace Enegbuma, Victoria University of Wellington*	**Requirements engineering in rail transport projects: challenges to information requirements development processes** *Assoc Prof Julie Jupp, University of Technology Sydney*
11.10 – 11.25am	**Career choice and professional preference of architecture students in Nigeria** *Dr Olabode Ogunmakinde, Bond University*	**Assessment of factors influencing innovation adoption by quantity surveying firms in Nigeria** *Damilola Akintunde, Obafemi Awolowo University*	**Leveraging blockchain for prefabricated construction supply chain management – A conceptual workflow framework** *Xueyan Zhang, Griffith University*
11.25 – 11.40am	**Using an Agile methodology for continuous improvements and delivery of university courses** *Tayyab Maqsood, RMIT University*	**SWOT analysis for blockchain-based Embodied Carbon (BEC) Estimator** *Navodana Rodrigo, Western Sydney University*	**Improving safety compliance of construction workers: A conceptual framework** *Diya Yan, Central Queensland University*
11.40 – 11.55am	**Hybrid learning of theoretical and practical structural mechanics in a workshop** *Dr Tim Law, Victoria University*	**Reconstruction technologies: a study over the effects of construction technologies on post-disaster housing recovery** *Alireza Shamloo, Massey University*	**Understanding the blockages to sustainability in building projects** *Dr Olubukola Tokede, Deakin University*
11.55 – 12.10pm	**A simplified approach in teaching Construction Cash Flow Forecasting – embedding basic cash flow techniques using a**	**The application of emotional intelligence in construction project management: a systematic literature review**	**Industry enabled work integrated learning through certificate of practice program**

	spreadsheet to chart a projects S curve *Dr Timothy O'Leary, University of Melbourne*	*Roksana Jahan Tumpa, CQUniversity*	*Assoc Prof Mary Hardie, Western Sydney University*
12.10 – 12.25pm	**Case study: using gamification to teach construction management concepts** *Dr Matt Stevens, Western Sydney University*	**Session Q&A**	**Supporting Decision-making and Education in the Construction and Property Sectors through Persuasive Virtual Reality** *Don Amila Sajeevan Samarasinghe, Massey University*
12.25 – 12.40pm	**Session Q&A**		**Session Q&A**
12.40 – 12.55pm	Break		
12.55 – 2.40pm	**Paper Session 12** Chair: Dr Gayani Karunasena	**Paper Session 13** Chair: Dr Nateque Mahmood	**AUBEA Council Meeting**
12.55 – 1.10pm	**The link between internal business integration and financial performance** *Barry Standing, Queensland University of Technology*	**Causes of accidents confronted by foreign workers in the Malaysian construction industry** *Rafidah Ismail, Deakin University*	
1.10 – 1.25pm	**Integral perspectives supporting sustainable decision making in building projects** *Dr Gesa Ruge, Central Queensland University*	**Critical appraisal of building information modelling research in Australia: A bibliometric analysis** *Dr Mehran Oraee, University of Melbourne*	
1.25 – 1.40pm	**An investigation of digital technology implementation in off-site construction: current practice, challenges and expectations** *Mudan Wang, University of New South Wales*	**A Collaborative approach for risk management in the design phase** *Lungie Maseko, University of the Witwatersrand*	
1.40 – 1.55pm	**Development of a framework to successful last planner system implementation: A systematic review** *Yiqin Yu, University of Melbourne*	**Barriers and benefits of self-organised housing: A systematic review of literature** *Will Mackie, Deakin University*	
1.55 – 2.10pm	**Barriers of offsite construction in**	**The impact of drafting styles on contract**	

	Australian low-rise residential buildings *Tong Lin, RMIT University*	**readability: An objective assessment of the New Zealand quantity surveying consultancy contract.** *Juwita Radzi, Massey University*	
2.10 – 2.25pm	**Augmented reality adoption in the Australian construction industry: A qualitative framework** *Yuxin Wang, University of Melbourne*	**Session Q&A**	
2.25 – 2.40pm	**Session Q&A**		
2.40 – 2.55pm	Break		
2.55 – 4.40pm	**Plenary Session 3** Chair: Prof Anthony Mills		
2.55 – 3.40pm	**The future of higher education within a digital world** *Prof Margaret Bearman, Office of DVC (Education), Deakin University*		
3.40 – 4.25pm	**Industry Panel and Q&A** *Hon Prof Norman Faifer, Norman A Faifer and Associates* *Prof Tony Arnel, Deakin University* *Prof Ron Wakefield, RMIT University* *Prof Valerie Francis, University of Melbourne* *Prof Margaret Bearman, Deakin University*		
4.25 – 4.40pm	**Conference Closing Statement and Best Paper Award Announcement** *Prof Imriyas Kamardeen, Deakin University*		

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Editorial

This section contains the abstracts and full papers presented at the conference. On behalf of the conference committee, we would like to acknowledge and thank the authors that submitted papers for consideration under the conference themes. Table 1 below shows the number of submissions and outcomes for 2021.

Table below: AUBEA 2021: Submissions and outcomes

Theme Abstracts	Received	Outcomes
Theme 1	25	9
Theme 2	32	14
Theme 3	60	22
Theme 4	45	23
Theme 5	32	8
Total	194	76

Full papers identified as 'Full Paper – Peer Reviewed' in the Conference Proceedings have undergone a double blind peer review process, with de-identified feedback and suggestions for revisions provided to authors. All submissions were also reviewed by members of the conference committee review panel. We gratefully acknowledge the generous work of the reviewers, a national group of colleagues who contributed their time and expertise to provide review commentary, including constructive and valuable feedback for all submissions.

These proceedings are published by Deakin University under ISBN 978-0-646-85008-5 (e-Book). We hope that this collection of papers will make a positive contribution to the ongoing discussion about those challenging issues that lie at the heart of assessment.

Disclaimer

The papers published in this Conference Program have been reviewed, edited and proofread to the best of our ability within the timeframe permitted. We acknowledge that there may be further proofing errors.

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- Xianbo Zhao, Central Queensland University

Career Choice, Socio-economic Status of Women in Construction Programs

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**Mariam Akinlolu*

Abstract
This study examines the differences in career choice predictors among a sample of women university students from diverse socio-economic backgrounds. This study surveyed 229 conveniently sampled students, enrolled in construction-related programs at two universities in South Africa. The samples were drawn from student cohorts enrolled in construction management, civil engineering, property development, land surveying, building and quantity surveying. Adopting the Social Cognitive Career Theory as the study's theoretical framework, the Kruskal-Wallis test was conducted to test for SES differences in the extent to which nine constructs determined a career choice in construction. The study found statistically significant differences in self efficacy beliefs among the high and low SES groups. A practical implication of the research is that results from the study suggest clear pathways to making a career choice in construction, for women who want to enter and remain in the construction work.

Keywords
Career Choice, Construction, SCCT, SES , Women

1 Introduction

Issues regarding gender equality and accommodation of peculiar gender needs are lacking in South Africa (Alves and English, 2018; Chileshe and Haupt, 2010). A lack of understanding of girls and women's career choice and development is a significant obstacle to attracting women into the construction industry. Although the industry has sought to find solutions to the problem of under-representation of women, progress seems to be very slow and erratic. Despite the existence of a significant range of studies on gender and women's career choice and development in construction (Ahuja and Kumari, 2012; English and Hay, 2015), limited progress has been made to develop interventions and strategies that can be applied to the women and minorities in the construction industry (Moore, 2006).

Another issue is the lack of understanding of social and cultural factors that influence women's career choices in the construction industry. Influences from the society and culture combined with the negativity they experience have been discovered to contribute to the few number of women in the construction profession, therefore resulting in a low number of mentors to attract young women into the profession. Numerous studies have explored women in other non-traditional and male-dominated environments (Shapiro et al., 2009; Wells et al., 2010), but few have specifically focused on the construction industry in the South African context, where the experiences of women may differ because of a variety of sociocultural influences.

Findings from previous studies suggest that demography and ethnic differences may have an impact on the career decisions of women and their perceptions of career-related barriers. While scholars have begun seeking the role culture and society plays on the career decisions of women and their development at the workplace, fewer studies have focused on inter-group differences (Holvino, 2010).

To increase the participation of women in construction programs in South Africa, this study applies the Socio-Cognitive Career Theory (SCCT) to understand the differences in career choices among women from diverse socio-economic backgrounds. This study contributes to research on the career choice of women in male-dominated environments in non-Western cultures.

2. Literature Review

Career Choice and Socio-economic Status

Socio-economic status (SES) is the position of a person based on their access to wealth, power, and prestige (Ali and McWhirter, 2006; Taylor and Yu, 2009). SES is also conceived with regards to a family or a person's income, occupation, level of education and social rank (Bécares and Priest, 2015; Xin et al., 2020).

In South Africa, the hierarchical structure of society, including access to wealth, prestige, and power, was constructed to be based on ethnicity through decades and even centuries of institutionalized inequality (Ali and Saunders, 2006; Taylor and Yu, 2009). Restriction was placed on the type of education people had access to, where people could live, and the kind of work they could engage in (Taylor and Yu, 2009).

Subsequent research has widened the consensus regarding SES as a strong predictor of educational and career outcomes in South Africa- a highly unequal society (Taylor and Yu, 2009). Studies have shown that the SES of a person has a significant influence on their educational achievement and career choices (Ali and Saunders, 2006, Patton and Creed, 2007, Taylor and Yu, 2009). Becares and Priest (2015) investigated the inequalities of educational opportunity, with the assumption that ethnicity could be the primary cause of inequalities. However, findings from the study suggested that neither did ethnicity and funding predict educational and career choice. Instead, family and socio-economic background were found to determine academic and career outcomes substantially.

Lee and Burkham (2002) found that significant differences in the cognitive ability of students could be associated with their SES backgrounds. Cheng and Starks (2002) ; Kao and Tienda (1998) reported lower educational and occupational aspirations for students from lower socioeconomic status compared to advantaged students. In many studies, family support has been identified as a direct influence, bearing in mind that parental education and occupation are an indicator of SES (Ali, McWhirter and Chronister, 2005 ; Taylor and Yu, 2009). Highly educated parents may offer better support to their children, as they have better access to information that could feed into the educational and career achievement of the children (Taylor and Yu, 2009).

In addition to the disparities among people from socio-economic backgrounds, different patterns in education and career outcomes among women with varying SES has also received longstanding attention (Becares and Priest, 2015). These differences have been attributed to the socialization process and gender role stereotyping within families, schools, and communities (Bécares and Priest, 2015; Cvencek et al., 2011). These socialization and stereotyping processes are also significant causes of educational and occupational inequalities (Bécares and Priest, 2015; Kelly, 2009).

Although substantial evidence in the literature has suggested that SES can significantly influence educational and career choices, samples have been bias towards higher SES categories (Bécares and Priest, 2015;Breen and Jonsson, 2005). Studies of women's career choices in male-dominated occupations have been found to rarely include women from low SES categories (Nieva and Gutek, 1981). To adequately examine SES differences among women, it is crucial to consider samples from a diverse range of SES backgrounds. Since men rarely undertake careers in female-dominated professions, the relationship between SES and career prestige has been adequate for the study of the career choices of men (Hannah and Khan, 1989). Betz and Fitzgerald (1987) suggest that the study of women's career choices are more complex, and the influence of SES on choices should be examined.

Comparisons have revealed that in lower SES categories, homogeneity and lack of exposure were found to hinder women's ability to contest gender norms, limiting their awareness to unconventional gender roles (Pozarny et al., 2016). Women from higher SES backgrounds are less pressured to conform to socio-cultural restrictions compared to their counterparts from disadvantaged backgrounds (Reichlin and Shaw, 2015).

Unterhalter et al. (2010) noted that issues of social exclusion concerning ethnicity and socioeconomic background, family composition and gender, strongly influenced educational attainment and career decisions of girls. The academic level of parents influenced their gender role perceptions. Sandıkcı (2018) associated social class to the value of higher education in high SES families. Families from high social classes have less traditional perceptions of gender roles for boys and girls. Lewis and Lockheed (2006) found that communities where ethnicity was a prominent part of the social structure displayed gender divisions regarding women's education.

Regarding education and gender role perceptions of women, Sandıkcı (2018) emphasized that discriminatory policies on women's education hinder the educational progression of most women with lower SES. Educating the girl child is given low priority, particularly in households where assistance is required in carrying out domestic chores and income generation (Chant et al, 2016). Majority of women do not make it beyond primary education and are usually encouraged to prioritize their families rather than pursue higher education. However, their counterparts from higher SES backgrounds have access to more significant educational opportunities and are encouraged to take up careers in engineering and business, which places them at an advantage of attaining higher social status (Lombard and Wairire, 2010). Parents from higher SES backgrounds might possibly encourage their daughters to break gender stereotypes and undertake careers in traditionally male-dominated environments (Chant et al., 2016;Lombard and Wairire, 2010).

Sonnert (2009) reported that in high socioeconomic backgrounds, mothers with careers adopted more egalitarian gender roles for their daughters compared mothers in traditional families. Daughters were also found to consult with their fathers concerning career choices. Watson et al. (2011) found that female students from higher SES backgrounds chose their preferred course of study without considering the professional value of such a field. However, girls from lower SES backgrounds were more concerned with areas of studies that would provide them with financial security in the future (Watson et al., 2011). Andres et al. (2007) concluded that regardless of whether the gendered reality of the labour market is accepted, career choices of women are strongly associated with their social background.

2.2 Socio-Cognitive Career Theory (SCCT)

This study was framed by the Social Cognitive Career Theory (SCCT) as it relates to the students' career choices in the construction industry. SCCT (Lent et al. 1994) is a direct application of the social cognitive theory by Bandura (1989) and elaborates exclusively on the educational interest formation, career development, performance, and persistence of individuals in their career endeavours. Processes whereby the educational and professional interest of individuals are developed; the influence of interests and other socio-cognitive mechanisms on career choices and the attainment of different levels of career performance and persistence are outlined in the SCCT (Lent et al., 1994; Ali and McWhirter, 2006).

SCCT focuses on the role of cognitive factors such as self-concept, self-efficacy, goal representations, interests, outcomes and expectations in the career development of an individual and how these factors interact with internal and individual variables such as gender, ethnicity, belief systems and social supports to influence the career behaviour of adolescents (Lent et al., 2000; Lent et al., 2008; Ali and Saunders, 2006; Kelly, 2009; Saifuddin et al., 2013). Biological, situational, and contextual factors such as race, sex, intelligence, culture, and gender role socialization are moderators of the formulation of choice goals and significantly influence career development (Ali and McWhirter, 2006; Kelly, 2009).

2.1.1 Self-Efficacy

Self-efficacy refers to "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura, 1989). From the social-cognitive perspective, self-efficacy is a set of beliefs concerned with specific performance domains and interact complexly with external and contextual factors. These beliefs help to determine the choice of activities, environments, persistence, and emotional reactions to certain events (Malach-Pines and Kaspi-Baruch, 2008). Ali and McWhirter (2006) ; Kelly, (2009) ; Lent and Sheu (2010) described self- efficacy as a person's perception of their capabilities and ability to perform at certain levels in a specific domain, that influence certain events which have an impact on their lives. It is a conviction by a person that a target can be achieved (Hunt et al., 2017). Commonly, a person has a higher level of self-efficacy when they believe they have the required competency and efficacy to obtain necessary results (Bandura, 1977). Elements of self-efficacy are perceived to assist a person in determining their choice of activities, degree of persistence, and emotional reaction to situations (Peña-Calvo et al., 2016).

Introduced to career development literature by Hackett and Betz (1981), self-efficacy has received wide attention in career literature and has been identified as a major predictor of choice to undertake and remain in a male-dominated career such as construction (Lent and Brown, 2006; Lent and Sheu, 2010).

2.1.2 Outcome Expectations

Outcome expectations refer to a person's beliefs relating to probable response outcomes and consequences of performing certain actions (Lent and Brown, 2006). Career choice behaviour is perceived to be significantly dependent on the subjective likelihood that a particular action will yield a certain outcome as well as the value a person places on those outcomes (Locke et al., 1986; Wanous et al., 1983). According to Bandura (1989), "people act on their judgments of what they can do, as well as on their beliefs with regards to the likely consequences of their actions." Physical outcomes (money), social outcomes (approval), and self-evaluative outcomes were highlighted as the types of outcome expectations (Bandura, 1989). Outcome expectations have been identified as one of the most salient predictors of career choice behaviour as individuals have positive expectations from engaging in the behaviour (Kelly, 2009).

2.1.3 Goal representations

Goals play a significant role in the career behaviour mechanism (Lent et al., 1994). Goals are the determination to undertake a particular action or to initiate a specific future outcome (Bandura, 1989). Goal representations result in extra input by a person in the relevant domain, inspiring the person to proceed energetically, making a career choice in the domain through organized planning (Lent et al., 1994). In most cases, a person defines some criteria for certain behaviours depending on their expectations and beliefs, and these criteria are referred to as goals (Ali and McWhirter, 2006; Peña-Calvo et al., 2016).

Numerous studies have suggested that several factors related to goals, influence career choice behaviour (Ali and McWhirter, 2006;Peña-Calvo et al., 2016). It is expected that firmly held goals will more likely influence career entry choice behaviours (Lent et al., 1994). Goals are also perceived to have a strong motivational effect on career choice behaviour to the extent that they are specific and clear, although may be challenging, are attainable and proximal (Hunt et al., 2017).

2.1.4 Social support

Although numerous studies have adopted the SSCT framework, a majority have emphasized more on individual and cognitive variables, ignoring one of the main constructs of SCCT- the influence of social and contextual variables (Pio et al., 2013). A major influencing variable on career decisions is social support (Hunt et al., 2017; Lent et al., 2001). Support from significant others such as parents, teachers, and peers are crucial social supports in occupational aspirations career decision making, and persistence of students is well documented in literature (Mau et al., 2000 ; Pio et al., 2013).

Lent et al. (1994) ;Whittock (2002) have highlighted support structures that may influence career choice. Exposure to role models, networking contacts, emotional and financial support from significant others are key support mechanisms that influence the career choices and progress of women in the construction industry (Burke and Mattis, 2007;Vainikolo, 2017;Yokwana et al., 2016).

2.1.5 Learning Experience

Career choice behaviour is guided by an interaction of learning experiences with person and contextual factors (Hunt et al., 2017). Studies have argued that previous learning experiences promote future career behaviours and that an accumulation of different kinds of reinforcements is responsible for career choices and that these prior experiences influence future career choice behaviour (Lent et al., 2008;Pio et al., 2013). During the socialization process, the environment exposes a person to a range of activities which might be of occupational relevance (Kessels and Taconis, 2012). A person also experiences and observe other people within their environment performing various vocational activities, exposing them directly and indirectly to diverse activities as well as differently reinforcing their aspirations to pursue certain activities (Kelly, 2009). By repetitively performing certain activities, role models, and feedback from models, people refine their career choices (Lent et al., 1994). Learning experiences produce values that are acquired through socialization and fundamental social learning processes, such as vicarious learning and self-evaluative experiences (Alexander et al., 2011). Interactions with family members, teachers, peers, role models, cultural and religious institutions, and media sources influence personal values and standards, which may consequently influence career choice behaviour (Charity-Leeke, 2012).

2.1.6 Interests

Interests are skills developed during a person's socialization process and ideally are translated into career choices, although social and environmental factors often influence the level of career aspirations and choice (Bécares and Priest, 2015). Jin et al. (2009) defined career interests as patterns of likes, dislikes, and indifferences with regards to career-related activities and occupations. Betz and Voyten (1997) considered interests as a state of mind that emerges before an action and is perceived as a principal motivator of career choice behaviour. A person makes continuous choices, which are often regarded as unconscious, without considering how their time and efforts will be spent (Rogers et al., 2008).

2.1.7 Gender role stereotypes

The influence of gender-stereotyped beliefs and attitudes on career choice has been a subject of scholarly inquiry among researchers (Blakemore and Hill, 2008;Deemer et al., 2016;Sáinz et al., 2016). The career choice of a person may be hindered by socio-cultural and stereotypical beliefs that undertaking certain careers are a violation of traditional gender norms (Blakemore and Hill, 2008). Individuals are mandated to compromise their stance regarding a career choice, by undertaking careers that are perceived as more realistic than ideal (Junk and Armstrong, 2010;Tsaousides and Jome, 2008). Numerous studies have argued that the under-representation of women in male-dominated occupations could be because of continued gender-role stereotyping of careers (Leung et al., 1994;Mendez and Crawford, 2002).

2.1.8 Access to Opportunity Structures

Lack of information on career opportunities may likely influence the career advancement and value individuals place on various educational and career options (Ali et al., 2005;Jamenya et al.). Reduced access to educational and vocational job-training opportunities have implications on opportunities for women to choose careers in construction (Vainikolo, 2017). Numerous studies have emphasized on the unequal access to training and development programs, networking opportunities and educational programs, and as a result, there is unequal awareness of a variety of career options that could broaden the career choices of women, with construction as a viable option (Aulin and Jingmond, 2011;Charity-Leeke, 2012).

2.1.9 Perceived Barriers

Individuals may perceive numerous barriers or hindrances to undertaking a career in the construction industry (Aulin and Jingmond, 2011;Everhart et al., 1998;Lowe and Woodcroft, 2014). These barriers include discriminatory attitudes, work-life conflict, the wage gap, workplace culture, lack of access to opportunities, challenges in career progression, poor working conditions, long work hours, glass ceiling, gender stereotypes, lack of knowledge and career information, lack of role models, sexual harassment, lack of education and training and lack of opportunities (Mendez and Crawford, 2002;Fraser et al., 2013;Hoobler et al., 2009;Kaewsri et al., 2013).

3 Research Methodology

A quantitative research method was adopted for the study. The study used a close-ended questionnaire in a survey of university students enrolled in construction-related programs in South Africa. Based on the advantages of the non-probability sampling method, the study used a conveniently selected sample from two public universities in the KwaZulu-Natal province of South Africa to participate in the study. The two universities were conveniently chosen because of their proximity to the researchers. Convenience sampling consists of selecting participants who are closest and more convenient to access (Sekaran and Bougie, 2010). This sampling method was preferred to conveniently select two universities, which were closest to the research domicile. Undergraduate students enrolled in construction-related programmes such as construction management, land surveying, building, civil engineering, quantity surveying and architecture in South African Universities were chosen as the sample frame. A sample size of 229 was used for the analysis.

The survey questionnaire was administered for five weeks. The questionnaires were designed using Google forms and administered electronically by sending out hyperlinks of the questionnaire via email and the WhatsApp platform. Google forms is a cloud-based and online tool used to create and customize questionnaires.

Following the result of the normality test, which revealed a non-normal distribution of data, a non-parametric test was deemed suitable to test for significant differences among the SES groups concerning the study constructs. In this study, the Kruskal-Wallis test was adopted to test for significant differences between the SES groups. Similar to the Mann-Whitney U test, the Kruskal-Wallis test is the non-parametric alternative to the one- way analysis of variance test (ANOVA) and is used to test for significant differences among three or more independent groups by comparing the scores on continuous variables (Field, 2013). An alpha level of 0.05 or less suggests a significant difference between groups.

4 Findings and Discussion

4.1 Demographic Statistics

To determine the socio-economic background of the respondents, participants were required to indicate the current or last occupation and the highest qualification of the breadwinner of their household.

Table 1 presents results relating to the socio-economic data of the participants. Most of the household breadwinners were unskilled workers such as housekeepers, farmers, waiters, and gardeners (n= 161; 70.3%), followed by graduate workers such as teachers, nurses, and police officers (n=39; 17%).

Table 1: Socio-Economic Background

Occupation of the breadwinner of the household	No	Percent
Unskilled	161	70.3
Skilled	21	9.2
Graduate	39	17.0
Specialist	8	3.5
Highest qualification of the breadwinner of the household	**No**	**Percent**
Post- Matric	59	25.7
Matric	54	23.7
High School	59	25.7
Primary School	57	24.9
Socio-economic Category	**No**	**Percent**
High SES	42	18.3
Medium SES	54	23.6
Low SES	133	58.1
Total	**229**	**100.00%**

Concerning the highest qualification of the household breadwinner, 59 (25.7%) had post-matric education, 54 (23.7%) had matric education, 59(25.7%) had high school education, and 57(24.9%) had primary school education. Based on the occupation and the highest qualification of the breadwinner of the household, 133 (58.1%) of the students were categorised to be of low socioeconomic status.

4.2 Differences in SES Categories subjected to the Kruskal-Wallis test

The test for significant differences in the influence of the career choice predictors between the SES groups among women shows that significant differences were found for self-efficacy (Chi-square =8.703, p=0.013) as the Sig. value was less than the alpha value of 0.05. An inspection of the mean ranks for the career choice predictors in all the SES groups suggests that outcome expectations and perceived barriers were the career choice predictor with the most influence.

Table 2. Test Statistics for SES and Career choice predictors

	High SES		Medium SES		Low SES		Kruskal-Wallis		
	MIS	**Rank**	**MIS**	**Rank**	**MIS**	**Rank**	**Test Static**	**Df**	**Sig.**
Self-Efficacy	17.94	**7**	19.13	**7**	20.36	**7**	8.703	2	0.013
Outcome Expectations	52.94	**1**	56.34	**1**	57.50	**1**	0.851	2	0.653
Goal Representations	26.26	**4**	28.27	**3**	28.84	**3**	0.795	2	0.672
Social Supports	22.21	**5**	24.34	**4**	22.56	**5**	2.407	2	0.300
Learning experiences	16.05	**8**	15.82	**9**	15.73	**9**	0.014	2	0.993
Interests	20.63	**6**	21.37	**6**	22.03	**6**	3.738	2	0.154
Perceived Barriers	47.05	**2**	38.89	**2**	40.16	**2**	3.185	2	0.148
Gender Stereotypes	30.57	**3**	22.72	**5**	24.50	**4**	4.205	2	0.122
Access to Opportunity Structures	15.89	**9**	16.75	**8**	16.18	**8**	0.653	2	0.722

Results from the post-hoc test presented in Table 3, shows that the only groups that differed significantly (p< 0.011) among each other where the high and low SES groups. There was no evidence of significant differences between the other pairs.

Table 3. Analysis of Dunn- Bonferroni Test

		Test Static	Std. Error	Adj. Sig.
Self-Efficacy	High-Medium SES	16.024	9.620	0.287
	High-Low SES	24.784	8..500	0.011
	Medium-Low SES	8.760	1.204	0.686

4.3 Women, SES, Self-efficacy and Career Choice

A statistically significant difference was found for the influence of self-efficacy on career among the SES categories. The follow- up revealed differences lie among the low and high SES groups.

Compared to men, limited research has been conducted on SES differences among women in male-dominated and prestigious occupations. However, the findings in the current is supported by (Burlin, 1976; Garrison, 1979 ;Henderson et al., 1988 ;Lueptow, 1981 ; Hannah and Kahn, 1989). Hannah and Kahn (1989) findings were mostly supportive, as the results reported that women from high SES backgrounds displayed higher self-efficacy beliefs and were more likely to choose male-dominated professions such as construction, compared to women from low SES groups. Betz and Fitzgerald (1987|) ; Zuckerman et al. (1980) reported SES differences between women who chose to undertake careers in male-dominated occupations, and further noted that women in male-dominated occupations who were from high SES backgrounds were more likely to have highly educated parents who made them more confident in their career choices. Similarly, Burlin (1976) ; Kenkel and Gage (1983) found that low SES girls with less-educated fathers were too traditional in their career choices and were less likely to choose careers in male-dominated environments. An explanation for this was that girls from high SES backgrounds had more access to family resources compared to low SES girls.

5 Conclusion

This study sought to understand the differences in career choices among women in South Africa from diverse socio-economic backrounds given the historic institutionalized inequality. To this end the Socio-Cognitive Career Theory (SCCT) was used. Whereas previous studies have focused largely on higher socio-economic status (SES), this study examined a diverse range of SES. High, medium and low SES were compared.

The study asserts that the socio-economic background, which is categorized as a person input will significantly predict career choices and have diverse influences on career choices in construction. A key finding of the study suggests that in the context of male-dominated industrial sectors such as construction, there are significant differences between women from high and low SES. This finding is generally not supported by literature given that very limited studies have been done in this context and comparatively between different SES ranges. Therefore, more studies should be conducted both as a contribution to the existing body of knowledge but also to be cognisant of the impact of socio-economic status when trying to attract more women to register for construction programs and consequently increase the representation of women in construction.

The findings of this study cannot be generalized across all construction program given that the convenience sample was drawn from only two universities in the KwaZulu-Natal province of South Africa. In order to validate the findings a further study needs to be done involving a larger sample of universities to determine whether the trends identified are consistent across the country.

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Assessment of Factors Influencing Innovation Adoption by Quantity Surveying Firms in Nigeria

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Abstract

Previous studies have shown that most construction and professional firms did not achieve the objective of client satisfaction because they failed to adopt innovative practices in their service delivery. This study evaluates the factors influencing the adoption of innovation by Quantity Surveying (QS) firms in Nigeria in order to improve services delivery. The data for the study were obtained through a questionnaire survey of QS firms based in Lagos State, Nigeria. Using a stratified sampling technique; the survey was administered on QS firms based in Lagos mainland and Lagos Island. This partition was considered because QS firms based in Lagos Island were perceived to be more elitist and it was worthwhile examining the way QS firms in Lagos Island embrace innovation compared to QS firms in Lagos Mainland. A total of 125 questionnaires were administered out of which 78 were returned and considered fit for analysis. Responses to the survey were analysed using mean ranking analysis, Analysis of Variance (ANOVA) and factor analysis. Results showed that there are statistical differences of opinions on some factors between QS firms based in Lagos mainland and those in Lagos Island. The factor analysis result showed that the factors identified as promoting innovation adoption in QS firms could be grouped into five; namely, organizational, economic, managerial, environmental and technological factors. The study concludes that an understanding of these factors will provide a basis for introducing innovative solutions in QS firms.

Keywords
factor analysis, influencing factors, innovation, Nigeria, quantity surveying

1 Introduction

Innovation is the generation or adoption of new ideas; design concepts or delivery processes, new to the adopting organisation, which when implemented will yield a reduction in cost and time associated with project delivery and improves the quality of outcomes (Kissi *et al.,* 2012). The new idea in this context might be associated with the adoption of new technology or system that benefits the organisation (Hua *et al.,* 2013).

World Intellectual Property Organisation (2019) produced the Global Innovation Index of 131 countries in the world. Out of all these, African countries such as South Africa was ranked 63rd, while Tunisia, Ghana and Nigeria ranked 70th, 106th and 114th respectively. In 2020, this ranking was conducted by the aforementioned body using the same yardstick, South Africa ranked 60th, while Tunisia, Ghana and Nigeria ranked 65th, 108th and 117th respectively. Therefore, comparing Nigeria with counterpart African countries, there is evidence Nigeria is lagging behind other major economies of the world when it comes to innovation.

Globally, major economies of the world construction industry such as the UK, Australia and the likes are experiencing escalating demand for technological innovation as these countries now enforce the use of BIM and other technological innovations available to the construction industry for major construction activities undertaken (Amna and Chris, 2015). Innovativeness itself has been linked to demand for innovation, adoption of innovation and competitive advantage (Porter, 1990). Latham (1994) and Egan (1998) however observed that most construction firms did not satisfy their clients because they failed or refused to adopt innovative practices in their services delivery. Innovation has been alluded to aid firms in overcoming the turbulent external environment, making it a key factor for business survival, especially in dynamic markets.

Yusof *et al*. (2010) highlighted the importance of innovation in quantity surveying firms because of rising construction costs, changing clients' requirements, increased competition, tighter control over environmental regulations and quality standards among others. However, for innovation to be an effective strategy that sufficiently sustains firms within the challenging business environment it should not be treated as a one-time event, rather, firms must continuously be innovative to sustain competitive advantage (Yusof, *et al*., 2016).

Studies have been carried out in various domains regarding factors influencing innovation adoption. For instance, Yusof, *et al.* (2010) investigated the factors influencing firms readiness towards innovation in the house building industry. Will *et al*. (2017) also examined factors promoting innovation and efficiency in the construction industry. However, there is a paucity of studies on factors influencing Quantity Surveying firms in adopting innovation in their services delivery. This gap in knowledge makes this study a worthwhile one. The study was conducted in Lagos metropolis, Nigeria. This is because Lagos is the commercial capital of Nigeria and the hub of construction activities where the majority of QS firms are based. Lagos metropolis was further divided into Lagos mainland and Lagos Island. This partition was considered because the QS firms based in Lagos Island were viewed to be a bit more elitist and it was worthwhile examining the way they embraced innovation compared to those on the Mainland.

2 Literature Review

2.1 Quantity Surveying Firms

Historically, the QS firms have contributed significantly to meeting the economic, social, and technological developments. QS execute their duties either as consultants or contractors to protect the client's interests (Senevirante *et al.,* 2008a). The QS has grown to become a highly reputable professional in the built environment with construction cost management for all stakeholders as their primary role (Ashworth *et al*., 2013). QS firms offer their expertise in diversified areas within the construction industry and non-construction industry (Hanid *et al.,* 2007a, Senevirante *et al.,* 2008b, Addai *et al.,* 2009). QS firms have seen expansion and modification of services to meet the demands of the industry (Smith, 2009).

QS firms have persistently diversified their knowledge base to evolve into services including project management, value management, arbitration, adjudication and facilities management throughout the construction and other non-construction industry sectors namely, banking and petroleum sectors (Hanid *et al*., 2007b). Today, QS firms explore opportunities in the financial industry, insurance industry, manufacturing industry and real estate sectors (Perera, *et al.,* 2007) as well as oil and gas. QS firms are principally oriented to be the major handlers of information in the built environment. The flow of major information evolves around quantities and cost. The advancement in demands of QS services affords the firms massive opportunity to adopt innovation (Smith, 2004).

2.2 The Concept of Innovation

Generally, there is no one specific definition of innovation. Various studies conceptualised innovation in different ways, with diverging perceptions on its effect on firms' efficiency, performance, development and survival. However, Law (2006) defined innovation as "any new approach to designing, producing, or marketing goods that give innovation adopters or firms an advantage over competitors". Since, employees and employers often have diverse opinions concerning the nature and types of innovation, having the knowledge of the different types of innovation which are technological, organisational, process and marketing are imperative (Goffin *et al.,* 2005).

2.3 Factors Influencing the Adoption of Innovation

Cox *et al.,* (2002) concluded that firms that engage in innovation were concerned with economic factors. He stated further that direct costs of innovation and the costs of finance were perceived to be the major constraint for them to adopt innovation. Also, the perceived economic risk that may arise from innovation adoption has been identified as another factor. An enterprise's internal capability was however regarded as less inhibitor (Will *et al.,* 2017).

Tornatzky *et al.* (1990) identified three different categories of factors influencing innovation adoption to comprise of organizational, technological, and environmental factors. Kimberly *et al.* (1981) identified three groups of predictors of innovation: characteristics of organizational leaders, characteristics of organizations, and characteristics of environments. In summary, four categories of factors can be found in technological innovation literature, which is as follows: managerial, organizational, technological, and environmental. However, all these identified factors are based on perception, lacking quantitative backing. Researchers have identified the following common environmental factors relating to technological adoption: pressure from competitors, customers or suppliers; the role of government (incentives); partners alliances; technological infrastructure; technology consultants; image of internet technology; and user's expectations (Aguila-Obra *et al.,* 2006a). Technological factors have also been identified to include complexity, compatibility, relative advantage, ease of use and usefulness (Rogers, 2003). The technological factors are related to barriers to technology adoption and its perceived benefits. The perceived benefits for managers could be direct, such as cost savings or income generation, or indirect, such as potential opportunities in new markets, marketing, or publicity (Poon *et al.,* 1999). Thus, when adopting an innovation, organizations must perceive the positive effects of the adoption and hence its potential value before starting the process (Vadapalli *et al.,* 1997).

The organizational factors that have been most cited in the literature include IT users community; organizational structure; firms processes; firm size; technological capabilities of the organization's members; the technological and financial resources available; the culture of the organization; the process of selecting and implementing the new technological innovation; management backing and support for the project and the project leader (Aguila-Obra *et al*., 2006b). Some researchers have integrated these factors into one model (Kuan *et al.,* 2001, Mehrtens *et al.,* 2001, Kamal, 2006), allowing for the treatment of all these factors and their interaction in one dynamic framework. Such a framework can explain marked differences in the performance of organizations in identical contextual situations (Montealegre, 1996).

From the foregoing, innovation is something new but not in absolute terms, since some ideas might be creative in developing countries but would not be regarded as such in developed economies. This study conceptualises innovation as any process or development, which consists of significant novelty for the adopting units or firms resulting in enhancing goals, but is not necessarily new to the world. Literature related to quantity surveying firms, the concept of innovation and factors influencing innovation adoption has been thoroughly reviewed in order to fortify the questionnaire administered to achieve the aim and objective of this study.

3 Research Methodology

3.1 Research Design

This study employs a positivist research approach with a quantitative research design. Under the quantitative research design, a structured questionnaire survey method was used involving a cross-sectional questionnaire survey. The target population for this study is made up of one hundred and fifty (150) quantity surveying firms in Lagos State registered with the Nigerian Institute of Quantity Surveyors (NIQS). Fagbemi (2008) posited that 75% of quantity surveying firms in Nigeria are either located in or have their head offices in Lagos State. A total of 125 QS firms are located in Lagos Mainland while 25 QS firms are located in Lagos Island as compiled by the Association of NIQS Consulting Firms (2018).

3.2 Data Collection

A stratified random sampling technique was adopted for this study. As a first step, the study population was stratified into two according to the geographical location of the study area; namely QS firms operating in Lagos Mainland and those operating in Lagos Island. A total of 125 QS firms are based in Lagos Mainland while the remaining 25 are based in Lagos Island. Out of the 125 QS firms based in Lagos Mainland, a proportional sample of 80% was selected using the table of random sampling, giving a sample size of 100. This is in accordance with the proportional sample selection suggested by Leedy *et al.* (2010). Furthermore, a total enumeration of 25 QS firms in Lagos Island was taken (Leedy *et al.,* 2010). These bring the sample size from the two strata to 125 QS firms as shown in Table 1.

Table 1: Sample size

Area of Focus in Lagos State	No. of QS firms surveyed	Total Sample Size
Lagos Mainland	125	100 (80%)
Lagos Island	25	25 (100%)
Total	**150**	**125**

3.2.1 Questionnaire Survey

A total of 24 factors promoting the adoption of innovation were obtained from literature and were investigated using a structured questionnaire survey. The respondents were requested to score the QS firms' level of importance attached to the factors influencing the adoption of innovation in QS firms on a 0-5, six-point Likert-type scale with 0- representing not applicable, 1- very low extent, 2- low extent, 3- moderate extent, 4- high extent and 5- very high extent. A questionnaire survey was administered to a sample of 125 QS firms. Out of these, 78 questionnaires were returned and found fit for analysis. This represents a response rate of

62.4% as shown in Table 2. This indicated a good response rate and conforms to Mugenda *et al.* (2003) stipulation that a response rate of 50% is adequate for analysis and reporting, a rate of 60% is good and a response rate of 70% and over is excellent.

Table 2: Questionnaire Distribution and Response rate

Respondent	Questionnaire Distributed	Questionnaire Retrieved	Respondent Rate (%)
Quantity Surveying Firms in Lagos mainland	100	57	57
QuantitySurveying firms in Lagos Island	25	21	84
Total	**125**	**78**	62.4

3.3 Methods of Data Analysis

For the purpose of statistical analysis, the data collected on the Likert-type scale were treated as interval data (Carifio *et al.,* 2008). Statistical Package for Social Sciences (SPSS) was used to analyse the data collected. First, the data collected from the questionnaires were edited, coded and keyed into the Statistical Package for Social Sciences (SPSS). Descriptive statistics in the form of frequencies and percentages were used for the first level of the data analysis. Further analyses were carried out using means score analysis, Student's *t-test* to determine the difference in the sample means of the two stratifications of QS firms. Mean ranking analysis was also employed in the ranking of the extent of the importance of factors promoting the adoption of innovation. Lastly, factor analysis was used to reduce the factors promoting the adoption of innovation available to QS firms into principal components.

4 Findings and Discussion

4.1 Reliability of Research Instrument

A measure of the reliability of responses, using Cronbach's Alpha is most commonly carried out when the internal consistency of a questionnaire or survey that consists of multiple Likert-type scales are to be assessed (Nurosis, 2010). This is supported by the rule of thumbs postulated by George *et al*. (2012) which stated that Cronbach's alpha value ≥ 0 .9 – Excellent, ≥ 0.8 – Good, ≥ 0.7 – Acceptable, ≥ 0.6 – Questionable, ≥0 .5 – Poor, and < 0.5 – Unacceptable. A Cronbach Alpha of 0.959 achieved in this study indicates excellent reliability of the responses.

4.2 General Information of the Respondents

The background information of the respondents was first determined to make sure that they meet the requirements for the research study. Issues discussed include designation of respondents, academic qualification of the respondents, professional qualification of respondents and their experience in the construction industry. These are presented in Table 3. below:

Table 3:Background Information of the Respondents

Background Information	Frequency	Percent
Respondents' designation		
Principal partner	4	5.1%
Senior Quantity Surveyor	32	41%
Quantity Surveyor	42	53.8%
Total	**78**	
Respondents' educational qualifications		
Higher National Diploma (HND)	49	62.8%
Bachelor's Degree	25	32.1%
Master's Degree	3	3.8%
Doctorate Degree	1	1.3%
Total	**78**	
Respondents' professional qualifications		
FNIQS	7	9.0%
MNIQS	56	71.8%
Others	15	19.2%
Total	**78**	
Respondents' years of experience		
1 – 5 years	42	53.8%
6 – 10 years	5	6.4%
11 – 15 years	19	24.4%
16 – 20 years	12	15.4%
Total	**78**	

4.4 Factors promoting the adoption of innovation by quantity surveying firms

The summary of the analysis of the factors promoting the adoption of innovation in quantity surveying firms is presented in Table 4. The Table shows the overall mean and ranking of factors promoting the adoption of innovation with respect to QS firms' located in Lagos metropolis. It also shows the overall ranking of the factors promoting the adoption of innovation.

The Table presents the result of the overall rank that replacement of existing services (MS = 3.77) and sufficient orientation towards adoption of innovation (MS = 3.77) were ranked as the first factors promoting the adoption of innovation by Quantity Surveying firms in Lagos metropolis. This is closely followed by improvement in quality services (MS = 3.72), ease of use (MS = 3.72), potential opportunities in new markets (MS = 3.71), enhancement of ability to adapt (MS = 3.70), cooperation and openness of top managers and subordinates (MS = 3.70), Improvement in profit margin (MS = 3.70), cost savings (MS = 3.68) and extension in the range of services (MS = 3.67), all occupying the top ten factors promoting the adoption of innovation by Quantity Surveying firms in Lagos metropolis. While the five least overall ranked factors promoting innovation are the generation of new clients for firms (MS = 3.49), clear understanding of expected goals from innovation adoption (MS = 3.38), supporting the culture of a firm (MS=3.36), technological capabilities of firms (MS=3.32) and location of firms (MS=3.10)

Table 4: Factors Promoting the Adoption of Innovation by Quantity Surveying Firms

	Overall		Lagos Mainland		Lagos Island		T-test	
Factors promoting the adoption of innovation	**Mean Score**	**Rank**	**Mean Score**	**Rank**	**Mean Score**	**Rank**	***T-stat***	***P- Value***
Replacement of existing services	3.77	1	3.65	2	4.11	15	3.262	0.08
Sufficient orientation towards adoption of innovation	3.77	1	3.53	4	4.44	3	0.830	0.36
Improvement in quality services	3.72	3	3.47	7	4.44	3	11.601	0.00*
Ease of use	3.72	3	3.43	10	4.56	1	0.040	0.85
Potential opportunities in new markets	3.71	5	3.51	5	4.28	8	0.850	0.36
Enhancement of ability to adapt	3.70	6	3.71	1	3.67	23	4.103	0.05*
Cooperation and openness of top managers and subordinates	3.70	6	3.49	6	4.28	8	0.181	0.68
Improvement in profit margin	3.70	6	3.41	13	4.50	2	2.224	0.14
Cost savings	3.68	9	3.47	7	4.28	8	0.830	0.37
Extension in range of services	3.67	10	3.55	3	4.00	17	0.080	0.78
Government regulations	3.64	11	3.43	10	4.22	12	3.631	0.06
Minimisation of constraints and challenges to innovation adoption	3.64	11	3.41	13	4.28	8	5.483	0.02*
Increase in income generation	3.64	11	3.39	16	4.33	6	0.012	0.93
Firm size	3.61	14	3.41	13	4.17	13	0.290	0.59
Financial resources available	3.61	14	3.35	18	4.33	6	4.540	0.04*
Attitude of professionals and trade associations	3.59	16	3.47	7	3.94	19	1.560	0.22
Pressure from competitors, clients and suppliers	3.57	17	3.43	10	3.94	19	0.091	0.77
Commitment by top managers	3.57	17	3.27	20	4.39	5	0.333	0.57
Government incentives enhancement programs	3.51	19	3.31	19	4.06	16	6.000	0.02*
Generation of new clients for firm	3.49	20	3.37	17	3.83	21	8.722	0.00*
Clear understanding of expected goals from innovation adoption	3.38	21	3.10	24	4.17	13	6.921	0.01*
Supporting culture of a firm	3.36	22	3.14	23	4.00	17	5.830	0.02*
Technological capabilities of firm	3.32	23	3.16	22	3.78	22	6.080	0.02*
Location of firm	3.10	24	3.25	21	2.67	24	5.650	0.02*

***Significant at 5% level**

Table 4 also show the factors promoting the adoption of innovation by Quantity Surveying firms in Lagos Island, the top ten (10) ranked factors promoting the adoption of innovation by Quantity Surveying firms are ease of use (MS = 4.56), improvement in profit margin (MS = 4.50), improvement in quality services (MS = 4.44), sufficient orientation towards (MS = 4.44), the commitment by top managers (MS = 4.39), increase in income generation (MS = 4.33), financial resources available (MS = 4.33), potential opportunities in new markets (MS = 4.28), cooperation and openness of top managers and subordinates (MS = 4.28) and Cost savings (MS = 4.28). The least five (5) ranked factors are pressure from competitors, clients and suppliers (MS = 3.94), generation of new clients for firms (MS = 3.83), technological capabilities of firms (MS = 3.78), enhancement of ability to adapt (MS = 3.67) and location of firms (MS = 2.67) and others as shown in Table 4.

Previous research on factors promoting the adoption of innovation by Quantity Surveying firms has highlighted factors like improvement in quality services, ease of use, potential opportunities in new markets, enhancement of ability to adapt, cooperation and openness of top managers and subordinates, improvement in profit margin, cost savings and extension in the range of services (Kim *et al.,* 2004b). The findings from this study are thus supported by previous research.

Further analysis was conducted using Student's t-test to test the hypothesis that there is no significant difference (at 5% level of significance) in the opinions of QS firms based in Lagos Island and those based in Lagos Mainland regarding their perception of the factors promoting the adoption of innovation by Quantity Surveying firms. The results indicate that while the two categories of Quantity Surveyors were unanimous in their perception on some factors promoting the adoption of innovation by QS firms, there are statistically significant differences of opinion in their perceptions of some other factors such as improvement in quality services, enhancement of ability to adapt, minimisation of constraints and challenges to innovation adoption, financial resources available, government incentives enhancement programs, generation of new clients for firms, clear understanding of expected goals from innovation adoption, supporting the culture of a firm, technological capabilities of firm and location of firms with significant values of 0.00, 0.05, 0.02, 0.04, 0.02, 0.00, 0.01, 0.02, 0.02 respectively. While their opinion agrees on the other factors that insignificantly promotes the adoption of innovations by Quantity Surveying firms as their *P*- values are greater than 0.05 such as government regulation (0.060, ease of use with 0.85 value and others as shown in Table 4.

5 Conclusion

Respondents were mostly unanimous in their opinions of the factors promoting the adoption of innovation by Quantity Surveying firms in Lagos metropolis. However, there are statistically significant differences of opinion between QS firms in Lagos Island and those in Lagos Mainland regarding some factors which include improvement in quality of services, enhancement of ability to adapt, minimisation of constraints and challenges to innovation adoption, financial resources available, Government incentives, enhancement programs, generation of new clients for firms, clear understanding of expected goals from innovation adoption, supporting the culture of a firm, technological capabilities of firm and location of firms.

Innovation is not a one-time event as pointed out from the study, therefore, QS firms should endeavour to keep training their staff from time to time on both product and organizational innovation.
Based on the conclusion regarding the factors that promote innovation adoption, it is suggested that top managers should be more supportive and proactive in ensuring innovation adoption in QS firms.

This research work is limited to Lagos metropolis, Nigeria. Therefore, further researches can focus on other major cities and states within the country and beyond for comparative purposes.

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Financial Risk Maturity Model for Public-Private Partnership Infrastructure Projects in Ghana: Modelling and Validation

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Abstract
Recently, the public-private partnership model has widely received acceptance in emerging economies to solve huge infrastructural deficits. However, one of the greatest setbacks of the projects built with this model is high financial risks. Scholars have ranked financial risks as one of the topmost causes of the long delays of completion and failure of PPP projects in emerging markets like Ghana. However, a tailor-made financial risk maturity model to tackle this problem is missing in the construction literature. The purpose of this study is to develop a theoretical model validated by experts on PPP projects to enhance the continuous improvement of existing financial management practices of PPP projects. The model was developed from theories, models and statements extracted from relevant literature on this topic. A test and validation were conducted on the developed model with factor analysis and experts' opinions where data were taken from online surveys and interviews in Ghana. The outcome of this study establishes a framework to guide project managers to cut down financial losses of PPP projects and serves as a springboard for further studies into this important topic.

Keywords: Financial risks, Ghana, Public-private partnership project, Risk maturity model

1 Introduction

In recent years, the public-private partnership model has featured prominently in national debates and it is being largely recognised by the Ghanaian government for all developmental projects. Numerous reasons account for this. First, the country has a huge infrastructure gap of \$30 billion (Eyiah-Botwe *et al.*, 2019, Owusu-Ansah *et al.*, 2019) which the government's limited budget cannot finance. Second, the current state of infrastructure in the country is poor as evidenced by congested roads and huge vehicular traffic volumes, poorly-maintained recreational facilities, and deteriorated schools and water supply systems (Ablo and Yekple, 2018). Third, infrastructural projects which are being constructed face long delays, huge cost overruns and minimum financial returns due to poor financial risk management.

Although studies such as Demirag *et al.* (2011), Akomea-Frimpong *et al.* (2020) and Aladağ and Işik (2017) acknowledge this problem (poor financial risk management) with PPP projects in emerging economies like Ghana, few empirical studies exist on practical financial risk maturity models to address this problem in the country. Another challenge related to this problem is the lumping together of all types of risks on PPP projects without a separate and thorough assessment and control of financial risks. The best approach to ameliorate this problem on PPP projects is to develop and implement a practical continuous improvement financial risk model to cut down losses and increase the financial success of the projects in the country (Akomea-Frimpong *et al.*, 2020, Jin and Zhang, 2011). Even though risk maturity is not a new concept in the construction industry and it has been been applied to a number of construction projects with evidence from studies such as Wibowo and Taufik (2017), Hoseini *et al.* (2019), Hillson (1997) and Chapman (2019).. However, a specific financial risk maturity model for PPP projects is missing in the literature.. Therefore, in this article (a portion of a Doctor of Philosophy thesis project), we aimed at developing and validating a financial risk maturity model of PPP projects in Ghana. The research objectives of this study are twofold: i) to develop a practical financial risk maturity model for PPP projects, and ii) to validate the financial risk maturity model of PPP projects.

The outcomes of this study provide a guiding framework for both practitioners and researchers in the PPP market in the country to design and implement measures to control the devastating consequences of financial risks to projects. The remaining sections of the paper are organized as follows. In the next section of this article, a review of existing empirical literature related to the two key concepts – financial risks and risk maturity model – is presented. The research process of this paper is shown from the retrieval of articles relevant to the analysis of the data in section 3. The results section reveals the theoretical framework underlying the financial risk maturity model developed from a critical review of the various risk maturity models and theories in the finance and construction literature. The theoretical model is validated with data from experts in the PPP market in Ghana. The concluding remarks of the study briefly summarise the outcomes of the study, implications and recommendations for future studies and practice.

2 Literature Review

2.1 Financial risks of PPP projects

In construction literature, there are diverse variations in the definition and constituents of financial risks of PPP projects. Schaufelberger and Wipadapisut (2003) listed fluctuations in currency exchange rates, inflation, and cost of capital (interest rates) as the principal financial risks of PPP projects. In the same vein, Kumar *et al.* (2018) focused on limited financial investments from equity instruments and misuse of contracted loans for the project as financial risks. On the other hand, Lam and Chow (1999) utilised the lifecycle phases of the PPP project as the benchmark to identify, group and examine the financial risks of PPP projects. The outcome of the study indicated that shortages of investment capital, poor credit ability, huge interest charges, increased liquidity risk, counterparty risk, high cost overruns, higher taxes and unstable microeconomic policies of a country are the prominent financial risks affecting Build-Operate-Transfer (BOT) projects. Xenidis and Angelides (2005) expounded the findings of Lam and Chow (1999) by conceptualising financial risks to the cash inflows, viability and profitability of the project. Twenty-seven major financial risks were identified and classified using the lifecycle phases of PPP projects. Further, the study regrouped the financial risks under the headings of the origin of the risk, the concession period and the market forces. Shen *et al.* (2006) and Aladağ and Işik (2017) simplified the various financial risks into financial risks that affect the financial returns of PPP projects and those that do not affect the financial outcomes of the project.

The source of financial risks of PPP projects arises from numerous conditions and transactions. First, prolonged loan repayment time: the longer the time contracted to settle the financial obligations of the investment, the greater the risks and interest charges expended on the project. Further, financial risks of PPP projects arise from the overdue delays and failure to meet deadlines leading to high cost overruns setting back the financial returns of the project (Akomea-Frimpong *et al.*, 2021). Following this, misuse of funds on the project limits the financial contributions of the private sector and increases the probability of the failure of the project (Xenidis and Angelides, 2005). Corrupt practices in the public sector in emerging economies account for this management of funds received from the private financiers to build public infrastructure (Demirag *et al.*, 2011). Lastly, some studies on PPP projects have also investigated and recommended practical measures to reduce the financial losses of the projects. For instance, Sun *et al.* (2018) recommended a minimum revenue guarantee (MRG) of the cash inflows of the project to be paid to private financiers in the event of the failure of the project. However, the MRG must be set at a level that could be borne by the government or the public sector (Tan and Zhao, 2019). Vasudevan *et al.* (2018) proposed hedging the uncertainties surrounding PPP projects with derivative instruments such as real options, swaps and futures contracts. While Siemiatycki and Friedman (2012) suggested reassessment of projects and improvement of the knowledge of the personnel managing the projects to avert cases of financial losses.

2.2 Risk Maturity models

Risk maturity models are organisational capability models to boost the efforts of organizations to measure, assess and continuously improve upon existing risk management practices to align the best interests and outcomes of the organisation (Bai *et al.*, 2018, Eadie *et al.*, 2012). According to Risk Management Research and Development Program Collaboration, the concept of maturity model propounded by the Software Engineering Institute at Carnegie-Mellon University led to the first maturity model (CMM) for software organizations (Zhao *et al.*, 2013). Scholars (Gao and Liu, 2019, Salawu and Abdullah, 2015) have investigated and conceptualised the link between maturity models and effective management of risks in organisations. In the same vein, the construction industry, which is inherently troubled by project risks, has seen the development and application of maturity models to tackle the generic risks of projects. Studies such as Hillson (1997), Hopkinson (2011) and Hoseini *et al.* (2019) detail a risk management maturity model to support project managers. A maturity model could consist of three, four, five, six or more levels of maturity depending on the project and the risks. The levels of maturity dictate the standardization and continuous improvement of the processes of the organisation towards project risk management. The attributes of maturity models capture systems, processes, people and culture. Collectively, the attributes complement the processes of risk management from identification to practical controls. Risk maturity models embrace top management, people and leadership in the implementation of managerial controls to ultimately shape an organizational system towards risk management (Hopkinson, 2017, Salawu and Abdullah, 2015). Also, the attributes reflect the fundamentals of risk management that assist in assessing and improving organisational capabilities (Hopkinson, 2011). Peculiar to PPP projects, risk maturity models rely heavily on multi-faceted stakeholders from the principal partners on the project to the workers at the construction site. This means that having a healthy work environment plays a significant role in the morale and successful execution of risk maturity modes on PPP projects. Thus, people and culture must be focused upon in addition to the identification, analysis, and standardization of the process of managing risks which are specifically concerned with the surrounding events (Davis and Walker, 2009).

3 Research Methodology

The process of achieving the research objectives in this article comes in three stages as illustrated in Figure 1.

Stage 1: Literature review

The research began with an extensive search and retrieval of literature on this topic. Scopus, Google Scholar and Web of Science are the academic databases where articles were searched. These databases host and publish top-tier journal articles on the financial risks of PPP projects. Also, they serve as an avenue to access research literature on economics, finance and construction which are relevant for this study (Rossi and Civitillo, 2014, Du *et al.*, 2018, Cui *et al.*, 2018). The search period covered recent years of 2000 to 2021 with keywords such as "financial risks", "financial losses", "risk maturity model", "maturity model" AND "PPP projects", "public-private partnerships" and "build-operate-transfer". The initial search results revealed 324 articles. A brief screening of the results led to the selection and acceptance of seventy-two (72) relevant articles. Content analysis was utilised to extract significant statements (variables) and theories from the 72 articles (Kavishe and Chileshe, 2019). In content analysis, key concepts and themes extracted allow for the interpretation of the text, identification of explicit information that is essential to build up a case, and development of theoretical models and frameworks in the PPP researches (Stevenson and Youde, 2021).

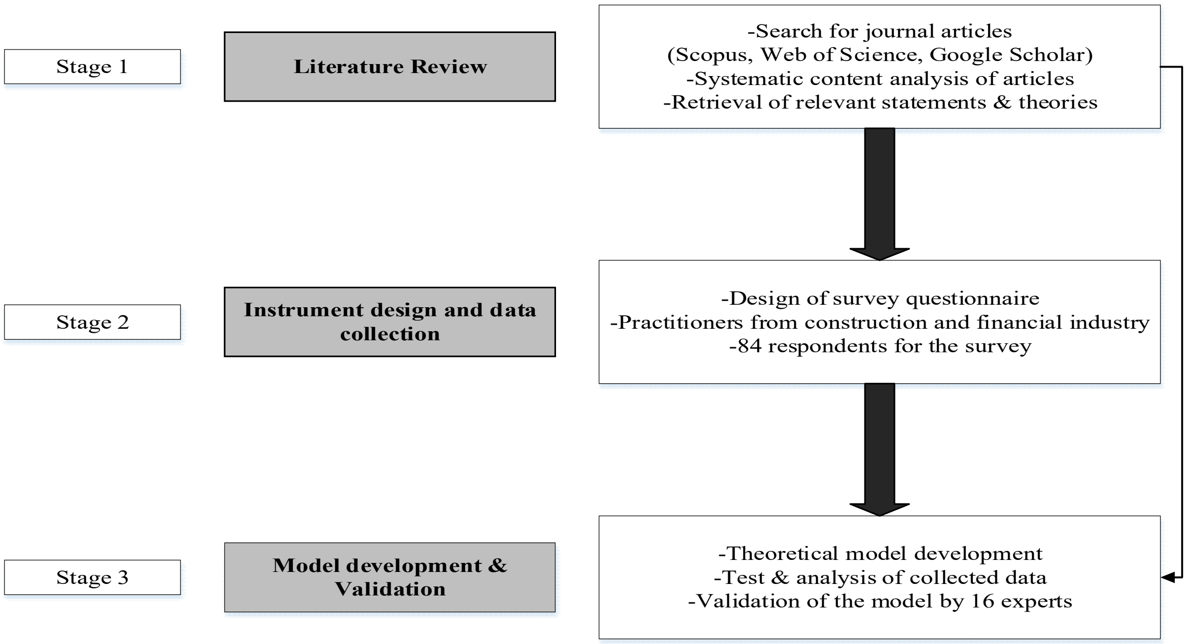

Figure 1: Research methodology map

Stage 2: Instrument design and data collection

The main data collection instrument designed to assist in addressing the research objectives is a survey questionnaire. It had two sections: background information about participants and statements on the financial risk maturity model. Statements in the survey were closed-ended variables extracted from the systematic literature review in stage 1. The statements were operationalised on a 5-point Likert scale representing the significance of the statements, from not critical totally (1), somehow critical (2), indifferent (3), critical (4) and extremely critical (5), into the Qualtrics online survey platform (Babatunde *et al.*, 2017). A pilot test was embarked upon to improve the survey with five (5) experts on PPP projects to eliminate ambiguous statements and ensure the acceptability of the survey to potential participants (Saunders *et al.*, 2007). The comments received from the experts were used to refine the questions, statements and the general structure of the survey (Myers, 2019). Afterwards, reliability and validity tests of the statements ensued to ascertain the distributable flow of the survey. The collection of the data using a survey began with the search for PPP practitioners and consultants/researchers who are experts in financial risks of PPP transactions. We targeted participants in the private sector, state institutions, project management firms, the financial sector and project management professional bodies in Ghana. Due to the Covid-19 restrictions, the targeted participants were contacted online through the collation of the e-mails and phone numbers from institutional websites, LinkedIn and other social media platforms. In addition, potential participants who agreed to be part of the data collection were asked to recommend colleagues who have vast knowledge of PPP activities in Ghana. In the end, we collated the details of a total of 114 targeted participants. We sent a survey link from Qaultrics via e-mails of the participants. Participants who fully responded to the survey were 92 out of 114 participants. The 92 responses were reduced to 84 responses after data cleaning to remove eight (8) responses that were found to be partly filled and incomplete. Thus, the sample size of this study is 84.

Stage 3: Model development and validation

The financial risk maturity model (FRMM) was built from the existing theories, models and statements in construction and business management literature. Then, the model was validated by testing the statements in the model to select the most significant variables. Factor analysis (FA) together with principal component analysis (PCA) was run of the data collected through the online survey. Various underlying tests were used such as Kaiser-Meyer-Olkin (KMO) to check the sampling adequacy, and Cronbach's alpha which measures the reliability and internal consistency of the variables and variance extracted analysis (see Section 4.2). The next step of the validation process was interviews with experienced project managers of PPP projects in Ghana. Participants (specifically project managers) who responded to the online survey and agreed to be part of the interview session of the study constitute the interviewees. Sixteen (16) project managers with more than 10 years of experience on PPP projects agreed to take part in the interviews. Prior to the interviews, the outcomes of the analysis of the survey data were distributed to the 16 interviewees. The aim of the interviews is to validate the relevant extracted statements/varibales to practices on PPP projects. The interviews took place on Zoom, a video teleconferencing platform and questions ranged from suitability, usability and benefits of our developed financial risk maturity model to PPP projects in Ghana.

4 Findings and Discussion

4.1 Financial Risk Maturity model

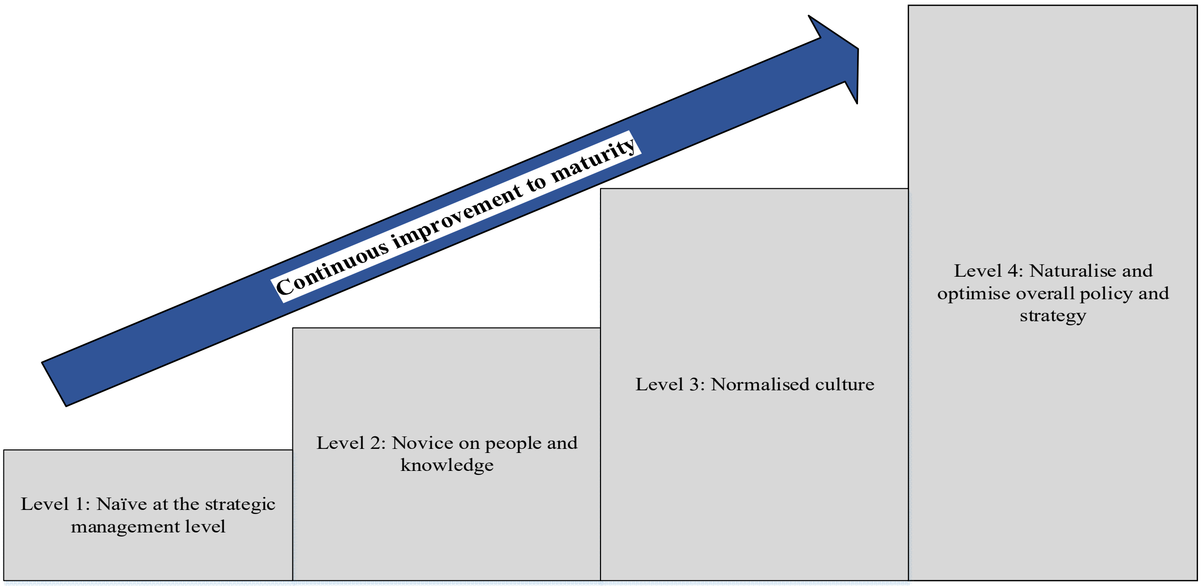

Figure 2: Theoretical financial risk maturity model (Authors, 2021)

The foundation of the financial risk maturity model (FRMM) is the existing theories and models on risk maturity, project risk theories and business management models (Hoseini *et al.*, 2019, Jankensgård, 2019). Although maturity models portray different levels of organisational processes and capabilities to deal with risks (Qureshi *et al.*, 2009), our FRMM has four levels. Also, FRMM differs from existing maturity risk models because it aims at solely controlling financial losses of PPP projects. In Figure 2, the FRMM is a top-down maturity model theorised on two conditions. First, level 1 of the model is akin to an uncoordinated stage of the financial risk management of the project where top managers have uncharted measures to confront the unpredictable events of financial losses (Xenidis and Angelides, 2005). Top managers have not embraced the financial risks due to little or no assessment of the risks. The existing risk management process designed from the strategic management level is either silent on financial risks or lumps them together with all risk factors on PPP projects. Financial risk is treated as trivial and repetitive, and documentation is limited and controls are largely dependent on individuals (Hoseini *et al.*, 2019). In the second level, the organisation acknowledges the existence and peculiarity of the financial risks to the projects. However, a lack of formalisation of the financial control processes to tackle the losses leads to limited understanding of the various partners and pertinent stakeholders who matter to the project (Chapman, 2019) and the contributions of these stakeholders to the creation and management of financial risks. Thirdly, level 3 embraces formal training of top managers, construction workers and relevant stakeholders on the project to embed the financial risk management processes into the organisational culture. Appropriate resources are invested into knowledge to improve upon the internal culture of the organisation in relation to financial risks. Documentations and processes are formalised, well-defined and consistently aligned to the overall objectives of the organisation and the project (Qureshi *et al.*, 2009). In the end, Level 4 organisational policies and strategies are optimised, details of the financial risk factors are defined and the managerial processes are subjected to continuous improvement. The continuous improvement of the processes influences the identification and planning of financial risks with assessment and controlling of financial risks (Akomea-Frimpong *et al.*, 2020).

4.2 Validation of the model

The validation of FRMM started with the testing and extraction of principal statements (variables) with factor analysis. Overall, the Cronbach's Alpha indicated 0.814 which proved the reliable and consistent relationships between the variables. In support of this finding, a Field (2013) mentioned that a Cronbach Alpha coefficient of greater than 0.7 is accepted. The norm distribution of the data was tested using the Shapiro-Wilk Test and the results generated were less than 0.05, indicating non-skewness of the spread of the data. No significant variations were detected among the responses given by the respondents using the Kruskal-Wallis Test, revealing greater than 0.05 significance level. Also, the level of sampling adequacy was measured with the Kaiser-Meyer-Olkin (KMO) Test resulting in 0.743, greater than the benchmark of 0.6 (Hair, 2009). The principal extraction technique used for the analysis was varimax rotation against promax, equamax and quartimax due to its simplicity. The outcome of the analysis of the 18 significant (critical) variables related to the FRMM out of 34 variables is shown in Table 1 together with 74.12 percent of the cumulative explained variance of the results. "✓ " in Table 1 indicates the criticality of the variables at a level of maturity. In Figure 3, the scree plot displays the eight principal variables (in groups) to be retained indicating the total variances of the squared loadings maximised.

After attaining the results from the survey analysis, interviews of sixteen (16) experienced project experts on PPP projects ensued in Ghana. The participants were shown with the theoretical model (Figure 1) and the results from the empirical analysis in Table 2. Some statements such as #No. 5, #No. 15 and #No. 18 from Table 1 were mentioned as irrelevant due to the predetermination of the PPP contracts. It is difficult to amend the terms of the contract. Participants recommended additional statements to be included in the model. Most of the recommendations were centred on continuous improvement at maturity level four (4). Different approaches to tackling financial risks were mentioned by the participants where they recounted few formalised systems relating to the financial risks of PPP projects. All the participants agreed on the relevance, usability and sustainability of the model and mentioned that they will use it to boost their internal organisational process on financial risks of PPP projects. For example, a participant recounted that "FRMM contains relevant statements my management team has discussed in the last 2 years concerning two road projects under construction with PPP model". Another participant stated, "currently, there are no formalised processes to deal with financial risks on our projects so we will accept FRMM if management approves it".

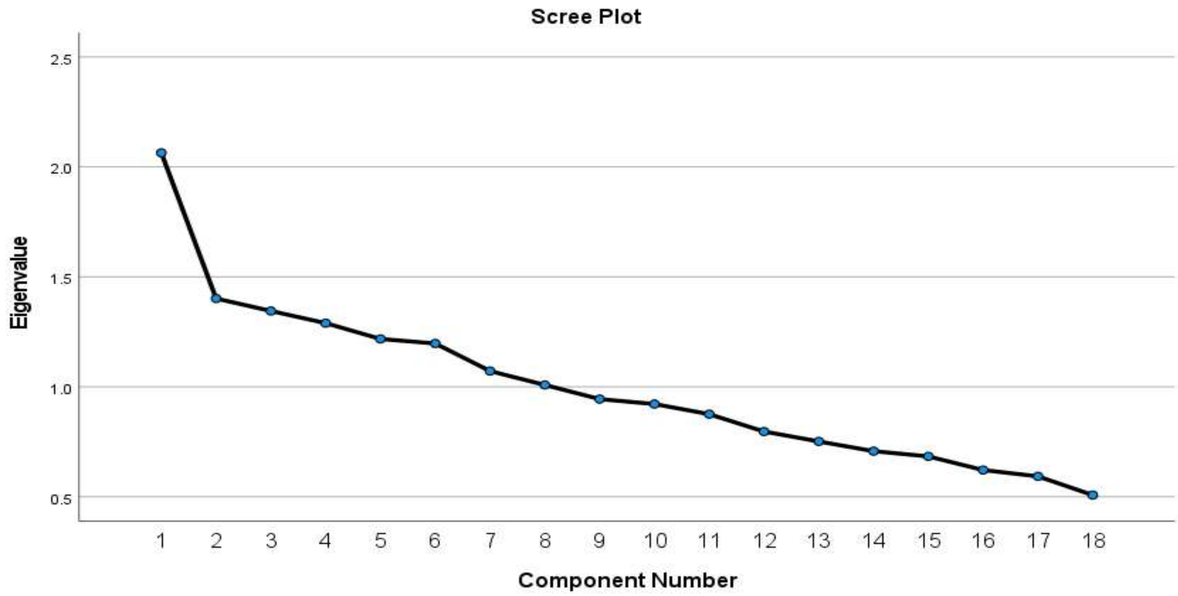

Figure 3: Scree plot of principal components of the critical variables

Table 2: Extracted principal variables of the FRMM model

Statements (Variables)	MCS	L1	L2	L3	L4
1. Review financial reports	4.41	—	—	✓	—
2. Initiate broad stakeholder consultation	4.38	—	✓	✓	—
3. Top management commitment	4.29	—	—	✓	—
4. Threshold of exposure on financial risks set	4.24	—	—	—	✓
5. Thorough analysis of contractual agreements	4.22	—	—	✓	—
6. Find the root causes of all the financial risks relating to the project	4.19	—	✓	—	—
7. Embed financial risks in policies and strategies	4.15	—	—	—	✓
8. Identify, select and prioritise financial risks	4.11	—	—	✓	—
9. Fairly allocate the financial risks based on expert judgements	4.04	—	—	—	✓
10. Use appropriate financial assessment tools	3.98	—	—	✓	—
11. Establish a Minimum Revenue Guarantee (MRG)	3.19	—	—	✓	—
12. Provide specialise training on financial risks	3.01	—	✓	—	—
13. Create formal structures on financial risks	2.92	—	—	✓	—
14. Audit projects and transactions	2.72	—	✓	—	—
15. Reassessment and renegotiation of financial agreements	2.60	—	—	✓	—
16. Utilise technology and track financial transactions	2.59	—	—	—	✓
17. Participative budgets involving key partners of the project	2.57	—	—	✓	—
18. Extend concession period to recoup investments	2.54	—	—	—	✓

Note: MCS=Mean Criticality Score; Cumulative variance explained of the relevant variables is 74.12 percent; L1 to L4 refer to FRMM levels in Figure 2.

5 Conclusions

In this article, a theoretical financial risk maturity model was built and validated. The aim is to reduce financial risks of PPP projects and increase the financial outcomes for principal partners of the project. Relevant literature was retrieved from widely accepted academic databases. Data collection instruments designed for this study were mainly surveys and interviews with 84 and 16 participants respectively. The outcome of the study shows that existing financial risk management processes need continuous improvement. Experts from the PPP projects in Ghana accepted the usefulness of the model to guide them to cut down financial losses. The implications of the study are twofold. The results serve as a guide for further studies on this important topic in PPP project management in developing economies. Second, project managers will receive assistance in developing financial models to tackle this problem. Despite these implications, the study is limited in relation to context and a small sample size. Although Ghana shares similar features with other developing economies, the external environmental conditions of PPP projects in the country are different from other countries. Thus, caution must be exercised when applying the results to other countries.

6 Acknowledgement

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Digitization of Construction Claim Management: The Case of Additional Cost Claims

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Abstract

Claims management is recognized as a complex phenomenon that often leads to disputes between contracting parties. A contractor can claim for many reasons including additional cost. Additional cost claims allow the contractor to recover cost occurred due to several reasons such as delays and/or disruptions, variations and escalations, which evidently result from events beyond the conditions of contract and control of contractors. However, the submission and evaluation of such claims is a challenging task for construction stakeholders because of the existing issues in the management of these claims using traditional approaches. Hence, there is a need realized by industry practitioners for shifting the traditional claim management process of these claims to a digital environment. This need can be fulfilled by a forthcoming Information and Communications Technology (ICT) platform such as Building Information Modeling (BIM). Therefore, in this research effort has been made to utilize BIM for effective management of claims for an additional cost that frequently occur in construction projects. To start with, issues in traditional claims management process of construction cost claims are identified, which is followed by development of a framework for a new system named as BIM - Based Cost Claims Management System (B-CCMS). Grounded on the Application Programming Interface (API) provided by one of the BIM software (Autodesk Revit), a plugin named B-CCMS is proposed for working of the developed system. The proposed system is expected to solve the identified issues in the management of additional cost claims, especially those related to documentation, time, resources, cost, presentation and impact. This will result in quick and transparent settlement of additional cost claims making it less prone to disputes between contracting parties.

Keywords

Building Information Modeling; cost; claims; contracts; claims; framework; API; plugin.

1 Introduction

Cost claim in construction projects is a compensation request by a contractor for an additional cost payable due to the amount of extra work, delays or disruptions that evidently results from events beyond the initial scope and conditions of contract (Adrian, 1988, Barrie and Paulson, 1992). Claims including those for compensable cost are turning out to be fact of life for most of the construction projects (Tan and Anumba, 2010). The vibrant, exclusive and multifarious nature of the construction industry makes such claims inevitable on projects (Ren *et al.*, 2001).

Construction key staff used to spend a lot of effort in project planning, project control and monitoring and project administration phase. But, due to the potential of claims to turn into disputes (Vidogah and Ndekugri, 1997), which globally costs around US$30.7 million and lasts for 15 months on average (Arcadis, 2020), the strategy is now being changed and most of the key staff devote a larger amount of their time in effective management of construction claims (Yates and Epstein, 2006).

Claim management is defined as “the process of engaging and coordinating resources to progress a claim from identification, notification and analysis through examination, and documentation, presentation, to negotiation and settlement” (Kululanga *et al.*, 2001). Poor management of claims is one of the major causes of construction disputes (Vidogah and Ndekugri, 1997). In spite of extensive research related to the management of claims, the ever increasing rise in disputes gives the indication that current methods are not very effective to meet industry requirements (Yogeswaran *et al.*, 1998, Ren *et al.*, 2001).

To the researchers' knowledge, an Information and Communications Technology (ICT) based developed system can be an effective solution in this regard (Vidogah and Ndekugri, 1998). The primary reason for this recommendation is the information difference between contracting parties, which creates problems during claims management and leads to disputes (Vidogah and Ndekugri, 1997). Therefore, an ICT based centralised hub will ensure that the most up to date claims related information are readily accessible to all the stakeholders of the project (Gibbs *et al.*, 2014).

Owing to this recommendation, an ICT based centralized repository need is realized in this research and a framework is proposed that could help in effective cost claims management and elimination of unwanted disputes between parties involved in a construction contract.

2 Research Gap and Aim

The quality of the report used during claims is a prime concern for obtaining desired results (Gibbs *et al.*, 2014). According to Pickavance (2010), digital data in the form of computerized presentation can be used for the effective presentation of claim evidence.

Building Information Modeling (BIM) is a forthcoming ICT platform (Ahmad *et al.*, 2018), and is used to facilitate the design, construction and operation processes of a built object through its shared digital representation (Azhar, 2011). BIM as an electronic, visual and demonstrative evidence tool for construction claims if used on a project from initiation and all records are stored in its central database, then all the project information would be linked to a 3D model (Gibbs *et al.*, 2014). This will help in claims identification, quantification and visualization (Gibbs *et al.*, 2014). Similarly, desired outcomes for claims can be achieved through visualization (Marzouk *et al.*, 2018). Therefore, BIM being a visualization tool can be adopted as a vital tool in proactive avoidance of construction disputes (Gibbs *et al.*, 2014).

However, the literature suggests that BIM has yet not been used for the management of construction claims for an additional cost (Marzouk *et al.*, 2018). This owes to the fact that BIM platforms do not have the inbuilt function of dealing with construction cost claims. Providentially, Application Programming Interface (API) that is provided by various BIM platforms such as Autodesk Revit can be used to develop plugins for enhancing the functionalities of BIM (Akinade *et al.*, 2016). In this way, modelling, data accumulation and visualisation capabilities of the existing

BIM platforms are utilized to accomplish specialized tasks.

Therefore, the aim of this research is to propose a framework for developing a BIM-Based Cost Claims Management System (B-CCMS), that will equip the BIM platform for the management of construction cost claims. This in turn will result in quick and efficient settlement of such claims with minimum disputes between contracting parties.

3 Literature Review

Extensive literature is studied to extract problematic issues related to the management of construction claims including cost claims. After critical review literature, 23 issues were identified as presented in Table 1.

Table 1. Problematic Issues in Construction Cost Claims

ID	Issues Identified from Literature	References
1	Lack of documents	Badger and Gay (1996), Chovichien and Tochaiwat (2006), Essuman (2017), Ren *et al.* (2001), Yates and Epstein (2006), Yoke-Lian et al. (2012), Yusuwan and Adnan (2013)
2	Documents inaccessibility when required	Bakhary *et al.* (2015), Enshassi *et al.* (2009), Surawongsin (2002)
3	Ineffective record-keeping system	Bakhary *et al.* (2015), Enshassi *et al.* (2009), Surawongsin (2002), Scott *et al.* (2004)
4	Poor paperwork by the contractor	Bakhary *et al.* (2015), Yoke-Lian *et al.* (2012), Yusuwan and Adnan (2013), Palaneeswaran and Kumaraswamy (2008)
5	No computerized documentation system	Bakhary *et al.* (2015), Enshassi *et al.* (2009), Surawongsin (2002)
6	Lack of contemporary evidence	Enshassi *et al.* (2009), Palaneeswaran and Kumaraswamy (2008), Ren *et al.* (2001), Surawongsin (2002)
7	Un-organized information to prepare claim	Alkass *et al.* (1995), Bakhary *et al.* (2015), Enshassi *et al.* (2009), Surawongsin (2002)
8	Time consuming	Alnaas *et al.* (2014), Bakhary *et al.* (2015), Chovichien and Tochaiwat (2006), Maduranga *et al.* (2016), Vidogah and Ndekugri (1997), Yoke-Lian *et al.* (2012)

9	Cause and effect determination complexities	Hughes and Barber (1992), Palaneeswaran and Kumaraswamy (2008), Ren *et al.* (2001), Vidogah and Ndekugri (1997)
10	Poor presentation of the impact	Enshassi *et al.* (2009), Hughes and Barber (1992), Ren *et al.* (2001), Surawongsin (2002), Yusuwan and Adnan (2013)
11	Time taking in information retrieval	Bakhary *et al.* (2015), Enshassi *et al.* (2009), Surawongsin (2002), Vidogah and Ndekugri (1997)
12	No standardised format	Bakhary *et al.* (2015), Chovichien and Tochaiwat (2006), Enshassi *et al.* (2009), Hassanein and El Nemr (2008)
13	Deficiency of personnel	Bakhary *et al.* (2015), Carmichael and Murray (2006), Chovichien and Tochaiwat (2006), Enshassi *et al.* (2009), Essuman (2017), Surawongsin (2002)
14	Not realizing what to claim	Chovichien and Tochaiwat (2006), Enshassi *et al.* (2009), Hughes and Barber (1992), Surawongsin (2002)
15	Verbal directions/variations	Bakhary *et al.* (2015), Chovichien and Tochaiwat (2006), Enshassi *et al.* (2009), Hassanein and El Nemr (2008)
16	Contractors exaggeration of claims	Palaneeswaran and Kumaraswamy (2008)
17	High cost in preparation of claim	Bakhary *et al.* (2015), Braimah (2013), Enshassi *et al.* (2009), Maduranga *et al.* (2016), Surawongsin (2002)
18	In efficient communication channel	Bakhary *et al.* (2015), Enshassi *et al.* (2009), Surawongsin (2002).
19	Lack of compliance with contract requirements	Yoke-Lian *et al.* (2012), Yusuwan and Adnan (2013)
20	Contractors delay in notification to Employer	Bakhary *et al.* (2015), Braimah (2013), Hughes and Barber (1992) Enshassi *et al.* (2009), Surawongsin (2002), Yusuwan and Adnan (2013)
21	Lack of contract awareness	Bakhary *et al.* (2015), Enshassi *et al.* (2009), Essuman (2017), Hassanein and El Nemr (2008), Keane (1994), Nguyen and Ibbs (2008), Surawongsin (2002), Yoke-Lian *et al.* (2012)

22	Lack of experts	Bakhary *et al.* (2015), Essuman (2017), Maduranga *et al.* (2016), Yusuwan and Adnan (2013)
23	Personnel leaving organization	Palaneeswaran and Kumaraswamy (2008)

To resolve these identified issues in the management of claims, particularly in cost claims, this research proposes a framework using a BIM environment to develop a management system for cost claims in the construction industry named B-CCMS.

4 Framework Development

Autodesk Revit Architecture 2017 (BIM platform), Structured Query Language (SQL) Server (Database Management System), and Visual Studio.Net (Software Development Environment) are used to develop the framework for B-CCMS. The reason for using Autodesk Revit Architecture as a BIM platform is its good visual presentation and ease of connectivity with external databases (Ali *et al.*, 2020). Moreover, Autodesk Revit's API provides a fully customizable.NET Program Development Toolkit for user interface and software logic development (Akinade *et al.*, 2016). The API of Autodesk Revit software will also create a data link between Autodesk Revit Architecture software and SQL Server. The plugin named B-CCMS will be created with Microsoft Visual Studio and the widely used multi-paradigm programming language C#.

5 B-CCMS Framework

The developed framework for B-CCMS is shown in Figure 1. It utilizes a plugin to be developed in a BIM environment named B-CCMS for cost claims management. The developed plugin (B-CCMS) is interacting with BIM software i.e. Autodesk Revit for its inputs and is connected to a centralized database. The framework and working of the B-CCMS plugin is as follows

1. In the first step, the BIM model of the project is launched in Autodesk Revit software.
2. In a case where a designer or employer has instructed for some design revisions, it will be first incorporated in BIM model.
3. After incorporating the changes or in a case where no such revisions are to be done B-CCMS plugin will be invoked in Autodesk Revit that will be connected to Autodesk Revit through its API.
4. After invoking the plugin, the model element against whom the cost claim is to be generated will be selected.
5. The plugin will provide the option for selecting the type of cost claim from three major types of cost claims i.e. 1. Variation Cost, 2. Extension of Time (EOT) Cost and 3. Escalation Cost. The proposed different types of input information required under each category of all three types are shown in Table 2.
6. The required data against selected type of cost claim will be then entered.
7. Evidence in the form of documents and reports etc may also be attached to strengthen the case and for future record.
8. The B-CCMS will be connected to a centralized database such as with an SQL server, where the data entered for cost claim will be stored.

9. The cost claim data can be then recalled in the form of cost claim register in B-CCMS plugin, which will also assist in 3D visualization of a model element within Autodesk Revit against which cost claim is generated. Similarly, the evidence added can be also seen in the cost claim register.
10. In case if more information is required for decision, it will also be added to the claimed element.
11. After viewing and visualizing the information, a decision can be made on the cost compensation.

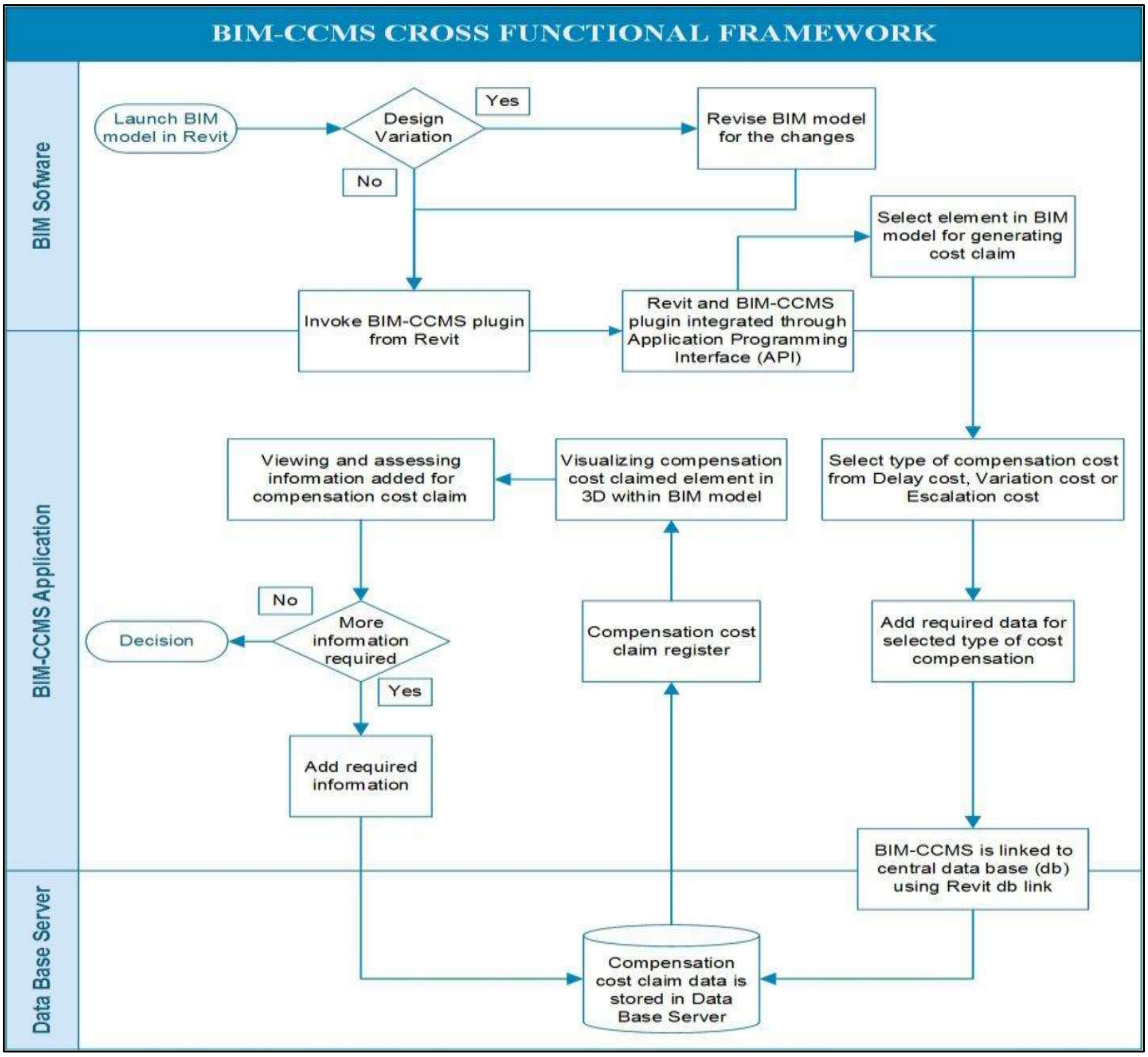

Figure 1. B-CCMS Framework

Table 2. Input Categories for Different Types of Compensation Cost

EOT Cost	Variation Cost	Escalation Cost
Plan Start	Quantity of Varied Material (Auto Picking from BIM Model)	Inputs are required as per relevant contract conditions on project or a standard escalation formula needs to be incorporated to calculate the escalation amount. For example, Price adjustment formula given by FIDIC Contract.
Plan Finish	Unit Cost of Varied Material	
Actual Start	Total Material Cost	
Actual Finish	Direct Cost	
Delay Duration	In-Direct Cost	
Direct Cost	Approved Direct Cost (Updated during decision stage)	
In-Direct Cost	Approved In-Direct Cost (Updated during decision stage)	
Approved Direct Cost (Updated during decision stage)		Escalation Cost Claim
Approved In-Direct Cost (Updated during decision stage)		Approved Escalation Cost (Updated during decision stage)
Attachments if any	Attachments if any	Attachments if any

Direct costs and In-Direct Cost will be calculated for the manhours and machine hours specified in the project schedule for the specified tasks based on productivity. Separate input categories with established backhand formulae for cost calculation can also be provided in the plugin.

6 B-CCMS Roles and Responsibilities

The roles and responsibilities of contractor, engineer (consultant) and a new stakeholder "BIM Manager" for the proposed system are also suggested as per the guidelines of standard contracts and BIM roles and responsibilities guidelines published by (Joseph, 2011). The proposed roles of contractor, engineer and a new stakeholder as "BIM manager" is shown graphically in Figure 2.

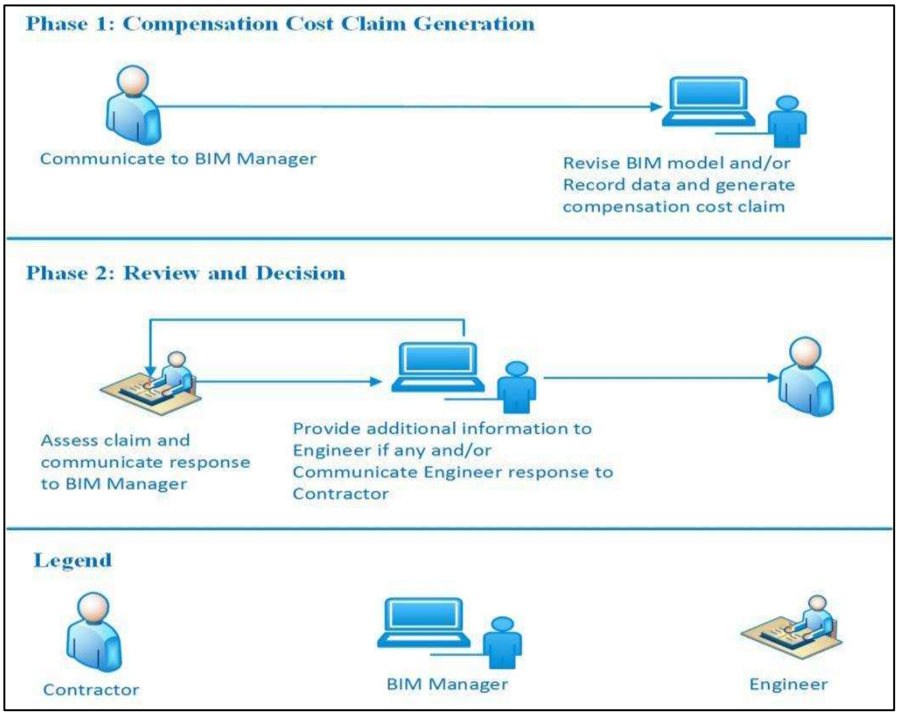

Figure 2. B-CCMS Roles and Responsibilities

7 Conclusion

BIM as a forthcoming ICT tool is utilized in this research to improve construction cost claims management. The problematic issues in existing construction cost claim management are identified in this research through an extensive literature review. Following that BIM technology is reviewed, and it is realized that BIM platforms do not have the in-built option to deal with cost claims but they provide the APIs that can be used to perform specialized tasks within BIM utilizing its visualization and centralized repository capabilities. Thus, in this research, a framework is proposed for developing a system named B-CCMS to deal with construction cost claims using BIM. Guidelines for developing a B-CCMS plugin using Autodesk API is also proposed within the developed framework. Roles and responsibilities for the newly proposed system are also recommended.

Using the developed framework for B-CCMS and developing the plugin on proposed guidelines will help construction stakeholders to utilize B-CCMS or dealing with construction cost claims. BIM together with B-CCMS plugin as the central repository for cost claims will provide the end user with records keeping, communication, presentation, resources and impact visualization of cost claims. Resulting in the elimination of relevant identified issues in present construction cost claims management to a large extent. Overall, this study will contribute to a more transparent and quicker conclusion of construction cost claims. And reducing the probability and impact of disputes in construction projects. Resultantly, construction projects will be completed within time without any unwanted delay and additional cost.

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Investigating the Causes of Subcontractors' Underutilisation of the Security of Payment Legislation in Australia

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Abstract

Within the Australian construction industry, small subcontractors are highly vulnerable to insolvency risk due to poor payment practices. The Security of Payment legislation was introduced to ensure that those subcontractors are timely paid for the work they do. However, since the enactment of the legislation in Australia, the utilisation rates of the legislation have been relatively low. Through a desktop study, this paper aims to identify and discuss the main causes of the legislation under-utilisation including affordability, lack of industry confidence, lack of knowledge and awareness, impact on business relationships and limited right to access the regime. Moving further, this paper will acquaint the lead author's PhD study, which aims to address the barriers and solutions to achieve an appropriate utilisation of the security of payment legislation.

Keywords: accessibility, adjudication, security of payment, subcontractors, utilisation.

1 Introduction

The construction industry is the third-highest revenue-generating sector in Australia, contributing around nine per cent of the gross domestic product (AISC, 2020). It employs around 1,180,000 people with the highest number of registered businesses of 394,575 (ABS, 2019, AISC, 2020). Since 1995, the Australian construction industry has been facing high rates of insolvencies, which became somewhat of an endemic in the sector (Coggins *et al.*, 2016, Griffiths *et al.*, 2017, Ebrahimi, 2019). In 2015, the Australian Economics References Committee published an insolvency report under the title: '*I just want to be paid*', which stressed the significance of reducing insolvency within the Australian construction industry. The report identified the payment practices as one of the primary triggers for insolvency (Economics References Committee, 2015).

Within the Australian construction industry context, the poor payment practices are primarily attributed to the unavoidable contractual hierarchical structure, which produces an unbalanced contractual power (Coggins *et al.*, 2016, Murray, 2017). The imbalance in power forces subcontractors to accept unfavourable conditional payment provisions in the contract. Additionally, contractors with higher power might be inclined to delay payments to use the money in other projects (Sahab and Ismail, 2011, Gerber and Ong, 2013, Davenport *et al.*, 2015, Griffiths *et al.*, 2017).

The pyramidal contractual structure imposes the highest financial risks on the subcontractors at the bottom of the hierarchy who perform most of the actual work in the projects. These financial risks manifest once any contractor at a higher tier becomes insolvent, which will impact all the subcontractors at lower levels through a domino effect (Cheng *et al.*, 2010, Yung and Rafferty, 2015, Coggins *et al.*, 2016, Griffiths *et al.*, 2017, Murray, 2017, Tay and Kong, 2018, Ebrahimi, 2019). Hence, small subcontractors who represent the highest proportion of registered businesses had the highest insolvency rates. For example, in 2018, 64 per cent of insolvencies were for subcontractors with less than five employees (ASBFEO, 2018). Therefore, this paper focuses on subcontractors at the bottom levels of the contractual chain.

The Security of Payment (SOP) legislation was introduced across Australia to mitigate the risk of insolvency by addressing poor payment practices and boosting cash flow in the industry. However, it failed to significantly reduce insolvencies due to variant shortfalls and some existing norms within the industry (Economics References Committee, 2015, Ebrahimi, 2019). One of the vital shortfalls in using the SOP process is the accessibility and utilisation of the process, especially for subcontractors at the bottom of the contractual hierarchy (Bowyer, 2018).

This paper aims to investigate the barriers facing small subcontractors to utilise the SOP process. To do so, this paper begins with an overview of the SOP legislation in Australia, followed by exploring the evidence for the low utilisation of the process. Then, the paper turns its focus to identify and discuss the associated barriers. At last, it identifies some measures that might help in improving the utilisation of the process. This paper embraces an exploratory desktop study that reviews the available literature including primary legal sources, journal articles, and governmental reports.

Background of the SOP legislation in Australia

In 1999, the first SOP Act was enacted in the state of New South Wales (NSW) to improve the payment practices within the construction industry, encouraging "pay now, argue later" principle (Murray, 2017). Henceforth, all other states/territories progressively, save for the Northern Territories, followed the NSW model with some variations. In 2021, Western Australia (WA) made significant changes to its SOP legislation by the virtue of *Building and Construction Industry (Security of Payment) Bill* 2021 to become more aligned with the NSW model based on the recommendations of the Murray Report.

An adjudication process was introduced within the SOP legislation to settle the payment disputes as quickly as possible. The NSW SOP legislation introduced a separate statutory right to payment along with the contractual payment scheme. The statutory right entitles claimants to get paid by seeking a summary judgement without the need for adjudication in case of respondent's failure neither to provide a payment schedule nor to pay the full claimed amount. Alternatively, the claimant can apply for adjudication within 20 business days of the payment due date instead of seeking a summary judgement. Furthermore, the claimant has the right to apply for adjudication to dispute a payment schedule within ten business days after receiving it.

To apply for adjudication under the NSW legislation, the claimant should submit an application to any Authorised Nominating Authority (ANA) within the allowed duration. The respondent may lodge an adjudication response within five business days after receiving a copy of the application. The ANA refers the application to an eligible adjudicator who must provide a determination within ten business days after the lodgement date of the adjudication response. The respondent must pay the adjudicated amount within five business days of receiving the adjudicator's determination; otherwise, the claimant may request the ANA to provide an adjudication certificate and serve notice to suspend the work. The adjudication certificate can then be filed as a judgment for a debt in any court of competent jurisdiction and be enforceable accordingly.

2 The evidence of low utilisation of the SOP

The underutilisation of the SOP process was identified as a concern in different studies and surveys. Bowyer (2018) considered the measures implemented in the SOP Act adequate to reduce the problems in payments but believed the underutilisation to be the main hurdle. Likewise, Evans (2015) and Brand and Uher (2010) considered the underutilisation by small subcontractors in both WA and NSW as the main issue in the SOP process. Similarly, Coggins *et al.* (2016) expressed a parallel viewpoint by indicating that the process is not used as much as it should be, although usage rates might appear healthy. A recent survey also reinforced the claim of having an underutilised process where only 23 per cent of respondents had ever used the SOP process. At the same time, 59 per cent of people who used it indicated that they are doubtful if they will use it again (Murray, 2017). Lately, Steensma and Evans (2020) highlighted a reduction in using the SOP process in WA, which they considered a significant concern for the industry. However, they indicated that there is a lack of solid evidence for the causes behind this reduction.

There is no reliable method of quantifying the utilisation rates for the SOP process since the actual number of payment disputes between parties is unknown due to the existence of many unreported disputes. In order to examine this further, a descriptive analysis of the annual volume of completed construction works as well as the annual number of adjudication applications in the leading states was carried out. Figures 1, 2 and 3 demonstrate the annual value of the performed construction work versus the number of adjudication applications in the states of NSW, VIC and QLD being the most active states using the SOP process.

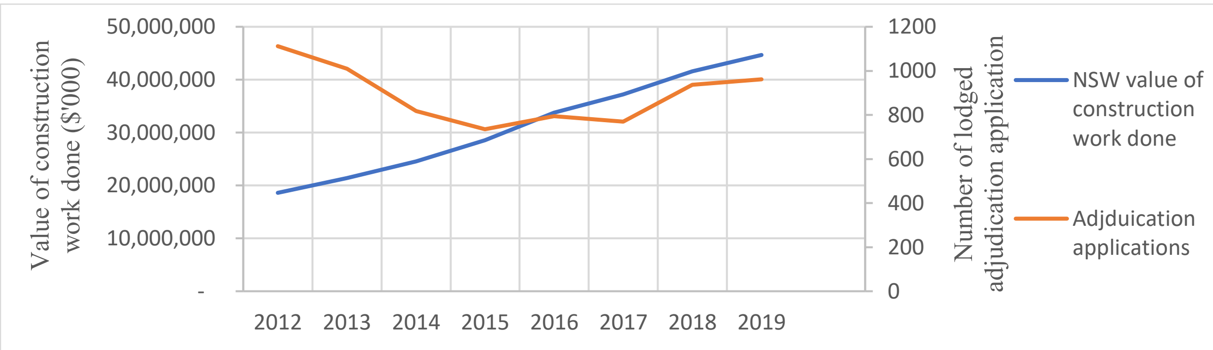

Figure 1. the annual value of construction work done ($'000) vs. annual number of lodged adjudication applications in NSW – Source: NSW Fair Trading (2012-2019); ABS (2020)

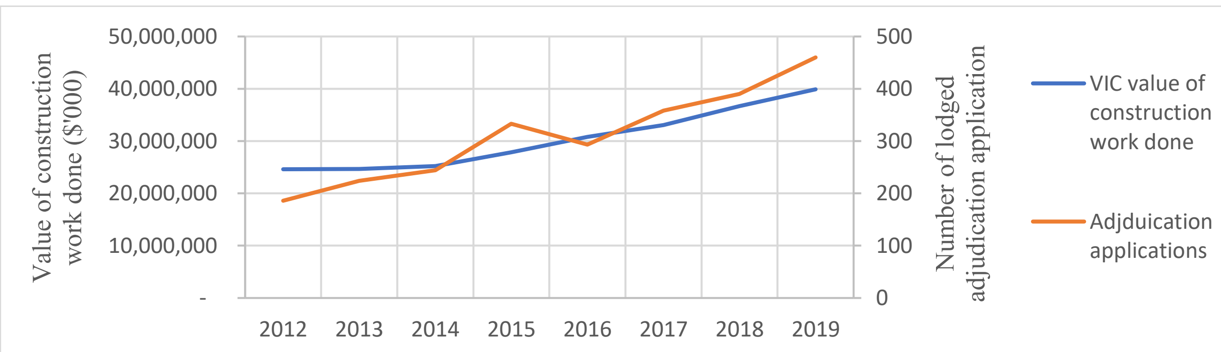

Figure 2. the annual value of construction work done ($'000) vs. annual number of lodged adjudication applications in Victoria - Source: VBA (2012-2019); ABS (2020)

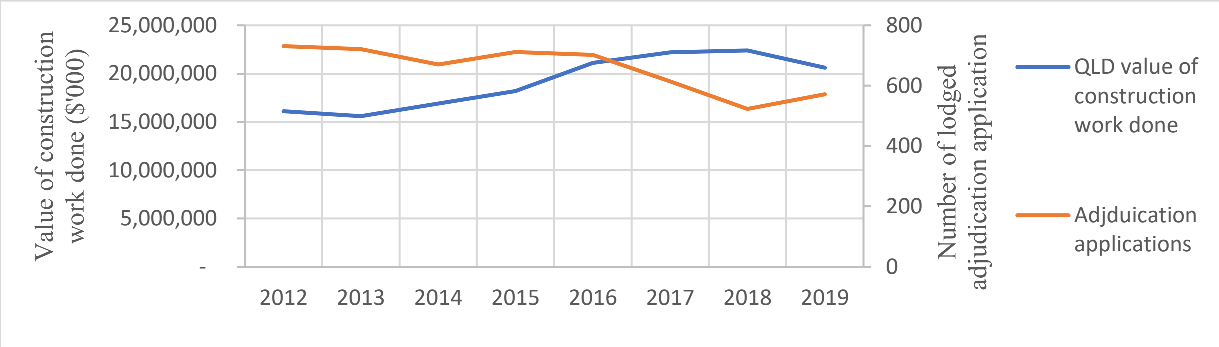

Figure 3. The annual value of construction work done ($'000) vs. annual number of lodged adjudication applications in Queensland - Source: BCIPA (2012-2014); QBCC(2014-2019); ABS (2020)

As shown in Figure 3, QLD demonstrated a continuous decline in the number of lodged adjudication applications while the values of the construction work were increasing. The same occurred in NSW between the years 2012 and 2017, as demonstrated in Figure 1. This decline might indicate less appetite from subcontractors for using the SOP process in NSW and QLD.

On the other hand, as illustrated in Figure 2, the consistent increase in the number of lodged applications in Victoria with a proportionate increase in the value of performed construction work is reasonable, as more construction work increases the probability of having more payment disputes. However, comparing the number of lodged applications in VIC against NSW is concerning since NSW had almost triple the number while having no significant difference in the construction work values. Similarly, the value of construction work in VIC was almost twice the value in QLD. However, the number of lodged adjudication applications in VIC was around half the number in QLD.

3 Causes of the underutilisation

By examining the literature, five main causes of subcontractor underutilisation of the legislation were identified as denoted in Table 1. Each cause is discussed in depth below.

Table 1. Underutilisation main causes

Underutilisation Cause	***Reference***
Affordability in terms of cost and time	(Coggins *et al.*, 2010, Wallace, 2013, Australian Legislation Reform Sub-Committee, 2014, Economics References Committee, 2015, Marquet, 2015, Skaik *et al.*, 2016a, Skaik *et al.*, 2016b, Murray, 2017, Skaik, 2017d, Skaik, 2017b, Fiocco, 2018)
Lack of industry confidence	(Ali, 2006, Chan, 2006, Kennedy, 2008, Supardi *et al.*, 2011, Wong *et al.*, 2014, Marquet, 2015, Skaik *et al.*, 2015c, Yung and Rafferty, 2015, Jayasinghe and Ramachandra, 2016, Skaik, 2016, Skaik *et al.*, 2016a, Skaik, 2017b, Lopez and Amara, 2018, Tay and Kong, 2018, Hassan *et al.*, 2019, Munaaim, 2019)
Lack of knowledge and awareness	(Brand and Uher, 2010, Coggins *et al.*, 2010, Wallace, 2013, Economics References Committee, 2015, Evans, 2015, Murray, 2017, Skaik, 2017d, Steensma and Evans, 2020)

Impact on the business relationship	(Brand and Uher, 2010, Coggins *et al.*, 2010, Australian Legislation Reform Sub-Committee, 2014, Economics References Committee, 2015, Murray, 2017, Skaik, 2017d, Coggins and Donohoe, 2018)
limited right to access the legislation	(Bell, 2011, Gerber and Ong, 2013, Wallace, 2013, Australian Legislation Reform Sub-Committee, 2014, Evans, 2015, Skaik *et al.*, 2015a, Skaik *et al.*, 2015b, Murray, 2017, Skaik, 2017b, Fiocco, 2018)

3.1 Affordability in terms of cost and time

Cheung (1999) investigated twelve attributes that motivate a party to use any dispute resolution process. Cheung found that the cost and time to be the most significant ones affecting the utilisation of any process. The SOP legislation typically has a relatively short timeframe for resolving payment disputes which attracts many claimants. The same applies to the direct cost of the process, which is relatively low compared to other forms of dispute resolution mechanisms such as arbitration. However, the cost-effectiveness of the adjudication in WA (based on the repealed legislation) in low-value disputes was criticised as adjudication fees were twice its counterparts in NSW and QLD for claims under $25,000 (Yung and Rafferty, 2015, Coggins and Donohoe, 2018). Similarly, Queensland was criticised for having a lengthy and costly process for adjudicating complex payment claims greater than $750,000 (Murray, 2017).

Whilst the SOP process is perceived as cost and time effective, which should ease the accessibility to the process, the actual duration until getting paid and the total cost involved makes the process much less attractive. In practice, the prolonged and costly adjudication process is highly influenced by the complexity of the regime, the claimant's administrative burden as well as heavy involvement by lawyers and courts (Skaik *et al.*, 2016b), as elaborated further below:

3.1.1 Complexities in disputes and drafting of the legislation

In order to achieve an efficient process, Murray (2017) emphasised the importance of avoiding complexity and providing a simple drafting style of the legislation. However, complexities within the legislation drafting and adjudication process exist; Lopez and Amara (2018) clarified that some parties perceive the legislation as a subjective, frustrating, stressful and painful process and are reluctant to use it for future disputes.

Some of the identified complexities within the legislation drafting are the reference dates and the adjudicator's jurisdiction. These complexities led to inconsistency of case law and increased judicial intervention. The inconsistency of case law is mainly associated with the different court interpretations of the jurisdictional errors that may be the basis for invalidating the adjudicator's determination. Such inconsistencies are confusing to all parties involved in the process, including lawyers and adjudicators. Therefore, some claimants avoid going for adjudication altogether and go directly to courts (Skaik, 2017e). Such inconsistencies produced uncertainties in the adjudication process and contributed to the lack of affordability of adjudication in terms of time and cost (Skaik *et al.*, 2016a, Bailey, 2019a).

Furthermore, allowing the parties to adjudicate complex disputes has been an ongoing issue that affected the accessibility and fairness of the process. It was one of the significant elements in exposing the deficiencies in the SOP regime, diverting it away from being a quick and cost-effective method (Skaik *et al.*, 2015c). Complex disputes typically include a large volume of submissions and technical reports, which are typically challenging for the adjudicator to appropriately consider the raised arguments within the strict timeframes. As a result, the determination might be challenged by respondents in the supreme court by way of judicial review. This means that claimants will not be able to recover the adjudicated amounts and be forced to invest more amounts of money in defending the determination in court (Skaik *et al.*, 2015a, Skaik, 2017d).

3.1.2 Claimant's administrative burden

Many stakeholders noted that the payment claims in the Australian eastern jurisdictions generate a substantial legal and administrative burden above the contract administration workload (Coggins *et al.*, 2010). From the claimant's perspective, the administrative burden is generated due to the need for identifying and recording what has already been paid for and what is not. This might be difficult, especially when the respondent intentionally aims to keep the claimant in the dark about what has already been paid for. Otherwise, the claimant will be under the risk of judicial intervention and having the determination quashed (Coggins *et al.*, 2010).

Another cause of administrative burden was highlighted by Murray (2017) for the subcontractors or suppliers who operate in different states. Those subcontractors and suppliers have to comply with the various requirements under the different jurisdictions they operate in; hence, it increases the administrative burden for them.

3.1.3 Involvement of lawyers

Since there are complexities within the legislation and the process, subcontractors tend to hire a legal representative to deal with these complexities. Therefore, subcontractors should account for legal and administrative costs, which represent a large portion of the overall cost. These costs might reach twice or thrice the adjudication fees, making the regime unfeasible for small disputes (Coggins *et al.*, 2010, Skaik *et al.*, 2015a, Yung and Rafferty, 2015, Skaik, 2017d). The impact of legal cost can be seen in the example of the UK (United Kingdom), wherein 60% of respondents to a survey believe that the transformation of the regime to a relatively formal and legal process is the main reason for it becoming expensive (Munaaim, 2017b). Moreover, considering the involvement of lawyers without the accompanied uncertainty might deceive a party to believe that hiring a lawyer is feasible while neglecting the increased cost in case of going for judicial review proceedings (Coggins *et al.*, 2010). On the other hand, uneducated subcontractors cannot abandon the lawyer's help if there is a lack of free support services which are usually provided by ANAs (Murray, 2017, Coggins and Donohoe, 2018).

3.2 Lack of Knowledge and Awareness

In a survey conducted in NSW, Brand and Uher (2004) found that one-third of the survey participants had low or no knowledge about the process and considered it the main reason for low usage rates. Six years later, the authors conducted another survey and found that over half of the participants had little or no knowledge about the Act in NSW (Brand and Uher, 2010). Therefore, they concluded that the awareness of subcontractors has not improved since 2004, but instead, it might have declined; they also found that small firms are not getting benefits from the legislation as the big ones do (Brand and Uher, 2010). Murray (2017) found similar results where around 50 per cent of his survey participants were familiar with the legislation, while 20 per cent had no idea about its existence. Similarly, Steensma and Evans (2020) indicated that there is a significant ignorance for the existence of the legislation in WA, especially between the subcontractors at the bottom of the contractual chain. In addition, many other legislative reviews identified the lack of knowledge and understanding of the legislation as the main obstacle for the appropriate utilisation (Evans, 2015, Fiocco, 2018).

3.3 Lack of industry confidence

The judicial intervention shifted the SOP away from its object by transforming adjudication from being a speedy, definitive, informal and cost-effective dispute resolution process to become a meaningless complicated legal process accompanied with a lot of uncertainties

(Kennedy, 2008, Marquet, 2015, Skaik, 2017b). Furthermore, the judicial intervention led the SOP legislation model adopted in NSW and other jurisdictions to be described as a practical but blunt tool due to focusing on speed over accuracy, which resulted in quashing high numbers of determinations in courts (Chan, 2006, Skaik *et al.*, 2015c, Yung and Rafferty, 2015).

From the utilisation perspective, the high rate of quashed determination increased uncertainties of the overall cost and time to secure payments and impacted the confidence in the regime (Wong *et al.*, 2014, Lopez and Amara, 2018, Hassan *et al.*, 2019). It also made subcontractors hesitant of using their right of suspending work when the adjudicated amount is not paid. This hesitation comes from the probable financial risks they might face if the determination is quashed by the court (Supardi *et al.*, 2011, Skaik, 2016, Skaik *et al.*, 2016a). Therefore, suspending or slowing work that should reduce subcontractors' costs and pressurise the respondent to pay the adjudicated amount became ineffective in protecting subcontractors. Consequently, subcontractors might avoid accessing the process and seek other avenues for dispute resolution (Ali, 2006, Jayasinghe and Ramachandra, 2016, Tay and Kong, 2018, Munaaim, 2019). Alternatively, subcontractors will be left to negotiate their rights to settle the dispute to avoid going to court, which is typically considered unfeasible for small claims (Skaik *et al.*, 2016b).

3.4 Impact on the business relationship

The preservation of the relationship between parties at the end of any alternative dispute resolution process is critical for the effectiveness of the process (Cheung, 1999, Gerber and Ong, 2013). Murray (2017) found that in the case of adjudication in Australia, only 12 per cent of the claimants who used it in the last two years have done business later with the respondents, which may confirm that the SOP process damages the business relationship.

One of the identified factors affecting the relationship between parties under the East Coast Model (ECM) is the requirement to endorse the payment claim under the SOP Act. Brand and Uher (2010) found that half of the survey participants believe that this endorsement impacts the relationship negatively to some degree which would demotivate claimants from accessing the SOP process due to their fear of losing future contracts. This impact primarily affects small subcontractors who represent the highest proportion of businesses in the industry; thus, it reduces the usage rate substantially (Brand and Uher, 2010, Coggins *et al.*, 2010, Gerber and Ong, 2013, Coggins *et al.*, 2016).

Although the endorsement might reduce the usage rate, its existence is essential for the process. The necessity of endorsing the payment claims under the Act comes from the fact that payment claim is the trigger of the SOP process, in which the payment claims intend to inform the respondent that the claimant is going to apply for adjudication if the amount is not paid on time (Magintharan, 2011). Additionally, it informs the respondent to comply with the timeframes under the SOP Act, otherwise face the draconian consequences of failing to do so under the SOP process (Magintharan, 2011). Furthermore, the existence of the endorsement increases the probability of amicable settlement as it encourages the parties to communicate and solve the dispute at early stages (Brand and Uher, 2010).

The impact of not having this requirement was witnessed in Singapore, which raised the "Sungdo principle" (see *Sungdo Engineering & Construction (S) Pte Ltd v Italcor Pte Ltd* [2010] SGHC 105). Under this principle, the respondents might not realise that they were served a payment claim; hence they might ignore it (Magintharan, 2011, Burr, 2017, Murray, 2017). On the other hand, a claimant might submit a document that is not intended to be a payment claim. However, it will invalidate the second payment claim served for the same reference date. This means that the claimant will lose the right to adjudicate the later payment claim (Coggins and Donohoe, 2018). Therefore, after removing the requirement to endorse the payment claim under the NSW Act in 2014, it was reinstated in 2018. In contrast, in QLD, this requirement was removed in the 2017 reform (Coggins and Donohoe, 2018).

3.5 Limited scope for accessing the process

Each SOP Act has some exclusions for parties to access the process. In Victoria, for example, the legislation excludes claims for some variations, compensation and damages due to their complexities (Bell, 2011, Skaik *et al.*, 2015a). However, this exclusion resulted in adding complexity to the process instead of easing it and shifting the associated review mechanism to become ineffective (Skaik *et al.*, 2015b, Skaik, 2017b). More importantly, this exclusion reduced the usage rates (Gerber and Ong, 2013, Skaik *et al.*, 2015b, Skaik, 2017b); as demonstrated previously when comparing the number of adjudication applications lodged in VIC to the relevant numbers in NSW or QLD. However, due to their impact on accessibility and being unfair for some contractors, many legislative reviews opposed implementing these types of exclusions anywhere in Australia (Wallace, 2013, Australian Legislation Reform Sub-Committee, 2014, Evans, 2015, Murray, 2017, Fiocco, 2018).

Another access limitation exists in all eastern states save for Tasmania, which is the exclusion of the residential construction work carried out by owner-builder (Bell, 2011). Having said that, NSW has recently amended its legislation to remove this limitation (see section 7(5) of the *Building and Construction Industry Security of Payment Act* 1999 and section 4(1) of the *Building and Construction Industry Security of Payment Regulation* 2020). Since most small subcontractors work in small residential projects (Brand and Uher, 2010), many are expected to be involved in contracts with resident owners. Hence, there might be a substantial number of subcontractors excluded from accessing the process(Wallace, 2013, Murray, 2017, Fiocco, 2018). This exclusion is implemented in the eastern states due to the unfairness of having an occupier unaware of the SOP process compared to a contractor who is familiar with the process (Kennedy, 2008); thus, subcontractors were left with no option but to go for litigation which requires a longer duration (Munaaim, 2017a).

4 Measures to address the under-utilisation:

To address the underutilisation, a separate adjudication process for low-value disputes is proposed with a wide scope of accessibility; following the one implemented in the UK "CIC Low Value Disputes Model Adjudication Procedure (LVD MAP)". In doing so, a fixed and simple template can be used to apply for adjudication, which will help the subcontractors who lack the knowledge in using the process and its requirements to submit a valid application with the proper documentation. Introducing such a process should reduce or eliminate the need for legal representation, decrease the complexity produced from the lawyer's involvement, and reduce unrecoverable costs of hiring a legal representative. Furthermore, providing a process for low-value disputes offers the opportunity to implement limitations on the size and type of the submitted documents, making it easier for the applicant and the adjudicator. Alternatively, limitations on the submitted documents can be implemented as the ones introduced in section 17 of the *Building Industry Fairness (Security of Payment) Regulation* 2018 (QLD), which limited the size of submissions to disputes that have a value less than $25,000.

Furthermore, there should be a compulsory registration requirement for new subcontractors to have at least one employee trained on using the SOP legislation and preparing valid payment claims and adjudication applications. Such a practice will increase the knowledge within the industry while bringing back the process to its intention of being inexpensive, quick, informal with less legal interference. Other measures identified from the reviewed literature are summarised in Table 2.

Table 2. Identified measures to overcome SOP underutilisation.

Identified measures	Reference / similar implemented measure
Developing a simpler, quicker, and more cost-effective process for low-value disputes	Similar to the CIC LVD MAP (Lindsey, 2020)
Limiting the submitted document	Implemented in section 17 of the BIF Regulation "*Building Industry Fairness (Security of Payment) Regulation 2018 (QLD)* (Australian Legislation Reform Sub-Committee, 2014)
Implementing a wide scope adjudication review process.	(Murray, 2017, Skaik, 2017c)
Implementing Cascading Trust accounts.	(Collins, 2012, Murray, 2017, Ebrahimi, 2019)
Allowing courts to invalidate part of the determination.	(Skaik *et al.*, 2016b, Bailey, 2019b)
Enhancing the performance of ANAs and adjudicators.	(Skaik *et al.*, 2016b, Murray, 2017, Skaik, 2017d)
Mutual agreement on the adjudicator or the appointer after the rise of the dispute as in NZ Act	(Coggins *et al.*, 2010)
Implementing reactive measures such as disciplinary actions (penalties and/or suspending or cancelling registration) on respondents who fail to pay the adjudicated amount or fails to provide a payment schedule	Implemented in *Building Legislation Amendment (Consumer Protection) Act 2016 (Vic)*, or QLD BIF Act (Murray, 2017, Fiocco, 2018)
Granting claimant with remedies to recover unpaid money from other venues (i.e., from client or lodging a statutory charge over the property)	(Tay and Kong, 2018)
Implementing wider scope of accessibility (i.e., removing VIC exclusions, claims against homeowner)	(Wallace, 2013, Australian Legislation Reform Sub-Committee, 2014, Evans, 2015, Murray, 2017, Fiocco, 2018)
Providing free advising services	(Wallace, 2013)
Offering a Pre-adjudication conference	(Munaaim, 2017a)

5 Conclusion and direction for future research

The need for reducing the insolvency rates within the Australian construction industry is at its peak. Therefore, there is an urgent need to increase the utilisation of the SOP process, especially for small subcontractors who are highly vulnerable to the risk of insolvency. This paper discussed the main causes of low usage rates for the SOP legislation in Australia. The paper considers, inter alia, the affordability, lack of industry confidence, lack of knowledge, impact on the business relationships, and the limited right to access the process as the main causes for underutilisation.

Although the paper identified some measures from the literature to overcome the identified barriers, many of those measures are not supported by empirical evidence. Therefore, the effectiveness of such measures in improving the utilisation of the SOP requires further investigation. Moving forward, the lead author, as part of his PhD study is currently critically investigating and evaluating all barriers and associated solutions for utilising the SOP process. To do so, a mixed-method approach is adopted, including a questionnaire survey and semi-structured expert interviews.

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Building Occupants and the Lack of Awareness in Energy Conservation Measures

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Abstract
Occupant behaviour (OB) is one of the most impacting variables in the energy intensity in buildings. Several interdisciplinary factors: psychosocial, economic, environmental, and cultural, impact how occupants interact with the building's systems and features. This paper provides the results from a case study performed on two University buildings from Western Sydney University in Sydney: a green-rated and non-rated building. The patterns of the occupants interacting with cooling, heating, lighting, equipment, shading, and windows were studied using questionnaire surveys and building simulation. Results have shown that the lack of awareness in energy conservation measures may represent a difference of 72% in the energy performance of these buildings. The green rating had no impact on the occupants' awareness related to the efficient use of energy. Moreover, 81% of the occupants had no information concerning the building systems and/or features and how to use them efficiently. Finally, this paper discusses several solutions to address the lack of occupant's awareness in terms of energy use.

Keywords
Awareness, building simulation, energy use, occupant behaviour, surveys.

1. Introduction

The behaviour of occupants is one of the variables with the highest impact on the whole building's energy performance. Among the lack of information and misunderstanding, awareness on how to interact efficiently with the buildings' systems and features are some of the main factors impacting the energy use in buildings. This paper presents the results of a study performed on two university buildings from Westerns Sydney University, in Sydney, Australia: a green- and non-rated building. The occupants were asked to participate in a survey to collect their interactions with cooling, heating, lighting, equipment, shading and windows opening. To quantify the impact of occupant behaviour in the overall energy performance of the two buildings, the behaviours collected in the surveys were then used as input variables in the 3D models of the two buildings and simulated, using building simulation, using the software DesignBuilder and EnergyPlus. This study aimed to understand how occupants impact the overall energy performance of a building and understanding the relevance of providing awareness to occupants (Cobben, 2017). Finally, this study intends to analyse if in a building rated as 'green' occupants were more aware, lining up with Darby et al. (2016a), and what were the main differences in the overall energy performance between the non-rated and green buildings.

2. Literature Review

Occupant behaviour is well for its unpredictability. This unpredictability is responsible for 64% of the difference between the operational and predicted energy, followed by 24% discrepancies related to the heating, ventilation, and air conditioning system, and 12% of inefficiencies associated with equipment's conductive heat losses and air rate divergences (Norford et al., 1994). Several other variables impact occupants' energy and comfort choices, including their moods, which makes occupant behaviour one of the most challenging topics within the building sector. The use of energy linked to occupant behaviour has been studied since the early 1950s. Dick and Thomas (1951) were one of the studies identifies in the literature related to the matter. The authors have discussed the relationship between occupants' window-opening habits and their implication in heat loss through air change rates. Then, Iwashita and Akasaka (1997) identified that the occupant behaviour was responsible for 87% of the total air change rates. By then, occupants were simple heat generators. The impact of their behaviours was ignored in most energy simulations (Emery and Kippenhan, 2006, Newsham, 1992). For example, occupants interactions with windows operation, shading, lighting, heating, etc., were ignored (Al-Mumin et al., 2003, Tanimoto and Hagishima, 2005, Nicol, 2001). Factors such as cultural or economic differences, lifestyle or social moral sense and occupant's location were not considered (Wilhite et al., 1996). This led to the gap between the designed predicted energy and the monitored data during the operation stage. The consequence was an overestimation of energy use because the building's systems were over-dimensioned during the design stage (Tanimoto et al., 2008a, Tanimoto et al., 2008b, Mahdavi et al., 2008). Occupants may impact the use of energy passively, due to their movement, presence, and the type of activities they are performing; and actively, by interacting with switching on and off the air conditioning (AC) set-point temperatures, equipment loads and lights, open or close blinds, and windows (Yan et al., 2017). Nevertheless, the behaviour of occupants may be impacted by several different factors. **Error! Reference source not found.** represents all the main factors (driving forces) impacting occupant behaviours related to energy use, according to the International Energy Agency (IEA) (Yoshino et al., 2017).

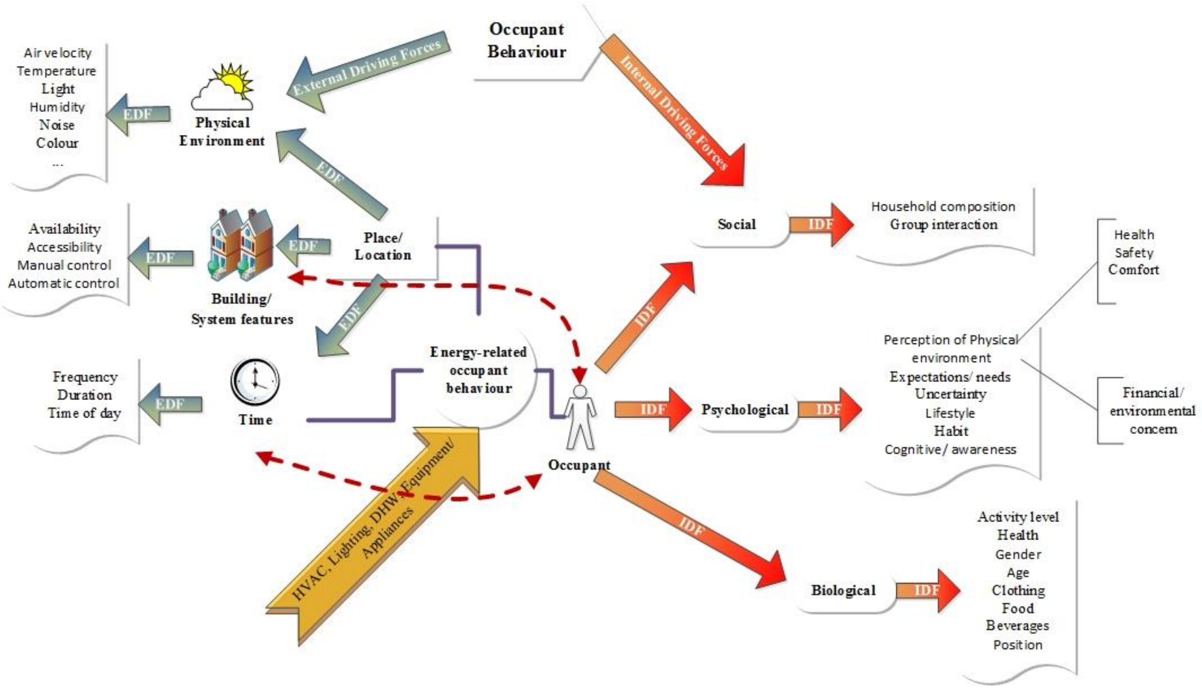


Figure 1. Driving forces impacting occupant behaviour related to energy use
Source: Adapted from Yoshino et al. (2017)

The behaviour of occupants is complex, needs a more profound understanding, and diverges according to occupants' diversity, backgrounds, social-psychological contexts, motivation, and demography (Hong et al., 2016). Occupants' energy choices are impacted by descriptive norms, where what other people do impact a specific behavioural response, and subjective characteristics are associated with their perceptions of what other people expect from their behaviours. For example, the choice to save energy is extremely impacted by a tendency to feel a moral obligation to a particular behaviour. Creating campaigns that promote efficient use of energy will significantly impact occupants' behaviours and choices (Al-Mumin et al., 2003, Nisiforou et al., 2012, Masoso and Grobler, 2010). Other tools may be used to increase occupants' awareness, such as social media, social networks and systems (Klöckner, 2019). However, the values of occupants must be taken into consideration if what is aimed is a behavioural change because it affects the way individuals and communities decide and behave (Burrows et al., 2013). Additionally, despite an increasing trend, the feedback provided by the smart meters needs further improvement, as it currently lacks in providing information to occupants on "how to act" and motivate them towards the implementation of practices that save energy (Bent and Kmetty, 2017, Hyysalo, 2013).

According to Darby et al. (2016a), the significance of the "green" tools and schemes are a positive catalyst to reduce energy use and raise occupants' awareness. Occupants tend to be more tolerant in a green-rated building than in a non-rated one, and even more in small buildings than in larger ones (Leaman and Bordass, 2007a). Just by having the "green" brand does not mean that the building is a "green building". The sustainable design concepts will only have real-time effects when used adequately by occupants (Khashe et al., 2015). A green building has lower emissions related to lighting, heating and equipment, and they can be reduced by 50% to 70% compared to a worst-case scenario (Roetzel et al., 2010).

Furthermore, occupants' satisfaction may be increased by allowing occupants to control these uses of energy, however, there is no clear consensus when addressing energy use. Nicol and

Humphreys (2002) stated as adaptive behaviours that, ‘if a change occurs to produce discomfort, people react in ways that tend to restore their comfort'. However, some literature support that energy use will reduce when occupants have control of their uses (Maniccia et al., 1999), while other states that the more occupants control their use of energy, the more energy will be used (Azar and Menassa, 2012). Surveys have been used as a reliable tool to evaluate occupants’ behavioural patterns in buildings related to their perceptions and opinions related to several different subjects, as light and noise levels, wellbeing, thermal comfort, and indoor air quality (IAQ), and energy use (Ek and Söderholm, 2010, Crosbie and Baker, 2010, Bluyssen et al., 1996). Hong et al. (2017) highlighted that decision-makers have been using surveys to report social, physical, and psychological factors that may impact the implementation of future efficient energy procedures. However, some disadvantages related to the use of surveys were identified, too. The difficulty of occupants to understand the aim of the questions, biases of social and psychological nature because of the feeling of having to perform ‘forced’ choice according to what is socially acceptable and the feeling of being observed, the lack of information related to the building systems, among other aspects. All these factors may impact and compromise the consistency of behaviours that are self-reported (Yan and Hong, 2018).

3. Research Methodology

3.1. Case study buildings

Two buildings from Western Sydney University, in Sydney Australia, were selected for this study. A building from 2016, certified as green according to the Green Star Australian certification scheme (Dawes, 2013) and a building without any rating, from 1989. The buildings, to be comparable, had similar characteristics in terms of the floor area, type of fabric, energy, annual intensity rates, occupancy rates and activity type. Table 1 and Figure 2 show the main characteristics of the buildings. The energy performance of these buildings was studied and analysed through building simulations with the software DesignBuilder and EnergyPlus. 3D models from the two buildings were created and calibrated according to actual energy data (electricity and natural gas) and physical characteristics. The models it was intended to create realistic representations of the green and non-rated buildings and evaluate the real impact of occupant behaviour in energy use (Almeida et al., 2020a).

a) b)

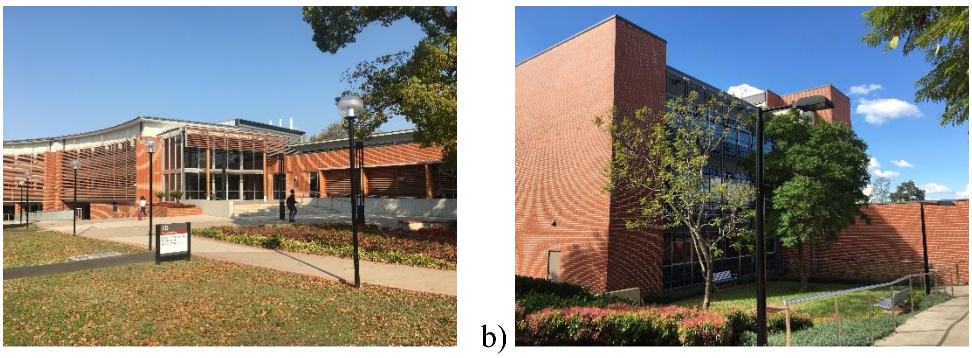


Figure 2. a) green building and b) non-rated building

Table 1. Characteristics of the buildings

	Green building	Non-rated building
Total floor area (m^2)	5696	5242
Conditioned area (m^2)	5181	4667
Unconditioned area (m^2)	515	576
Energy intensity [kWh/(m^2.yr)]**	187.22	190.45
Average light intensity (W/m^2)	6.07	10.85
Average equipment intensity (W/m^2)	16.04	23.15
Average occupancy intensity (occ/m^2)*	0.16	0.11
Energy for cooling and Hot water	Electricity	
Energy for heating	Natural gas	
Main activities	Offices, computer-/classrooms, laboratories, and corridors	
Occupant type	Students, academic, administrative, and technical	
Location	Parramatta, NSW	Kingswood, NSW
Latitude and longitude	33°48'41.14' S 151°01'37.98' E	33°46'06.14' S 150°43'44.83' E
Elevation (m)	12	20
Orientation (°)	2	7

* Per conditioned area
** Calculated through building simulation

Source: Adapted from Almeida et al. (2020a)

3.2. Collection and quantification of occupant behaviours

The behaviours of occupants towards energy use were collected under 100 questionnaire surveys delivered in the two buildings. The surveys aimed to provide occupant questions addressing their awareness in using energy and analyse their behaviours when interacting with the lighting, cooling, heating, equipment, shading, and windows opening (Almeida et al., 2020b). Tables 2 and 3 represent the main characteristics of the two samples and the probabilities of occupants interacting with the previously mentioned systems.

Table 2. Demography of the samples

		Green building	Non-rated building
Gender	**Female**	68%	27%
	Male	32%	73%
Work role	**Academic**	16%	45%
	Student	52%	41%
	Administration	12%	7%
	Technical	20%	7%
Age	**Average**	30–40	30–40
	Standard Deviation	0.862	1.337

	Maximum	50-60	>60
	Minimum	<30	<30

Source: Adapted from Almeida et al. (2020b)

Table 3. Probability[1] of occupants interacting with the buildings' systems

System	Actions	Green-rated building	Non-rated building
		$P(A)_{GB}$	$P(A)_{NRB}$
HVAC[2]	Adjust thermostat when cold	0.11	0.18
	Adjust thermostat when hot	0.09	0.23
Light	Reduction due to glare and visual discomfort	0.50	0.38
	Switch off lights at the end of the day	0.50	0.61
	Switch off lights during daytime	0.30	0.43
Plug loads	Switch off plug loads Offices at the end of the day	0.58	0.78
	Switch off plug loads Labs at the end of the day	0.38	0.49
	Switch off plug loads Circulations at the end of the day	0.53	0.74
	Switch off plug loads General at the end of the day	0.53	0.74
	Switch off plug loads Offices during daytime	0.38	0.48
	Switch off plug loads Labs during daytime[1]	0.20	0.36
Windows	Open/close windows during daytime when hot/cold	0.51	0.36
Shading[3]	Close shading due to glare	0.31	0.31

Source: Adapted from Almeida et al. (2020a)

The occupant behaviours collected in the surveys, after being collected, were introduced in the building simulations models as input variables. The impact on the overall energy performance of the two buildings was then identified and quantified (Almeida et al., 2020a).

4. Findings and Discussion

The results from the buildings presented in Table 1 and Figure 2 show that the leading indicators in terms of energy, greenhouse gas emissions and costs, for the non-rated and green buildings are; 187 kWh/m^2, 192 kg$CO_{2\text{-}eq}$/m^2 and 11 AUD/m^2, and 190 kWh/m^2, 194 kg$CO_{2\text{-}eq}$/m^2 and 10 AUD/m^2, respectively. The actual behaviours of occupants, represented in Table 3, in terms of energy use (Almeida et al., 2020a), represent 25%, (47 kWh/m^2 pa out of 190 kWh/m^2 pa) in the non-rated building, and 19%, (35 kWh/m^2 pa out of 187 kWh/m^2 pa) in the green building, of the total energy used. The highest potential for reduction in energy was verified for the equipment, while the heating was the function most impacted by the behaviours of occupants. The end uses impacted the most by occupant behaviours in the two buildings

[1] The probabilities were calculated with the equation $P(A) = \sum_{i=1}^{n} P(A/E_i)\ P(E_i)$, where 'P(A)' represents the probability of a specific action to occur, 'P(A/Ei)' is the probability of occupants' interaction at an event i due to action A and 'P(Ei)' refers to the probability of the occurrence of the event i.

[2] The percentage of occupants interacting with the air conditioning system is low because the management system mainly manages this system. Only a few rooms have individual units such as Splits or Multisplits

[3] According to the results from the questionnaire surveys, occupants only activated the shading system due to glare in 68% of the rooms with shading in the non-rated building and 61% of the rooms with shading in the green building

were: heating, lighting, and equipment, in the non-rated building, with 81%, 66%, and 46%, respectively. In the green building, occupants impacted lighting, heating, and cooling in 43%, 28% and 24%, respectively (see Figure 2).

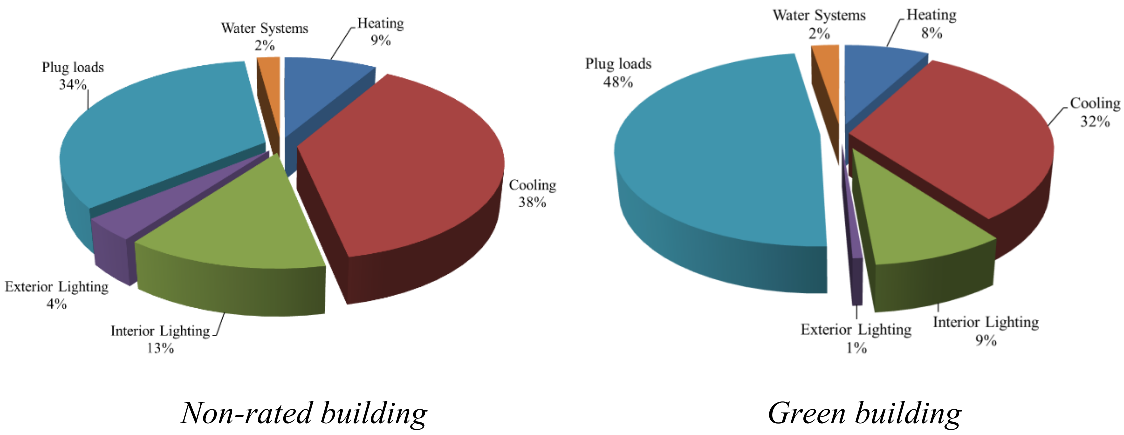


Figure 2. Energy distribution per end-use based on the occupant behaviour
Source: Adapted from Almeida et al. (2020a)

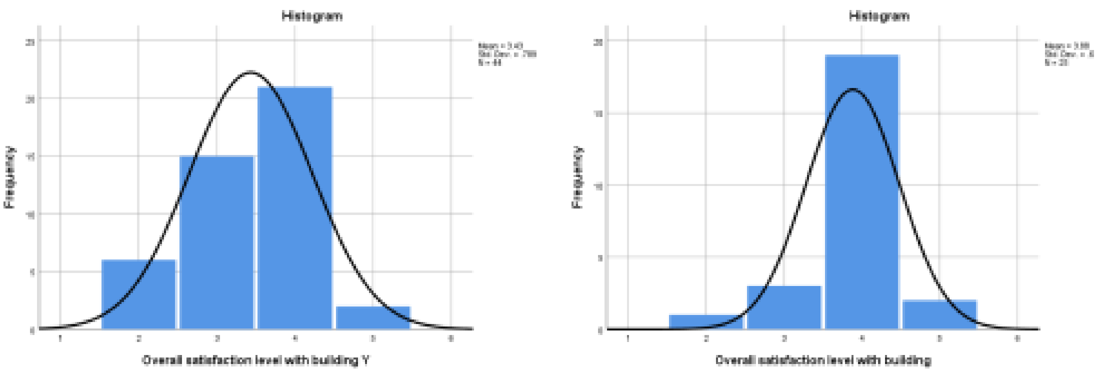
With the results, it was possible to verify that an intensive type of energy user increased by 29% the energy use. However, a saving type of user decreased by 43% the use of energy. This means that the difference between an aware type of energy user and an unaware one may reach 72%. Moreover, because of occupants' interactions with the temperature set-points, it was possible to verify that the green building was not operating according to its certified standards. The green building was operating as a non-rated building. Therefore, it was possible to verify that the green rating had no impact on the overall energy use or on the way occupants perceive the energy, contradicting past literature that mentioned that 'green' tools and brands are a positive catalyst for the reduction of the energy use and increase the occupant awareness (Darby et al., 2016b). The results showed that the importance of energy awareness campaigns discussed by Masoso and Grobler (2010) does not apply to all situations. In this study, 25% of the occupants in the green building answered that they had been educated in how to operate the building systems, while only 15% of the occupants in the non-rated building replied affirmatively to this question. From the combination of the two buildings, 81% of occupants are left without knowing how to operate the building systems. The lack of information on how to efficiently use the building systems, leading to substantial losses due to energy wastes, and the urgency for occupant awareness aligns with the literature (Al-Mumin et al., 2003, Nisiforou et al., 2012, Masoso and Grobler, 2010).

Several solutions to increase occupants' awareness were explored in the literature. The use of flyers, images or short text blocks (Cobben, 2017), campaigns to promote energy efficiency (Al-Mumin et al., 2003; Masoso & Grobler, 2010; Nisiforou et al., 2012), social-media and interactive networks technologies (Klöckner, 2019), smart meters with feedback to the occupants on their preferences and uses, and, finally, green tools and schemes (Darby et al., 2016) were used and suggested as having a positive impact on the behaviour of occupants. However, these solutions are not enough. They do not provide extensive information on the best practices or building's characteristics to drive the building towards an optimised version of itself. Yan and Hong (2018) highlighted the relevance of creating a guidebook with information related to occupant behaviour to aid simulation users during the design stage. Almeida et al. (2021) suggested the elaboration of a user's building optimal performance (U-

BOP) manual to be implemented during the operation stage of a building and have open access to occupants and other building users, with guidelines and information on how to use the building and its systems efficiently.

Furthermore, from the questionnaire surveys researched in detail on the authors' paper Almeida et al. (2020b), the green rating impacted the overall satisfaction of occupants, which agrees with previous literature (Leaman and Bordass, 2007b). Because occupants were more satisfied (see Figure 3), they became more tolerant. Furthermore, occupants' interactions with shading are not related to increase the level of natural light in their working spaces but are related to visual discomfort. Gender, age, workplace size, location, and occupant's working role impact energy uses. For example, older generations have more energy conservative behaviours than younger generations.

Similarly, women are more energy aware than men in the green building; however, the opposite was verified in the non-rated building. Men tend to interact more frequently with building features, while women interact with the building systems (e.g. lighting). The built environment and workplace size encourage occupants' interactions with the lighting system.



a) Non-rated building b) Green building

Figure 3. Overall satisfaction levels in the a) non-rated building and b) green building
Source: Adapted from Almeida et al. (2020b)

The GHG emissions and costs were lower in the non-rated building when compared to the green one (see Figure 4). The study showed a similar range of carbon emissions reduction for the green and the non-rated building, 52.5% (761 $tonCO_{2eq/yr}$) and 57.3% (747 $tonCO_{2eq/yr}$), respectively. This fact has shown that carbon emissions are not always associated with a green-rated building, but a similar range of reduction is also possible to be verified in a non-rated building, contradicting past research stating that carbon emissions related are lower in a green-rated building (Roetzel et al., 2010). The occupants in the non-rated building use 25% less energy than the occupants of the green building. Because a green building is already an optimised version of a building, occupant behaviour had a higher expression in the non-rated building. Any changes in the behaviour or actions of occupants will strongly impact the overall energy performance of a building.

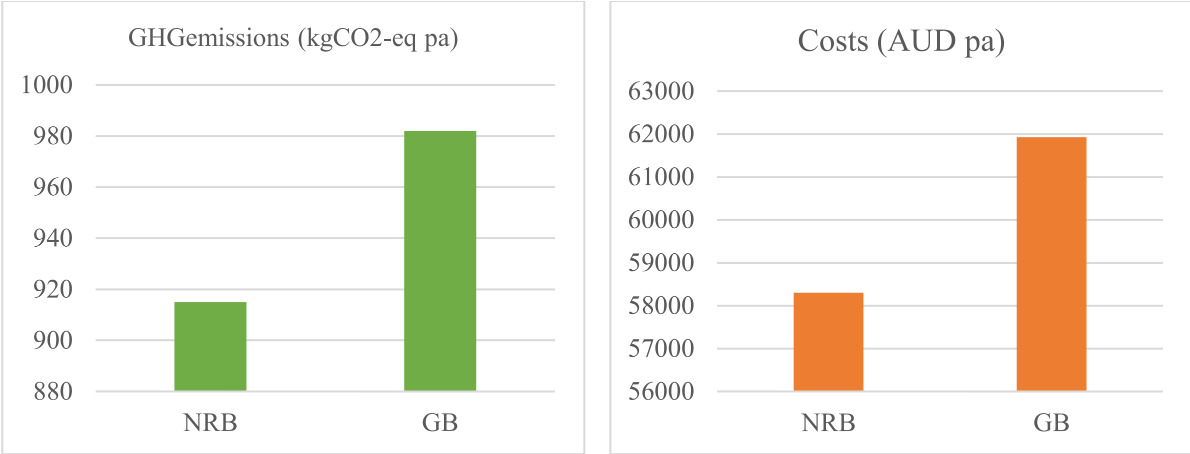


Figure 4. Total greenhouse gas emissions and costs in the non-rated (NRB) and green (GB) buildings

The actual energy data per all the end uses monitored by the university's management system was impossible to be distributed. Despite the intended accuracy of the models used in this study and of the calibration process to refine them, the lack of additional monitoring points, the high investment needed to install them, the limited time for this study and to have access to the building's systems, as well as internal changes in the management system, were the main reasons. Another limitation of this study is the data collected for the non-rated building. This building is from 1989, and some information was not accessible or did not have enough detail. This information was mainly related to the building envelope. Other limitations included; the sample size, psychological factors were not accounted for, and both buildings are home to different schools at the university. One is related to social sciences and the other with computers and mathematics.

5. Conclusion

This paper provided a case study performed on two university buildings, in Sydney Australia, a green and a non-rated building. Occupants' opinions and behaviours related to energy use were collected in questionnaire surveys, and their behaviours were analysed and quantified using building simulation. One of the main results showed that the GHG emissions and costs were higher in the green building when compared to the non-rated one. Both buildings had similar ranges of reduction in the GHG emissions, 52.5% for the green building and 57.3% for the non-rated one, showing that carbon emissions decrease is not always associated with green buildings. Moreover, occupants used 25% less energy in the non-rated building than those from the green one. The difference between an aware energy user and an unaware one may reach up to 72%. The surveys have also shown that, in both buildings, 81% of the occupants have not received any information concerning the building systems and how to use them efficiently. To increase occupants' awareness, several methods were studied in the literature. This study has suggested implementing a users' building optimal performance (U-BOP) manual during the operations stage of a building as a tool to provide guidelines related to the efficient use of building systems and features, to drive the building towards optimal performance.

6. Acknowledgement

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Building circularity in infrastructure and commercial construction

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Abstract
This paper discusses on issues, challenges and opportunities to engage with circularity and the circualr economy in the property construction and infrastructure sectors. In particualar when looking at procurement delivery methods in which operational expenditure (Opex) can offset higher upfront expenditure (Capex). Oportunities are here discussed for Governements and private sector to increase their environmental credentials and project performance. At the hart of this lies engaging with values for circularity through *procurement*. Two whole of life-cycle procurement methos are discussed in relation to opportunities including: Public-Private Parnerships (PPPs) and Build to Rent (BTR), each presents opportunities for Value for Money (VfM); increased project quality; and reduction of carbon footprint and waste in building and infrastruction projects. This paper concludes with an argument on business opportunities with circularity and whole-of-life-cycle (WoL) in mind. And reminds on the moral and ethical responsibility to all proprty, construction and infrastructure stakeholders.

Keywords
Procurement, Circular Economy, Infrastructure, Sustainability

1 Building Circularity in Construction

The World Economic Forum recognises the challenges that come with sustainable construction, our current practices are not sustainable. In 2019, over 92 billion tons of materials were extracted from the planed and processed, contributing to about half of the global CO2 emissions. The resulting waste – including construction related materials – is takin gits toll on the environment and human health (WEF 2016). The circular economy, which promote the elimination of waste and continual safe use of natural resources, offers an alternative that can yield up to $4.5 trillion (USD) in economic benefits to 2030. According to the Circular Gap report only 8.6% of the world is circular (2021).

But what do we mean by circular economy or circularity? “Circular development is a model of economic, social and environmental production and consumption that aims to build a sustainable society based on a circular model. The purpose is to be able to form a model that is no longer linear and transforms toward a circular economy. The aim is to enable economies and societies in general to become more autonomous, sustainable and in tune with the issue of environmental resources” (CGRi Report 2021)

The World Economic Forum identifies four key value drivers for generating asset and resource productivity. Their value creation potential results from extending the use of cycle length and count, increasing asset utilisation, while reducing the creation of new product from virgin materials and producing less waste (Intelligent Assets WEF, 2016) With over 80% of global

GDP generated in urban areas, there are multiple opportunities to optimise construction and supply chain material flow, including waste recovery and asset reutilisation.

Although there has been much R&D on circularity and closed-loop construction systems little has been implemented. The authors argue that there are various procurement contractual structures that contribute to its slow uptake including the lineal staged approach of construction contracts from schematic design, design documentation, contract administration and building operations and facilities management (FM). The transformation toward a circular construction and building operations would demand more business integrations across the engrained silos and this means to convert the prevailing lineal structures into circular loops. The construction industry is still in its early steps toward such integration. The construction sector has identified that directly and indirectly contributes for 18% of global greenhouse gas (GHG) emissions, it was the largest consumer of raw and manufactured materials in 2005 and as such it was labelled as a major emitting (polluting) industry. In other studies (Levermore 2008 and Huang et. al 2018) the construction sector is said to account for 40% of primary energy utilization. This condition rises serious concerns on the impact to GHG impact and calls for strategies for tangible CO_2 reduction at various projects stages, from design through construction and int Whole-of-Life cycle (WoL) operations and FM. The question here is on how much procurement methods could directly contribute to the reduction of CO_2 in the WoL of a building on infrastructure project?

The circular economic model is a direct response to the United Nations Global Development Goals and the Sustainable Development Goals to achieve a green economy. It aims at transforming our economy into one that is regenerative in which *waste* is dramatically reduced or become non as the result of a close-loop production model in which product such as building elements, domestic appliances, clothing or cars reutilise materials and components at the end of the life-cycle and thus land field waste is reduced to a minimum.

This paper discusses opportunities for the construction industry to increase circularity and closed-loop models as a requirement within whole-of-lifecycle (WoL) procurement in both, infrastructure, and commercial construction sector. An important component to consider in the WoL procurement in the operational and Facilities Management (FM) stage as it accounts for a majority emission, but which could be reduced at the design and construction stages. Facilities Management and behavioural programs in building occupancy is an important factor to consider when thinking on operational energy and its related carbon emissions. Also, the 'unoccupied' built environment such as roads, bridges, and other infrastructure, also accounts for embodied energy emissions for over 90% of life cycle emissions, for example, this would be the case of the use of concrete (such as Portland cement) for instance. The embodied energy would typically include 1) direct energy which is the energy required for the on-site construction operations (construction, maintenance/renovation and demolition); 2) indirect energy which is the energy required to providing products and services for the construction operations. Most of the energy used in the construction sector are mostly from non-renewable resources thus the urgency to chance our *modus-operands.*

2 Circularity Requirements in Procurement

Project lifecycle also referred as whole-of-life-cycle (WoL) considers the utilisation span of a service, product or building from the design stage, through construction, building operations and Facilities Management. WoL contracting can stretch up to three decades which is often the case of Public-Private Partnerships for the delivery of economic and social infrastructure (Grimsey and Mervin, 2013). In the private WoL procurement which can take the form of the increasing popular model Build to Rent (BTR). Both methods provide an opportunity to maximise value as WoL plays a role in evaluating improved overall services (output specifications) and risk management which looks at shifting the risk from the client into private sector consortium. In the case of PPPs transferring risk to the private sector experts who can bear the cost of design, construction over-runs are a way in which PPPs can potentially add value for money in a public project. In both, PPP and BTR construction risk are not the only aspect to be addressed. There are also risks attached to site use, building quality (or standards), operations, revenue, financial conditions, service performance, obsolescence, and residual asset value, amongst other. Other WoL construction and procurement methodologies including Design-Build-Operate (DBO) had the advantage of including building operations in the design team. Grimsey and Mervin (2005) define Value for Money as 'the optimum combination of whole life cost and quality to meet the user's requirements. These scenarios present opportunities for increasing *circularity requirements* and close-loop systems (fully defined in next section) to increase project long term (1) quality, (2) operational performance and (3) waste reduction.

In defining **quality** as general term applicable to any trait or characteristic whether individual or generic. Quality is defined by the Merriam-Webster dictionary as *'how good or bad something is,'* also as a characteristic or feature that someone or something has: seeming that can be noticed (or felt) as part of a person or thing. Quality often denotes something of a high level of value or excellence (in which quality is an adjective rather than a noun). In building and architecture, quality might simply be *'fitness for purpose.'* Authors such as Cook became seminal references for the objective (technical) evaluation of design quality including areas of architecture, environment, user comfort, WoL costing operations known as Operational Expenditure (OpenX), detail design and user satisfaction. In more recent times international benchmarks of building quality such as the building occupancy survey (BUS, 2017) and WELL (2020) have become a standard or quality reference for corporate tenants. Both provide a method to benchmark buildings international as to providing keep performance indicators (KPIs) for auditing purposes. Questions of quality in high rise residential construction in mayor Australian capital cities have emerged after recent events of facades catching fire or signs of cosmetic and structural defects in new developments. Governments have also increased occupant/end-user evaluations of infrastructure services such as in transport, health, and education. Either public or private construction needs to bring quality back as a core output and better finance, procurement methods with a strong operations and service delivery need to increase uptake. The next two subheadings introduce PPP and BTR.

In defining **building operations performance,** we can simply think on energy consumption and green principles from not only from building operations and Facilities Management aspect of mechanical, electrical, plumbing and air-conditioning (MEP/AC) equipment but also from green building occupant behaviour too. This has increased to attract attention, with commercial office spaces and ways to benchmark occupant wellbeing as an indicator of operations performance. This approach brings the discussion on an early design stage the durability of equipment and materials, cleaning and maintenance costs, energy efficiency to balance as an example option for passive construction solution, that can be expensive initially versus the offset of costs in cooling and heating energy bills. Recently, the Australian government created the Clean Energy Finance Corporation (CEFC, 2021), to boost clean, green rental stock and extend the benefits of clean energy to Australian renters. Following this commitment some initiatives were taking in place to finance project in built-to-rent (BTR), like Qualitas which made available a new fund to finance the construction and management of energy efficient, low emissions build-to-rent (Qualitas, 2020) residential buildings .

Waste reduction, construction is notoriously known for being a highly wasteful sector. Building operations and FM also contribute to waste production during the lifecycle of a project. Incentives to reduce waste should make business senses. In traditional contracting incentives are next to know. This is because of the silo effect of contracting which opposes the principles of circularity, the circular economy, and close loops systems. Waste reduction must be an integral decision process vertically and horizontally such as design-construction-operations and supply chain.

2.1 Building Circularity in Public-Private Partnerships

Public Private Partnerships (PPPs) are a refinement of the private financing initiatives for infrastructure that started in the early 1990s and describe the provision of public assets and services through the participation of the government, the private sector, and the consumers (Grimsey and Lewis, 2005 and 2013).

There is no single definition of a PPP. Depending on the country concerned, the term can cover a variety of transactions where the private sector is given the right to operate, for an extended period, a service traditionally the responsibility of the public sector alone, ranging from relatively short term management contracts (with little or no capital expenditure), through concession contracts (which may encompass the design and build of substantial capital assets along with the provision of a range of services and the financing of the entire construction and operation), to joint ventures where there is a sharing of ownership between the public and private sectors. PPPs fill a space between traditionally procured government projects and full privatisation (Foster, 2013).

Although many consider PPPs to be a new version of privatisation (Grimsey and Lewis, 2013), in our view PPPs are not privatisation because with privatisation the government no longer has a direct role in ongoing operations, whereas with a PPP the government retains ultimate responsibility and the asset is returned to Government at the end of the concession period. Nor do PPPs simply involve the one-off engagement of a private contractor to provide goods or services under a normal commercial arrangement. Instead, the emphasis is on long-term contracts and strict performance regimes, such as Build-Operate-Transfer (BOT) or Design-Build-Finance-Operate (DBFO) projects to design, construct, finance, manage and operate infrastructure under a concession, with revenues (either from government or users) according to services supplied. The private sector partner is paid for the delivery of the services to specified levels and must provide all the managerial, financial, and technical resources needed to achieve the required standards. Importantly, the private sector must also bear the risks of achieving the service specification (Aranda-Mena and Vaz-Serra, 2018).

There are various reasons as to why governments might undertake PPPs, although paramount is the objective of achieving improved value for money (FM), or improved services for the same amount of money, as the public sector would spend to deliver a similar project. There is a long history of publicly procured contracts being delayed and turning out to be more expensive than budgeted. Transferring these risks to the private sector under a PPP structure and having it bear the cost of design and construction over-runs is one way in which a PPP can potentially add value for money in a public project (Foster 2013; Grimsey and Lewis 2013). Circularity should be integral to risk transfer and value for money considerations.

2.2 Building Circularity in Build to Rent

Build to Rent could be the response to designing, building, and operating commercial development with whole-of-lifecycle in mind and as such tapping into the opportunities that circularity could provide. The supply of rental dwellings via emerging financial routes such as ‘build to rent’ is a promising procurement route for dwelling and commercial development (BTM, 2019).

What is ‘build to rent’? The ‘build to rent’ model focusses on increasing the supply of rental housing through improving investment options and outcomes for institutional investors. As such developers and their financiers build multi-unit buildings and, instead of selling the units, retain them to rent to tenant households. Rents may be set at market rents or, for affordable housing, an appropriate discount to market rents could be offered with appropriate government support to make up the funding gap (Dunn, 2019).

‘Build to rent’ is an established practice in both the UK and USA but it has not been taken up in Australia. Developers cite Australia’s tax settings, which were designed for a ‘build to sell’ model, as a major impediment, land taxes and the inability to defer GST costs on construction materials makes retaining dwellings unprofitable. In Australia, the experience of tenants has included developing a ‘build to rent’ and a large corporate landlord (LCL) sector (AHURI, 2019). While these two sectors may share similarities, there is a subtle difference between them.

Previous AHURI research identified several barriers for institutional investment in the Australian market, reducing the attractiveness of 'build to rent' for investment by the large banks, insurance companies and the superannuation funds. These barriers, which reflected the market conditions at the time of the published research in the early 2000s include low returns, high risk, high management costs, illiquidity, poor market, and no track record. Recent media coverage suggests these conditions have changed, and with the right policy settings, Build to Rent would become a more attractive development option (Ashurst, 2019; AHURI 2019).

Once the building phase is completed, ‘build to rent’ developers may become large corporate landlords in their own right. However, the skills and expertise in managing a tenant base are different from the skills required to obtain finance, design, and construct a large residential building.

Large Corporate Landlords (LCL) could be compared with the automotive and aerospace industries, circular production and procurement models which have continued to grow. Circularity as a model for social-technical change requires a shift in prevailing systems and although “renting” carpets and floor tiles may seem a minor change to the status quo, such changes have a direct impact on how we all collectively perceive, use, and repair good and services (2020).

Rent to lease in the property and infrastructure sector could easily consider many more examples as the above one and lessons from more mature industries such as car manufacturing. From a client perspective there is also a need in changing values and perceptions. For example, buildings will be designed with a view to be dismantle at the end of their lifecycle and reutilised with no (or reduced) waste which also means less carbon footprint and economic incentives for a highly pollutant industry. 39% of global energy-related carbon emissions are attributed to buildings and this situation needs to be addressed according to the World Green Building Council (WGBC 2020). More efficient building energy performance is needed. Better Facility Management and Building Operation services can alleviate the current situation. In such case, tenants are expected to receive quality, not only as built form but as a service. This brings economic incentive for investors and partners adding to the wider quality of life and sustainability drivers much required in our current urban environment.

LCLs are different in that they are financial institutions that acquire large numbers of dwellings and make them available to the rental market, or potentially at a discount to market rents for low-income tenants if appropriate government support is provided. LCLs do not necessarily build new housing stock, they can purchase properties in the market or through mergers and amalgamations with other LCLs. Indeed, the largest LCL in the USA, Mid-America Apartments, (99,939 apartments in 2017) was created in 2016 through the merger of two smaller LCLS that had each been established in the 1970s. Another LCL, Blackstone's Invitation Homes, grew through purchasing 200,000 already existing single-family dwellings between 2012 and 2014 (spending $100 million per week at one stage in 2013). Even a small change or improvement in this scenario would have a substantial direct impact.

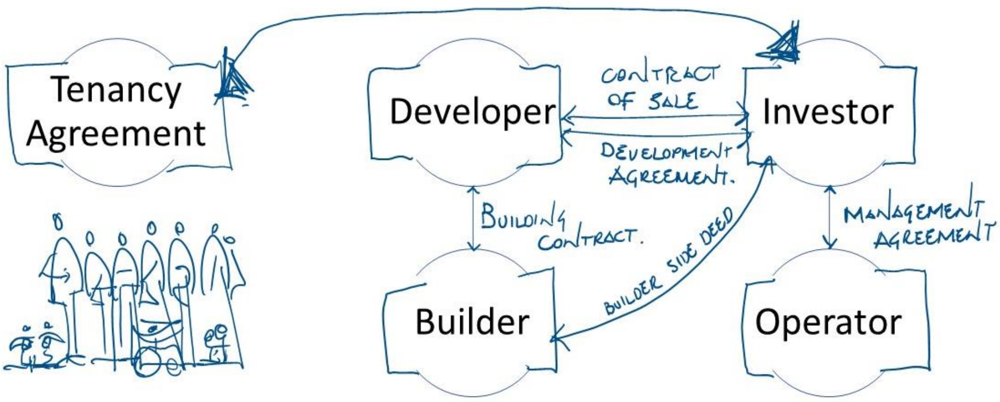

Figure 1. Circularity in Built to Rent, adapted from CBRE

Proponents claim LCLs and 'build to rent' schemes offer greater supply of rental housing, greater security of tenure for tenants, and better professionalism in tenancy management than small scale 'mum and dad' landlords, opportunities and benefits could include initiatives towards adopting circular thinking and circular practices.

Although Built to Rent suggests that successful implementation in Australia requires adequate regulation to ensure the proposed benefits an opportunity rises to built-in requirements for circularity and adding for a better housing experience by increasing materials, products and finishes standards under a tenancy agreement for instance (e.g., see above Figure 1).

2.3 Building Circularity in Design for Manufacturing and Assembly

If defining **building performance**, the appeal of DfMA concepts in the high-rise construction industry derives from the likelihood of repetition, which is often an inherent characteristic of tall buildings, and by the high stakes of economic risk and public safety, which are associated with the timely completion of speculative commercial projects. The idea of applying DfMA strategies in the conception and erection of tall buildings is, therefore, a theme of debate that has gathered interest in the CTBUH community (Vaz-Serra et.al, 2017) and idea that is not new and dates to the early 1900's with the advent of car manufacturing (Kieran and Timberlake 2004).

Designs conceived with ease of manufacture and assembly in mind can contribute to more efficient tall building construction. This argument is often presented as the justification for high-rise experiments in modular construction. Case studies have been shown where strategies of "partial modularization" have brought tangible benefits of productivity for contractors. One study claimed up to 60% reduction in on-site labour and 30% reduction of program time (McFarlane and Stehle 2014). Moreover, the transfer of DfMA principles from the industrial manufacturing realm to that of construction has an even stronger appeal when applied to three-dimensional modular construction systems, also known as prefabricated prefinished volumetric construction (PPVC). The affinity between the manufacturing of products and the assembly of

PPVC modules is almost self-apparent and suggests that there are abundant opportunities for direct transfer of technologies and processes of production from vehicle manufacturing to building construction. Notwithstanding that PPVC may remain as a vital component of the high-rise innovation agenda for years to come, the construction of high-rise buildings with three-dimensional modularization also has significant limitations (Mills et al. 2015; Krulak 2017). It is often suggested that three-dimensional vertical modularization will continue to grow in the future (Wallace et al. 2015), but it is doubtful that PPVC design will be the primary conduit through which DfMA concepts can more effectively bring circularity in the construction industry.

Building circularity through DfMA in the built environment such as efficient processes of innovation with flat-pack systems, rather than three-dimensional modularization, although an small component it can act as an effective catalyst for circularity by volume or repetition such as the utilisation in tall building projects. The validity and possible repercussions of DfMA for tall buildings are discussed by using the case study of a wall-integrated plumbing system that was developed for the bathrooms of a high-rise apartment tower in Australia one small change like this one could provide a high impact or at least a steady step in the right direction.

2.4 To summarise

The selection process for the best procurement route, when the decision to build with circularity in mid is to have a commitment between investor and final user, is paramount. Measure properly unbalanced risk aversion or preventions rather than partial outcomes, thus identifying best value for money solution for overall project lifecycle (McCann et. al, 2014a and 2014b). A call for a level of leadership in integrating circularity and lifecycle procurement. The comfort-zone in selecting known procurement methods is pervasive and at time not much seems to have changed since those utilised in the mid-1990's (Turner's 1997 Pg.81). Circularity must come into the previous and other similar multicriteria analyses tools applied for the selection of procurement methods including build to rent/lease or Public-Private Partnerships in social infrastructure.

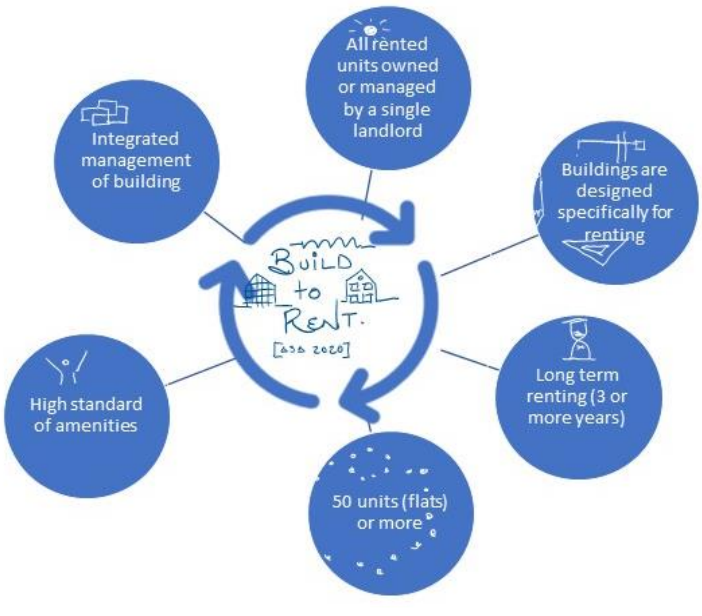

Figure 2 Circularity in Built to rent report for Australia (Adapted from Ashut, 2019).

In construction build to rent (or to lease) presents a clear opportunity to bring commercial incentives to uptake circularity in private sector development, need to have a specific procurement due to the nature of the asset. Integrated management systems of the building in a design stage are essential for the success of the projects (see Figure 2). According to Scheule (2020) the Australian market can benefit largely from the BTR model like attractive solutions for those unwilling or unable to buy their own homes, allowing people to live near the job, and less volatility for long term investors. The procurement method should cover the long-term operational costs, promoting the increase of quality in building environment high more sustainable solutions, high standard of amenities and reducing long term energy costs. BTR for residential buildings is supported by the Clean Energy Finance Corporation (CEFC), looking at the construction and management of its energy efficiency and low emissions (Qualitas, 2020) and with the potential for engaging with the supply chain of products and services.

Several construction companies, developers and real estate agents in Australia are looking and using BTR concept to start new business models and adapt their strategic plan in a long-term commitment with property investors which are likely to be owner-occupier.

2.5 Worked scenarios

The method is that of Schon's Reflective Practitioner in which the authors think, reflect and critically discus industry cases publicly available through government and business reports:

Icon's experience in South Yarra, where it is currently delivering the Iglu student accommodation project primes it for the contract. Hickory could also be expected to bid for the development, given its current pipeline of residential developments including the Aspire tower on King Street in the CBD and Galleria in Glen Waverley. Multiplex is another strong contender with potential to compete, with the Tier-1 builder soon to reach completion on several high-profile projects including Southbank's Australia 108 tower. Probuild, another Australian tier one contractor has indicated interest. Grocon, whose pipeline houses several build-to-rent projects, is not likely to compete, given its partnership with Singaporean investor GIC. Kane, Watpac and Citta are all currently competing for the tender to deliver the state government's build-to-rent projects in Prahran, Brighton, and Flemington, and following announcement of a preferred builder, are expected to express interest in Greystar's development (Love 2020).

Mirvac created a concept based on their rental revolution (Mirvac 2020) for the strategic BTR brand called LIV. CBRE developed the concept of designing a lifestyle, expecting to have continuity in the 2020 BTR gaining momentum in Australia and to have 1800 units completed by 2021. This presents clear opportunities to build circularity in the WoL of high-rise construction, especially due economies of scale. BRE experts advocated that BTR demonstrated resilience through the current COVID-19 pandemic offering a safe haven for investors (BTR 2020).

Figure 3 – Integrating circularity in Built to Rent Adapted from CBRE 2020.

Trends of change in the Australian construction industry suggest that the long-term implications could change the sustainable landscape of an entire industry. The subcontracting market may take a decisive turn in the future, moving towards circular scenarios in which the actors most able to integrate different green production and circular possess in the production of technological systems may emerge as market leaders. The case of prefabrication with integrated plumbing is, in fact, a global phenomenon on the rise, of which very sophisticated examples can be witnessed in prominent recent buildings under construction worldwide, such as at 100 Bishopsgate in London. Such example may have seemed unthinkable in the context of traditional schemes of procurement only a few years ago. However, processes of innovation that depend on the concentration of know-how have occurred long before in other subsectors of the high-rise industry, such as unitized curtain walls (Vaz-Serra et. al. 2019).

As a final statement and if considering the reduction of upfront risk in WoL procurement shifting major project risk to building operations, here lies the opportunity for higher upfront commitment to circularity in a way that makes a *'business sense'* in reducing the operational cost as increasing the building quality. There are also clear opportunities to reducing risk because of a more integrated supply chain of products and services. Infrastructure projects most provide a well justified evaluation of Value for Money (VfM), circularity could be a key assessment criterion. It is our hope that this paper is a first step toward government and private sector engagement with concepts of circularity across design, build and operational stages of commercial and public sector procurement.

3 Final remarks

To conclude, this paper has promoted the concept of circularity in WoL procurement, in particular Public-Private Partnerships (PPPs) and Build to Rent (BTR). The aim was to provide insights into opportunities to engage with close-loop systems integrated across design, construction and building operations as a contractual *service* obligation. The opportunity rises as the popularity of leased over ownership model is on the rise. The benefits that come with the model have been discussed, the most obvious is the long-term contract duration as concession period which can stretch for up to 30 years. In the public sector PPPs have demonstrated Value for Money for Governments and Risk Transfer to private sector means that projects are financed, executed, and operated efficiently by teams of expert specialists and as such a circularity benchmark assessment should be an integral part of VfM in PPPs. In the case of private sector, residential and commercial development, there is also a business case to engage with the circular economy. Circularity on return on investment (RoI) outcomes under the 'Build to Rent' procurement method is plausible. Current cases in the Built to Rent scenario were discussed and future scenarios illustrated. Finally, Design for Manufacture and Assembly (DfMA) clearly provides incentives for circularity a close loop could provide technical efficiencies and component performance such as the example of BMW (2020). The above three scenarios have direct implications to increase building performance during life cycle operations and Facilities Management. Ultimately, *circularity* is about the environment and improving a highly wasteful industry sector, it did not get a single mention in two of the most influential construction industry surveys (KPMG 2021 and Deloitte 2021), nor recycling and not even waste. What a shame!

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Enhancing Employability of Project Management Higher Education Graduates: Should Universities Adopt an Integrated Competency Approach?

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Abstract
There is an increased awareness among higher education institutions of the importance of engaging with industry partners to define learning and skills outcomes that meet the employability needs of their graduates. This paper reports findings of an initial narrative literature review to underpin a wider study that aims to contribute to the debate on project management graduate employability in Australia by merging industry-specific and generic employability skills for graduates and highlighting similarities and differences between different schools of thought on the competence of project practitioners. This review was guided by the following research questions: How do employer expectations of higher education project management graduate knowledge and skill differ from the actual attributes that graduates bring to the workplace? What are generic employability skills and how do they relate to project management discipline skills? How could project management performance standards contribute to the employability of higher education graduates?
Insights gained from these questions are expected to lead to suggested improvements for project management higher education curriculum design and pedagogy. For this paper, different theories of graduate employability skills are explored and aligned with a proposed integrated model of competence for project management roles, to provide a more holistic view of work-ready project/construction management graduate practitioners. The paper concludes with some remarks on how perceived gaps may be addressed through enhanced dialogue between employers and higher education institutions, and the possible adoption of a competence-based approach by higher education institutions, possibly mediated by professional organisations in their role as custodians of performance standards.

Keywords
Australia, generic employability skills, graduate employability, integrated model of competence.

1 Introduction

There exists a well-supported view in the literature that higher education programs in project/construction management are producing graduates who are not always equipped to handle the complexities of today's workplace environment (Crawford, L., 2005; Ramazani, J. and Jergeas, G., 2015; Thomas, J., Mengel, T., 2008). Crawford and Hoffman, applying the Dreyfus and Dreyfus model for skills acquisition (1980) to project practitioners, suggest that the development of meta-competencies is required to complement threshold competencies, or minimum standards for project management knowledge and skills, to produce reflective practitioners (2011).

The above argument is put forward within the realm of project management, and while no comprehensive list of the intended meta-competencies is provided, reference is made to the work of Cheetham and Chivers who suggest that they include communication, creativity, problem-solving, learning, and self-development, mental agility, analysis, and reflection (1998). It is noted that none of these attributes is discipline-specific and are resembling traits that are also characterised as *generic employability skills* in literature (Curtis, D, McKenzie, P, 2002), in which case the suggestion by Crawford and Hoffman accords with research findings that the project management industry values generic abilities more than discipline skills in general, except for employers that are looking for entry-level recruits, who prefer industry-specific skills above generic skills (Chipulu, M., Neoh, J.G., Ojiako, U., Williams, T., 2013).

As teamwork and stakeholder management is central to project management, it could be said that projects are both scientific and social endeavours and that soft skills such as self-awareness and social confidence could be seen as core skills, considering that some authors believe that the human factor is also the main source of complexity involved in managing projects (Stevens, C, Patton, J, Cooke-Davies, T, 2011). It is therefore suggested in this paper that generic skills are needed at all levels of experience as part of the project management discipline and should be acquired not exclusively by experienced, reflective project practitioners, but should be included as early as possible in a project management career, i.e., during the formation stage.

Further, universities, more than vocational learning institutions, aim to produce project or construction management graduates capable of assuming roles of accountability in their profession soon after graduation and not entry-level recruits (Curtis, D, McKenzie, P, 2002), enforcing the need to incorporate both generic skills and project management skills into higher education curricula, with the caveat that they are not separate families of capabilities but complementary elements of employability, as elaborated in various models of graduate employability discussed below (Dacre Pool, L, Sewell, P, 2007, Hillage, P, Pollard, E, 1998, Yorke, M, Knight, P, 2006).

This paper will suggest some initial ideas on the inclusion and alignment of these generic employability skills to existing theories of project practitioner formation. However, as it is argued that meta-competencies can be 'learned but not taught' (Crawford, L, Hoffman, E, 2011) such inclusion would necessarily have to be accompanied by a re-evaluation of our education system, and perhaps most significantly higher education. This is not a novel or revolutionary idea, and while several initiatives to include new pedagogies globally and locally are reported (Olawale, Y, 2015) and novel concepts like *employability* (Fletcher-Brown, J, Knobbs, K, Middleton, K, 2014) and *signature-agogy* (Webber, R, Todhunter, A, Love, P, 2015) have been advocated, not all have achieved high levels of implementation (Jackson, D, 2014, Nagarajan, S, Edwards, J, 2014). The authors have therefore resolved to re-examine some of the foundations of modern management education.

2 Literature Review

2.1 Theories of graduate employability

2.1.1 Generic employability skills

'Generic skills' is a term with many possible meanings, and the Australian Council for Educational Research (ACER) report on employability skills for Australian Industry (Curtis, D, McKenzie, P, 2002) identifies the need for uniformity of terminology at the outset. It suggested that the term 'generic employability skills' best captured the state of the ongoing debate at the time (pp. vii).

The ACER report draws heavily on the findings of the Mayer Committee (1992) which it expands in the light of emerging workplace requirements, with a renewed focus on the attributes of individuals. As discussed below this focus on graduate attributes also occurs in the literature on project management competence, which distinguishes between output-based and attribute-based competence (GAPPS, 2021), and the need to combine the two to obtain a more holistic understanding of the capabilities of a person (Crawford, L, Hoffman, E, 2011).

2.1.2 Components of employability as per the DOTS, Hillage and Pollard, USEM and CareerEDGE models

Studies conducted in the United Kingdom during the 1970s towards the broadening of curricula to improve students' transition into the ever-diversifying world of employment resulted in the identification of decision learning, opportunity awareness, **t**ransition learning, and **s**elf-awareness, collectively known as the DOTS model. This model gave rise to substantial further research as career development learning became a crucial part of the employability framework for higher education (Small, L, Shacklock, K, Marchant, T, 2017).

Hillage and Pollard (1998) allowed for the changing nature of the employment market, which they argued is no longer providing job security, and emphasised the need for graduate jobseekers to market and sell what they termed their 'employment assets'. These assets are categorised at three levels: base-line assets, referring to essential personal attributes such as reliability and integrity, intermediate assets comprising occupation-specific skills, generic skills like communication and problem solving and high-level assets contributing to organisational performance, such as teamwork, self-management, and commercial awareness (Hillage, P, Pollard, E, 1998). The most notable change in this model compared to the DOTS model is the inclusion of occupation-specific skills, perhaps somewhat arbitrarily placed in the 'intermediate assets' category (Small, L, Shacklock, K, Marchant, T, 2017, p. 155).

Subsequent research into graduate employability has further led to the proposed USEM account of employability (Yorke, Knight, 2006), illustrated in Fig. 1, and the CareerEDGE model of graduate employability (Dacre Pool, L, Sewell, P, 2007), illustrated in Fig 2. Of relevance to this discussion is that both these models continue to include both generic as well as discipline-specific knowledge, skills, and understanding as key components of employability, although no clear hierarchy is intimated.

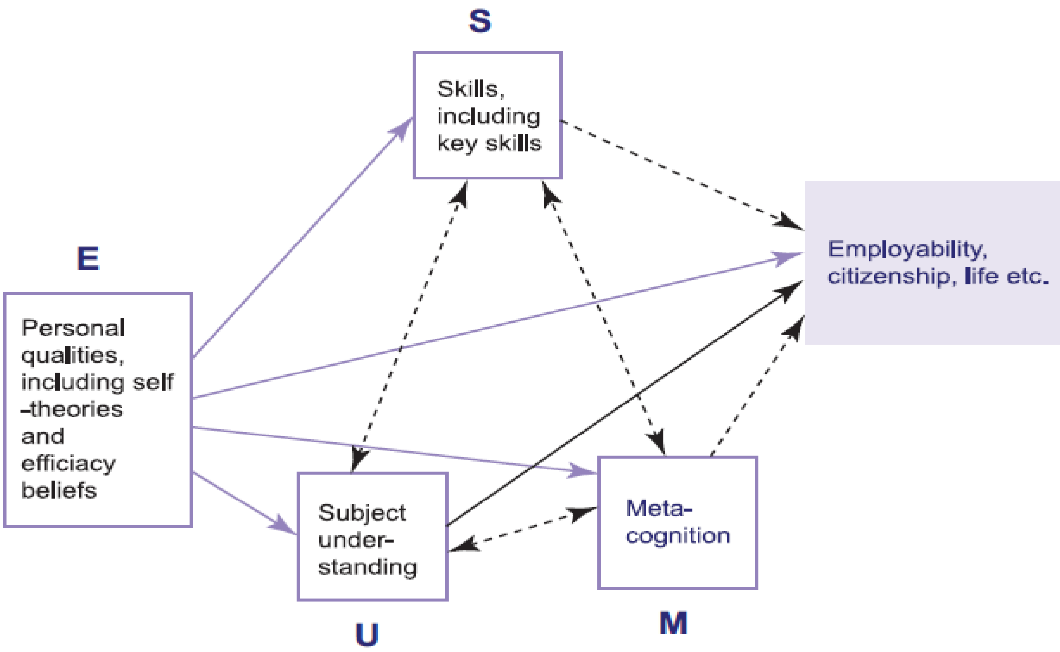

Figure 1: The USEM model of employability (Yorke & Knight, 2006)

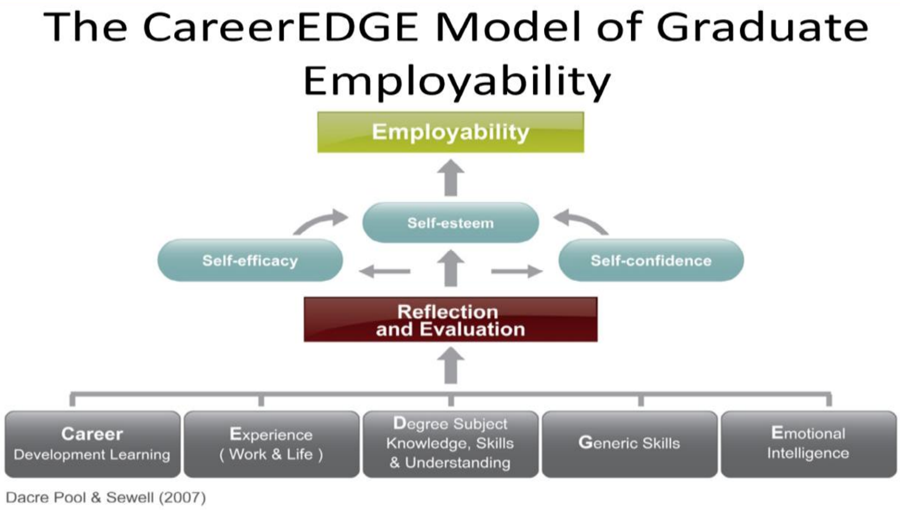

Figure 2: CareerEDGE model of graduate employability (Dacre Pool & Sewell, 2007.)

2.2 Measuring project management proficiency

2.2.1 Performance-based and attribute-based competence standards in project management

Standards for project management performance define minimum requirements for individual practitioners, organisations, and individual projects, and are usually developed by national or international project management professional associations, although companies may also use industry- or organisation-specific standards of performance for recruitment and skills development. Requirements for individual practitioners, and lately also for project organisations, are conceived as taxonomies of competence at various levels of proficiency and across different areas of the field such as scope management. Opinions differ however as to how this competence is assessed, and one view is to gauge competence by judging the quality of outputs produced by a candidate in a real-life environment, supported by evidence. Standards that propose outputs as the basis for assessment are often referred to as performance-based competence standards. Another view depicts competence based on personal attributes, which, if established and proven *infer* a candidate's capability to produce acceptable performance.

Most standards, like the Australian Institute for Project Management (AIPM) Professional Competency Standards for Project Management are output-based where certification is awarded based on evaluation of demonstrated work results produced at a certain level of engagement. Five levels of engagement are identified: Certified Practising Project Practitioner (CPPP), Certified Practising Project Manager (CPPM), Certified Practising Senior Project Manager (CPSPM), Certified Practising Project Director (CPPD), and Certified Practising Portfolio Executive (CPPE). These standards are under constant revision, and all have been updated in 2021, except for the CPPM standard which has been replaced with a (certification) applicant guidance document, probably awaiting further development (AIPM, 2021). Critics of this method argue that the production of a one-time output does not guarantee consistent performance, and that input competence and personal qualities are overlooked.

Attribute-driven standards like the International Project Management Association (IPMA) Individual Competence Baseline version 4.0 (ICB 4.0, 2015) contain key competence indicators that reveal personal attributes needed for satisfactory performance. Critics of this approach argue that personal attributes are more difficult to establish and even if ascertained, that a capacity to perform does not guarantee performance in a real-life context. A merged grouping of these competence categories is proposed by Crawford and Hoffman (2011) and illustrated in Fig 4.

2.2.2 Meta-competencies for project management practitioners

The meta-competencies required for superior performance of project practitioners as suggested by Crawford and Hoffman (2011) are conceived as higher-level competencies, developed over years of practice, as shown on their adaptation of the Dreyfus and Dreyfus model. This placement of meta-competencies as part of advanced proficiency levels is based on research findings that traditionally, it took 15-25 years to develop a project manager capable of handling a mega-project (Turner, JR, Keegan, AE, & Crawford, L, 2000) and that those competencies cannot be taught through formal education methods. However, the same authors also contend that this traditional on-the-job learning path is no longer a viable option as demand for expert project managers is rising exponentially due to a growing volume of increasingly complex undertakings. Adoption of this learning in higher education curricula requires a taxonomic model of employability skills, and a possible configuration using the employability assets as conceived by Hillage and Pollard is shown in Fig. 3.

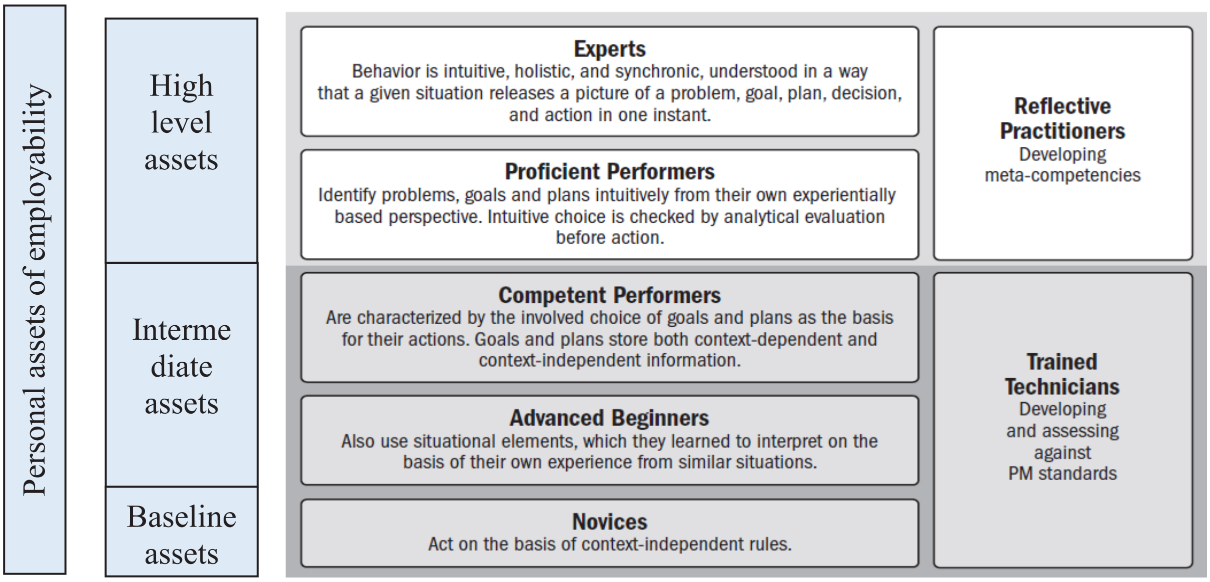

Figure 3: Summary of the Dreyfus & Dreyfus model of skills acquisition as presented and modified for application to project management by Crawford and Hoffman, 2011, modified here to show possible alignment with employability assets as per Hillage and Pollard on the left.

3 Research Methodology

This paper reports the findings of an initial narrative literature review undertaken to frame a wider study that aims to contribute to the debate on project management graduate employability in Australia by merging industry-specific and generic employability skills for graduates and highlighting similarities and differences between different schools of thought on the competence of project practitioners.

The search into generic employability skills used the terms ‘employability skills of graduates’, ‘project management’, ‘construction management’ and ‘Australia’ and yielded 19 articles from 5 databases. As this was not a full systematic review, findings were further contextualized to enhance credibility (O’Leary, Z., 2009) through comparison with the AQF framework (2013), the QILT 2020 Graduate Outcomes Survey (2020) and 2020 Employer Satisfaction Survey (2021), and ACER Report on Employability Skills for Australian Industry (2002).

Industry-specific skills requirements were selectively gathered from the AIPM project management competence standards because of their relevance to the Australian context, the IPMA ICB for its international relevance and attribute-driven approach, the South African SAQA standards for project management because of the high familiarity of the lead author with this standard, and the GAPPS standard for leadership in complexity for insight into higher-order competence. The intent of the authors here was to create ‘initial or preliminary conceptualisations and theoretical models … to combine perspectives and insights from different fields’ (Snyder, H, 2019, p. 336.), and to guide further research.

Further steps in the research may employ emerging methodological design (O’Leary, Z., 2009) including a phenomenological study of the perspectives on both sides of the employment spectrum through interviews; however, this has unfortunately been delayed due to a pending ethics approval and can therefore not be reported in this paper.

4 Discussion

4.1 Alignment between generic and subject-specific models of competence

4.1.1 Areas of overlap between generic employability skills and project management competence.

The literature review clearly shows that theories on employability of graduates, while initially focusing on personal attributes alone as in the DOTS model, have gradually included discipline-specific knowledge and skills as a component of employability. However, levels of proficiency are not as pervasive as they are in project management competence standards. This may be because they are aimed at entry-level graduates, however, the literature suggests that these skills need to be honed and nurtured along with a life-long career along with occupational skills (Curtis, D, McKenzie, P, 2002) and would therefore become suitable for taxonomic analysis. It is not inconceivable that Australian universities, whose status requires alignment of their learning programs with the higher levels of the Australian Qualifications Framework (AQF levels 7-10) are deterred by this perceived lack of taxonomy for generic skills.

Conversely, project management competence standards are generally contextualised by range statements, and importantly underpinned by generic skills. There is however an important difference in how these generic skills are positioned in a competence standard, depending on whether it is performance-based or attribute-based. In a performance-based standard such as those published by AIPM, these skills are peripherally included as 'underpinning skills and knowledge', while the South African Qualification Authority (SAQA) uses the term 'Critical Cross-field Outcomes' and are not explicitly assessed during certification. Moreover, in the AIPM standards, the underpinning knowledge is largely discipline-specific while the underpinning skills seem generic.

The IPMA ICB 4.0, an attribute-based competence document, outlines three areas of competence: perspective, people, and practice, hence the generic skills component is not only intrinsically included, but it also represents about half of the competence elements and is very much assessed as part of the accreditation process of individuals.

4.1.2 Towards a holistic model of competence

As mentioned earlier, Crawford and Hoffman (2011) advocate an integrated competence model using both output-based and attribute-based approaches to obtain a holistic view of a practitioner's capability to manage projects in a complex environment, and hence this model includes the generic skills deemed essential in a competent practitioner, as noted in the adapted model outlining the generic skills area as shown in Fig. 4.

It is argued that problems may still arise from the different 'verticality' of the two sides of the model, as performance-based standards typically comprise several levels, (5 in the case of AIPM), directly aligned with a level of certification. An attribute-based standard like ICB 4.0 is conceived more like a binary on-off standard and less of a factor in determining certification levels. While IPMA certification comprises a 4-tier structure, the three higher tiers (IPMA A, B, and C) all require 'possession of the competencies described in the ICB' while the lower level D requires 'knowledge' of the same, and the level of the certification accredited depends on proven experience (IPMA.world). Admittedly the ICB 4.0 includes project, programme, and portfolio management attributes but they should be seen as different competencies rather than as different levels of the same competencies. The important point to note here is that generic skills are now included as part of a holistic view of project management competence.

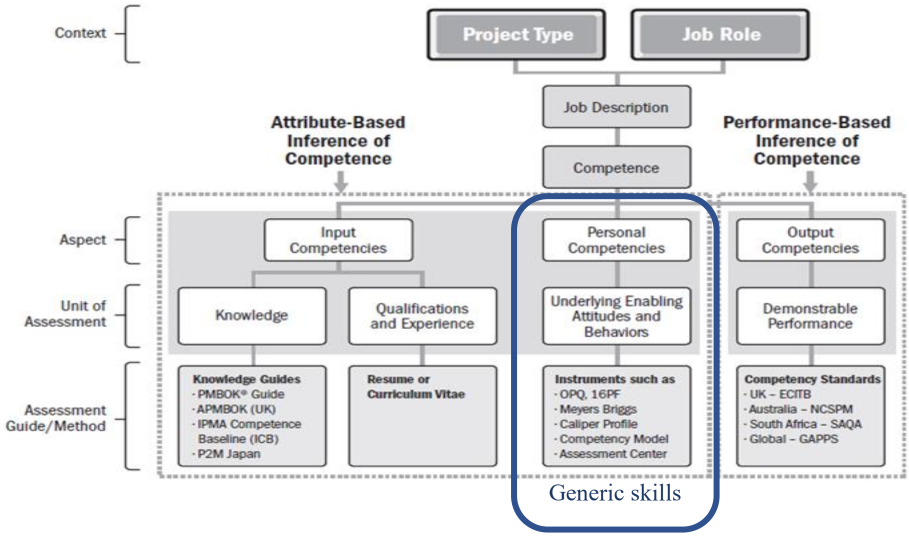

Figure 4: Integrated model of competence for project management roles (Crawford and Hoffman, 2011.) highlighting the generic skills.

4.2 Learning outcomes, graduate attributes, competence

4.2.1 Definitions of learning outcomes and competence

A notable difference between higher education and the VET sector in Australia is that universities traditionally specify indicators of achievement as learning outcomes and graduate attributes, rather than use competence-driven descriptors (Martin, L. and Mahat, M. (2017). A possible contributor to the reluctance of universities to adopt the competence approach may be that the term 'competence' is not uniformly accepted (e.g. versus 'competency', 'skill', 'ability', and other terms) or defined (Kennedy, D, Hyland, A, Ryan, N, 2009), or the view that 'advanced levels of performance on cognitively complex tasks are not amenable to disaggregation into discrete competencies' (Curtis, D, McKenzie, P Curtis, D, McKenzie, P, 2002, p.7.), the latter having a profound impact on the respective approaches to curricular and pedagogic design by the different education sectors, and acknowledging the notion of complexity in projects and project management. Another more political reason may be that universities do not want to be associated with the recent challenges of the competency agenda in Australia that led to the major restructuring of the state-owned Technical and Further Education (TAFE) institutions.

For this paper, the authors have resolved to adopt the term 'competence', also used in the ICB 4.0, and suggested as preferred term in the ACER report (Curtis, D, McKenzie, P, 2002), and meaning 'the ability to do something well or effectively' (www.collinsdictionary.com).
While terminology in the literature remains diverse and often nebulous, comparing the ICB competence standard with the Australian Qualifications Framework reveals an interesting similarity between the definitions of competence and learning outcomes: The former defines competence as 'the application of knowledge, skills, and abilities in order to achieve the desired results' (ICB 4.0, 2015, p. 15). while the latter describes learning outcomes as 'a taxonomy of what graduates are expected to know, understand and be able to do *as a result of learning*, expressed in terms of the dimensions of knowledge, skills and the application of knowledge and skills' (AQF, 2013, p.11). Another interesting link between competence and learning outcomes is made by Hartel and Foegeding, who depict a competency (sic) as 'a general

statement detailing the desired knowledge and skills of students graduating from our course or program' and outcomes as 'very specific statements that describes exactly what a student will be able to do in some measurable way.' (Hartel, R.W., and Foegeding, E.A, 2004, p. 69.), positioning learning outcomes as criteria for assessing competence.

4.2.2 Foundations of university project management curricula

A widespread view on the role of universities is that they are expected to "equip graduates with higher-order intellectual skills" (Curtis, D, McKenzie, P, 2002, p. 25), while many project management performance standards in the world, including in Australia, are typically based on industry consultation and are conceived as competency-driven, and more and more inclusive of generic skills, as demonstrated by the recently published Guiding Framework for Leadership in Complexity by the Global Alliance for the Project Professions (GAPPS, 2021).

For this reason, it is argued that the reluctance of universities to follow a competency-based approach is an increasingly less tenable position, a viewpoint further endorsed by a survey of PM university degree programs in Australia that identified a prevalence of curricula based on prescriptive standards, basic bodies of knowledge, commercial publications, and project management methods such as PRINCE2® (Bredillet, C., Convoy, K., Davidson, P., Walker, D., 2013).

4.2.3 The need for higher education- industry dialogue

Research on project management competence in the construction industry suggests that academic programmes are essential in building project management competence, but the knowledge and skills required to maintain it are obtained largely from experience, and to a lesser degree from formal training, rather than academic courses. (Edum-Fotwe, F.T. and McCaffer, R., 2000). The maintenance of professional certifications through short-term training courses is further underpinning this preference. This finding accords with the ACER report in that workplace training takes on an ever-important place in generic employability skill development in Australia (Curtis, D, McKenzie, P, 2002). However, while workplace training seems to be more adopted as an essential element of vocational formation and is recently re-gaining significance in the VET sector under a new paradigm (Hager, P, 2007), it is far less assimilated in university education (Kenvale, 2021).

Without compromising the ethos of furthering the scholarly dimension of the subject expected to be acquired by a higher education graduate, it is suggested that in many university curricula meta-competencies and generic employability skills are insufficiently addressed and that the industry-higher education dialogue is under-developed in the Australian context.

5 Conclusion

The view that project and construction management graduates need discipline skills as well as generic employability skills to become and stay employed is now well accepted in literature and is particularly relevant to the project management environment as it could be argued that most soft skills could be seen as essential to the discipline. Research shows that employers of project managers attach high value to the possession of these skills. However, some higher education institutions in Australia have been slow to adapt to this need. This paper has suggested several possible reasons for this: First, there seems to be a reluctance of higher education institutions to pay more attention to graduate competence rather than gained knowledge. While it may be worthwhile for higher education institutions to take notice of recent developments in this area, it is argued that to overcome this reluctance the image of the notion of competence needs to be cleared, its terminology and structures unified and accepted, and the body of research into the basis for assessment of competence needs to be substantially strengthened. This paper has shown that project management competence theory is evolving within the discipline by incorporating both output driven and attribute driven standards and assessment philosophies and argues that further integration with a taxonomic model of generic employability skills may be needed to produce a holistic view of a graduate's ability to successfully enter the workplace.

Second, the fact that employability skills are more intrinsic and are perceived to augment over the years with work experience, and therefore difficult, or even impossible, to teach in an academic curriculum. To change this perception a systemic rethink of higher education instruction may be needed, and while valuable research has been reported in this area over the past decades, examples of successful implementations remain scarce.

A third reason may be that graduate entry and exit attributes are not reliably, or only partly measured, and therefore disparities between intended and actual attributes are not addressed. This is not discussed in this text but may have a significant impact on graduate employability and prove fertile ground for further research.

Closer examination of employability skills specific to project and construction project management roles is necessary and may even have to be categorised into skills preferred by project suppliers (contractors) and buyers (client organisations) to make a rounded contribution to the debate.

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Starting suicide prevention from home by incorporating social, spatial, biophilic and value management aspects to house design

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Abstract: Built Environmental design has a purpose to provide environments for people to live and work, but often places a lack of contribution to promoting human wellness. Numerous research studies conducted on improving workspace, productivity and improving health and healing environments provide considerable evidence for improving the 'home construct' to improve user health and wellbeing. Existing design research shows benefits and methods to reduce injury and suicide events, as used in health spaces, to be considered for home designs. Considering home design aspects of, safety, security, comfort, and family in planning and construction process can provide spaces to improve health and wellbeing. This paper reviews literature on human studies, developing theory considering home design inputs to combat suicide rates in at-risk groups with focus on youth, middle age, and unemployed groups. Results of this scoping review provide comprehensive analysis for improving homes by integrating healing and productivity using design aspects, that can be considered with value management considerations. The review purpose will designate outcomes and pave a holistic strategy to prevent suicide in homes. The scoping focusses on improved architectural design information for increasing mental comfort and wellbeing, using; social, spatial & biophilic design. The strategy will contribute to addressing social and economic problems associated with suicide in built environment home designs. This suicide research will be used for public health promotion by improving benefits of mental wellbeing (management) for suicide alleviation in Australian homes.

Keywords: Built Environment; Suicide; Home Design; Environmental psychology; Value Management.

1. Introduction

Current global pandemic situation has applied lock downs in most countries, which has compelled people to stay at home most of the time. This is quite unusual practice to most people; therefore, well-being is under scrutiny. The unexpected situation has restricted people's life and work routine; for example, they have missed their daily jogging or routine workouts in the gym from life perspective, whereas they must work at home from work perspective, but there is doubt whether safe work environment exists in homework environments. New statistics of increased suicides and suicide attempts currently provides convincing evidence that home design can be an influential factor for committing suicide. This paper reviews suicide prevention in the home through environmental design and examines research and design theory available, from existing literature. The research spans multi-disciplinary fields, of economics, building design and environmental psychology. This scoping review aims to contribute to the body of knowledge for suicide prevention by design, in an effort to *"Start suicide prevention from home*."

The research hypothesis examines design methods and available theory to improve wellbeing in homes, to ameliorate causes for suicide in homes (Wang et al., 2020). This scoping review of building design studies shows quantified methods for improving health effects (Jiang et al., 2021, Manzar et al., 2021, Pollock, 2019, Raby, 2018, Thodelius, 2018, Wang et al., 2020) surrounding ideation and suicide events. Preventative measures and restorative health design measures can be used in conjunction with environmental psychology design for risk management in planning for home designs. The scoping of this review aims to provide a more holistic framework for starting suicide prevention in the home, using design research methods of biophilic, spatial and social design principles. This article analyses existing research and emerging theory showing evidence based design methods (Bailey et al., 2021, Berg and Joye, 2012, Chrysikou, 2019, Connellan et al., 2013, Gaminiesfahani et al., 2020, Mackett, 2021, Peters and D'Penna, 2020, Thodelius, 2018, Zingraff-Hamed et al., 2021) to provide built environment design solutions that improve human wellbeing, to reduce suicides in homes. This scoping research has been conducted to consider wellbeing impacts through lock-down events in homes, with existing research providing methods from health, healing, (Chrysikou, 2019, Connellan et al., 2013) education (Peters and D'Penna, 2020) and workspaces (Egner et al., 2020, Thodelius, 2018) to improve wellbeing.

The scoping review provides information to support future research with a cost-benefit (value management) analysis, to model economic benefit for the design measures to consider pareto optimality economic modelling. Cost/benefit research provides a value measure for planning (Kelly et al., 2014) and this can be used to consider suicide prevention design, for homes. Cost benefit design methods consider economics to consider suicide prevention in design planning analysis stages. Economic modelling using impact measures can consider a wider scope for planning analysis to include suicide impact. Building design methods have proven impacts to users, where negative impacts resulting in injury events impact society (Spence et al., 2010).

2. Research methodology

The research methodology for this scoping review was limited to available data and theory for this conceptual research topic. Data analysed included key finding studies and peer review articles within 12 years focussing on suicide, health spaces and proven effects of design and greater health impacts resulting from design. Mental health design research focusses on commercial built environments that can be applied for home designs improving health and wellbeing. A Prisma diagram is shown in Figure 1 to display research scoping methods of this academic investigation. Data was collated and refined according to a five-point value scale with relevance value scores higher than 3-5, dismissed prior to submission. All articles were evaluated against quality metrics by topics of social, spatial and biophilic design aspects. The evaluation qualified 55 research articles as relevant with 22 articles used relevant to the research topic. Data was evaluated to improve wellbeing in homes using biophilia, social and spatial methods quantified for healing environments. VM in planning can include economic values for suicide prevention and risk management to include low-cost prevention strategies listed in Table 1. The data collection process used academic analytical process' regarding validity of the research hypothesis, with research evidence used for qualitative synthesis. Data was evaluated across academic fields before review by industry experts. Data included reflexivity accordingly by information reporting by "Mind frame" media guidelines (Mindframe).

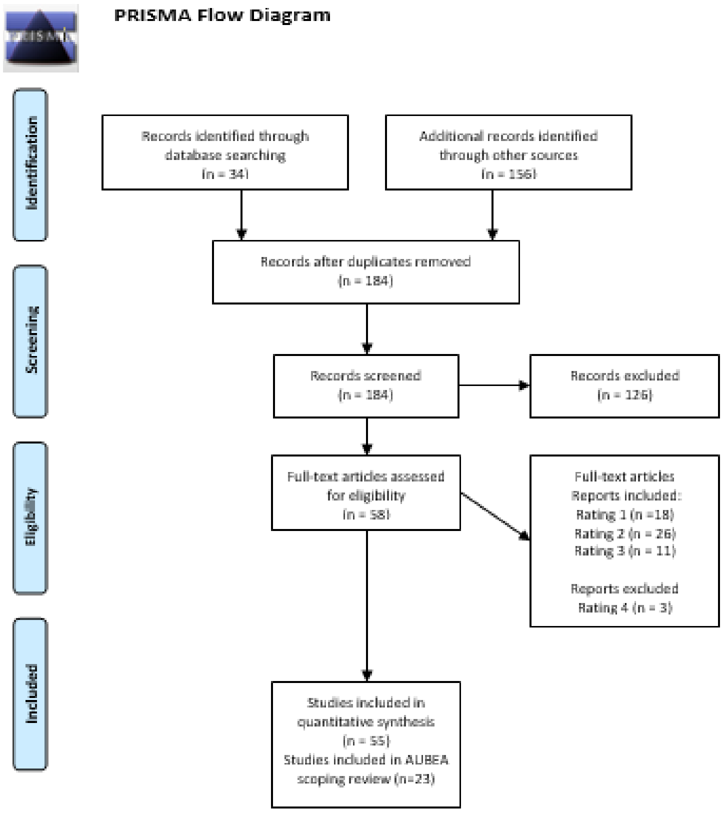

Figure 1. Prisma methodology diagram, adopted from Prisma example (2009)

3. Literature Review

Building designs support positive emotions and sensory impacts, and this research reviews sensory impacts of biophilia with supportive healing environment research. This research considers suicide impact for future economic cost/benefit analysis to compare findings for pareto optimality modelling. The Biophilia hypothesis was presented in the late 1980's by Kaplan and Kaplan in their book *"The experience of nature: A psychological perspective"*.

The research by the Kaplan's provides design theory on human wellbeing and restoration potential, exploring relative perspective theory of; Attention restoration theory (ART) as environment psychology (Kaplan and Kaplan, 1989).

3.1 Biophilia

Biophilia is a theory of connecting or preserving nature for inter-relatedness in construction designs, by relating to nature gaining benefits of nature connection. The research into biophilic effect is quantified by much research into human experience and surveys. The article by Mata et al., (2020) "*bringing nature back into cities*" evaluates human nature connection, including cultural relevance by locality, as experienced in Australian cities. The article outlines key approaches for regenerating 'whole of country' including positive biophilic design aspects. The article by Mata et al., (2020) provides considerable well-being improvement for homes and greater urban footprints, listed as follows:

- Acknowledge sovereign Indigenous knowledge systems and land management
- Inclusive decision-making
- Ecology in action

- Uptake of innovative 'bringing nature back' actions
- Engaging with built-environment professionals
- Evaluating the success of 'bringing nature back' actions
- Overcoming barriers and addressing concerns

The article includes biophilic design methodology for re-introducing nature-based systems into cities and urban areas to include local flora and fauna into more urban residential designs. By including nature corridors and green space networks it serves greater society by improving biodiversity, to preserve endangered plant and wildlife species, with benefit to "*country*" for cultural, individual, and societal wellbeing. Education and public engagement including public knowledge for improving urban areas will improve residential wellbeing. Consultation with community and stakeholders fosters resilience for future generations to heal country, and emotional wellbeing (Mata et al., 2020).

Biophilic design provides restorative impacts to well-being as researched by Newton and Rogers (2020), in their research "*Transforming Built Environments: Towards Carbon Neutral and Blue-Green Cities". *The research provides biophilic research for wellbeing in the home toward 'suicide prevention' by including biophilia design for collective well-being.

The article by Newton and Rogers into carbon neutrality and design of cities for blue and green spaces provides considerable input for renewable, sustainable, cost-effective design measures, using smaller case studies as applied in Australian communities. This article by Newton and Rogers (2020) identified positive design for wellbeing through larger strategic built environment goals. The residential sector has opportunity to apply renewable materials/energy goals, climate change design to include carbon capture elements such as water storage and power generation for every home design. An enormous number of homes can use solar and water capture, using natural designs and native species repopulation to provide biophilic versatility in homes and surrounding areas. Green spaces (biophilia) used in high-density housing design can be increased to facilitate wellbeing. Design for wellbeing can be considered for legislation by green credits to encourage roof top community gardens for food security, inclusiveness, and human well-being.

Therefore, tall buildings can include increased basement water storage, solar fences (to prevent access) with green spaces (natural resource provision) for biophilia connection. Design solutions for tower residents provide benefits with restorative environments, foster spiritual and cultural wellbeing, improve environmental psychology, provide social inclusion, and maximise spatial benefits for improved wellbeing in homes. COVID-19 has highlighted issues for mental health in homes, where fresh water, food security, safety, and restorative spaces for wellbeing, provide important design considerations to support: Suicide prevention in homes. Community planning governance is considerable for community stability and emotional wellbeing, as provided in urban development planning and governance research. Economic incentives such as green economy rewards can bolster capital investment, in an effort to begin transitionary policies to align with sustainable urban development objectives. Green economy rewards can increase Biophilic design inclusions, for carbon neutral cities, as a cost effective more productive design for cities to include regenerative urbanism designs (Newton and Rogers, 2020).

Environmental psychology designs influence people's wellbeing and productivity as reviewed across research with biophilic design review of urban post-secondary educational environments. This review of learning environments by Peters and D'Penna (2020) titled;

"*The influence of the built environment on university students: emotional stress, happiness, stimulation, cognitive function, social support, belonging, places to study, lighting, and ventilation"* examines wellbeing by design, for learning environments.

The review by (Peters and D'Penna, 2020) provides impact to students as positive experiences resulting from:

- Nature views and nature images
- Natural colours and natural materials
- Auditory aspects of nature,
- Water and water features
- Indoor plants, campus landscapes
- Daylight access, thermal and environmental comfort for study spaces

Biophilia research confirms improved student wellbeing, with these improvements useful for home designs. The research discussed providing considerations for Evidence-Based Design Guidelines for biophilic design in university settings, with design guidelines for consideration to; "*Starting suicide prevention in the home*" listed as follows.

Campus (Evidence-Based design) guidelines:

- Campus-defining landscape - multi-sensory nature connection for stress reduction
- Improve vegetation - views, improve thermal comfort, microclimates, mediate noise
- Path and transition spaces improved by biophilia (vegetation)
- Spatial design for refuge, restrict unnatural form, campus views, local culture, art

Classroom (Evidence-Based design) guidelines:

- Connect to natural systems for more productive workspaces (views, nature, lighting)
- Operable windows, natural ventilation, auditory benefits of nature
- Daylight and lighting variability, lighting, and shading adaptability
- Nature inspired patterns, fractals as subtle nature connections
- Indoor plants (biophilia) and green views

Guidelines to improve wellbeing provide additional psychological benefits to; foster place attachment, personal development (developmental psychology) and location experience (culture/emotions) by environmental experience. The article includes recommendations for design benefit by cultural and environmental design to encourage place attachment at outer campus spaces, with orientation of buildings to optimise daylighting, reduce thermal loads, as a precursor for occupant comfort (Peters and D'Penna, 2020).

The impact of mental health (wellbeing) is demonstrated in the article with positive design elements for consideration in home designs to include Biophilia (natural aspects), social (wayfinding, refuge, sanctuary, inclusion) and spatial (wayfinding, views, orientation) design arrangements to improve wellbeing.

Benefits of Biophilic design is explored for healthcare settings in the paper *"Biophilia and salutogenisis as restorative design in healthcare environments"* by Abdelaal, M., and Soebarto, V., (2019). This article provided a design framework for improving therapeutic impacts, by connecting with nature to alleviate people's distress, depression, anxiety, and pain, using salutogenic and biophilic design principles (Abdelaal and Soebarto, 2019). The framework was tested for the research by analysing the "*Royal Children's Hospital*" design in Melbourne, Australia. The findings of the article by Abdelaal, M., and Soebarto, V., (2019), provides positive collective and personal wellbeing benefit to mental health of patients when experiencing a stressful health event, by improved experiences resulting from biophilic design (Abdelaal and Soebarto, 2019).

Extensive literature reviewed demonstrates positive effects on humans by exposure and time in nature (biophilia). The articles show biophilia improves mental health in health and learning spaces to provide evidence base to; Start suicide prevention at home using biophilic, social and spatial design principles, to reduce suicides and improve experiences in homes.

3.2 Health and healing environment

The research into wellbeing through environmental design has been conducted across multi-disciplinary fields to provide design and impact measures, that can be adopted for starting suicide prevention in home designs. A relevant area of research often overlooked in building design is mental health in consideration of a home designs impact. Design history creates feelings born from experiences that can form negative stigmas associated by experience, such as police stations, incarceration facilities and mental health spaces. Form and space design is evolutionary, and health spaces gained increased design attention for design theory for positive design impacts of SRT and ART to increase healing (Kaplan and Kaplan, 1989).

Design of health spaces is reviewed for wellbeing design methods to use in designs of residential spaces; to improve wellbeing in homes as an impact point for suicides in society. The article by Chrysikou, E., (2019) titled *"Psychiatric institutions and the physical environment: Combining medical architecture methodologies and architectural morphology to increase our understanding*" regards medical design for mental health as a paramount design consideration; to facilitate healing and improve user experience in confronting spaces.

Psychiatric institution designs of physical environments is examined in this article to provide design considerations and improvements for staff and patients. The focus of the article is on harm and self-harm minimization (safety & security) with social integration for wellness. This research is useful regarding mental health for acute illness situations, where statistically most persons are subject to poor mental health impact at some point through their lifetime (Chrysikou, 2019). This research provides positive design outcomes for improving wellbeing using methods of socio-spatial design to provide positive outcomes for participants. This acute mental health research shows effects of poor design that can provide adverse reaction of stress, illness, and confusion. Experiences of acute mental health can continue as resultant future sequalae from adverse experiences and impacts (Chrysikou, 2019).

Therefore, more complex (density) home designs can improve spatial design aspects such as wayfinding, safety, and security as a method to improve wellbeing. Social design for inclusivity, cultural impact, refuge, art as cues, signs, sculptures, colour, and themes provide benefits for ease of navigation, and will improve mental health for residents.

The research by Gaminiesfahani et al. (2020) in the research *"Scoping review of the impact on children of the built environment design characteristics of healing spaces"* aims to research impacts on health and well-being of children by the design of healing spaces. The research examines impacts of social, spatial and biophilic design aspects for improved wellbeing in health environments, providing wellbeing benefits for home design applications. This younger audience study provides positive sensory experiences as impacting healthcare and healing spaces for child users. The study covered design for; Smell, temperature, decorations, presence of photographs, playing with toys, computers, and TV's. Architectural design benefit for children's wellbeing in healing spaces was identified by this design review to provide positive benefits. Benefits are expressed as child friendly spatial layouts, appropriate room sizes, with window placement for views to nature, including child friendly décor, colours, fixtures, fittings, and furnishings. The research design shows benefits for child friendly design of spaces to improve wellbeing and enhance positive experience, focusses on (1) noise, (2) music, (3) lighting, (4) gardens and nature, (5) crowding, (6) colour, (7) spatial needs, (8) play and distraction, and (9) art (Gaminiesfahani et al., 2020).

More ambient design features for benefit to children were identified as, Lighting and natural light, noise and acoustics, and environmental temperature control, ventilation, with patient and family centeredness. The research identified positive benefits from design for personal space, privacy, security, space for family, wayfinding and directional signs, leisure, and recreational facilities, including landscaping, garden areas, and external recreational areas (Gaminiesfahani et al., 2020).

Spatial design research provides design methods to accommodate wellbeing for children; overcoming crowding, using colour for wellbeing and wayfinding ease, with purpose specific child metric spatial designs; including play spaces for distraction, with heightened aesthetic values using art, music, and thematic designs for enjoyment. The inclusion of biophilic aspects and social design through photographs and family centredness shows applicable design methods useful to design for children's well-being in homes.

A relevant recent article by Mackett, R., (2021) on "*Policy interventions to facilitate travel by people with mental health conditions"* provides significant design guidelines relative to mental health resulting from wayfinding (spatial design), quantified by results from a health survey of transport users. The article shows the nature of anxieties (wayfinding design impact) that a large proportion of travellers have when they travel in public spaces, in London. The key finding of relevance to well-being for home design considerations, is for persons with existing ailments that experience negative impacts from wayfinding (Mackett, 2021). The research shows positive design impacts by clear information, before and during travel for user benefit. Spatial design can be improved in complex urban settings with benefits for users in dense residential settings. This research reinforces research and shows clear impacts by spatial design (wayfinding) that cause stress and anxiety, and future sequalae that restrict human movements (Mackett, 2021).

The research paper by Spence et al. (2010) into the *"Psychological and coping strategies after an urban bridge collapse"* provide traumatology consideration for design impacts considering mental health impacts. Adverse design impacts often have widespread impact to society wellbeing from environmental design failures. Impact to community wellbeing can be related to home designs, such as "*The Opal Towers*" or "*Grenfell fire*" that impact resident and societal wellbeing as negative externalities, impacting the emotional safety of society.

The elements of research relate to the I-35 bridge collapse, where a 1,907-foot bridge fell into the Mississippi River, and onto roadways below in Minneapolis, Minnesota, killing 13 and injuring a further 145 persons. The elements of research interest were faith, interpersonal communication, self-efficacy, and gender, where the analysis methods included survey by gender and emotions following a bridge collapse (Spence et al., 2010).

The results of the research were recorded directly after and at a later point in time for qualitative measurement. The article by Spence et. Al. (2010) highlights psychological processing involved, and for alerting society about risks, and shows benefits of planning for crises by design impacts, with impact measures to emotional wellbeing. This article shows reliance of public trust on policy makers to consider multiple audiences with different psychological needs. The article highlights gaps in information relative to emotional wellbeing as a "*cost*" and "*impact*" for officials who design systems, controls, and legislation. Results in this study considers distress as public impacts, during, and post event. Planning design often results following an adverse design impact, considering the holistic impact. Planning design provides codes and standards for design with informative programs and improves goals to meet user needs. Mental health needs are considered for health spaces and legislation planning can address needs for coping and/or choices of societies after building crisis events. This event article shows a wide demographic audience impact following loss events, related to personal or wider audiences by "*loss of life*" events. The research relevance provides value management considerations for home design research, of a wider audience regarding emotional impact considerations by "*loss of life*" construction events. The article shows coping strategies, provides resilience consideration for environmental design, considering design failures resulting in deaths (Spence et al., 2010). The article considers mental health phenomena from a bridge collapse, that is comparable to impact from COVID-19 lockdown, by considering wider scope of "*loss of life*" and greater mental health (wellbeing) effects in homes.

Comprehensive research was conducted by Connellan et al., (2013) in the mental health design article on "*stressed spaces",* that provides design evaluation of mental health and wellbeing in health facilities. The article on stressed spaces compares literature across a multi-disciplinary focus, (mental health and architecture) examining design impacts (Connellan et al., 2013). The article shows existing evidence for guidelines to improve wellbeing in health spaces that can be used for suicide prevention in homes. Themes of this article provide great significance to this research topic, as follows; Security, light, gardens, impact of architecture on health outcomes, interior design, art, and adolescents (Connellan et. al., 2013). The article provides a systematic review that highlights positive restorative outcomes from proposed design methods, to apply as acceptable design outcomes for wellbeing design methods. This article shows clear evidence to strengthen the design focus to "*Start suicide in the home using social, spatial and biophilic design methods*" to improve health and wellbeing in homes. This mental health design research provides data for adopting the design methods as evidence-based design solutions for health environments to be used in residential home spaces.

The work of Pollock, N., (2019) in the article, *"Place the built environment and means restriction in suicide prevention"* provides significant research evidence to use in suicide prevention. The article shows prevention methods for spaces in residential designs or adjoining public spaces by restricting access and structures for self-injury events. The aims of the article examine built environment and place-based approaches to means restriction in suicide prevention by considering connections between place, location, and suicide methods (Pollock, 2019). The relevance to for the research for the scoping of this review shows that existing legislation applies in institutions (prisons) and hospitals for suicide prevention. Prevention is considered by removing ligatures and anchor points for hanging deaths, combined with screening and barriers in spaces of height access (Pollock, 2019). A persistent challenge for built environment design approaches to similar design for means restriction applies to statistics that 75% of suicide deaths occur at home (Pollock, 2019). Structural barriers and signage at bridges or train stations are installed in public spaces to increase safety and prevent jumping (Pollock, 2019). Methods for means restriction apply to high-risk residential spaces. This review provides means restriction as a valid prevention method for tall building spaces (carparks, bridges, towers) and as such designs can consider fall barriers, catch nets and signage as suicide prevention strategies for building design.

4. Value management (Economic cost/benefit suicide prevention value considerations)

Value management (VM) of building projects provide opportunity to improve benefits as presented in project life cycle and life cycle cost planning measurements. VM historically considers planning decisions for specified performance outcomes, such as legislative compliance (Kelly et al., 2014).

Value for clients relates to economics and design outcomes that is improved through planning and data analysis. Value can be considered by more detailed designs, changes of plant or change to construction methods to improve value outcomes such as efficiency, material durability, or aesthetics (Kelly et al., 2014). VM provides opportunity for issues analysis, risk management, function analysis, legal issues, and community consideration (Kelly et al., 2014) to suit design goals. Suicide prevention methods can include VM cost/benefit measures in residential projects. The value workshop phase of VM planning should consider suicide prevention methods, such as means and access restriction measures, mental health and emotional wellbeing impacts, as future considerations for risk management. Risks can be reduced by design methods of, social, spatial and biophilic design identified by this research that can be evaluated as cost/benefit measures. Therefore, design consideration for suicide prevention can provide VM analysis, with basic examples listed in table 1. for impact measures in cost/benefit VM design planning.

Table 1. Cost/benefit value management design planning value examples (Booth, 2021)

Design method	Cost ($)	Benefit	Wellbeing benefit	Prevention
Biophilia	Low	Yes	Yes	No
Spatial	Medium	Yes	Yes	Yes
Social	Low	Yes	Yes	Yes
Access (intervention)	Medium	Yes	No	Yes
Education (signage)	Low	Yes	Yes	Yes
Green economy (reward/incentives)	Medium	Yes	Yes	No
Biodiversity (impacts)	Medium	Yes	Yes	No
Urban resilience design (governance)	High	Yes	Yes	Yes

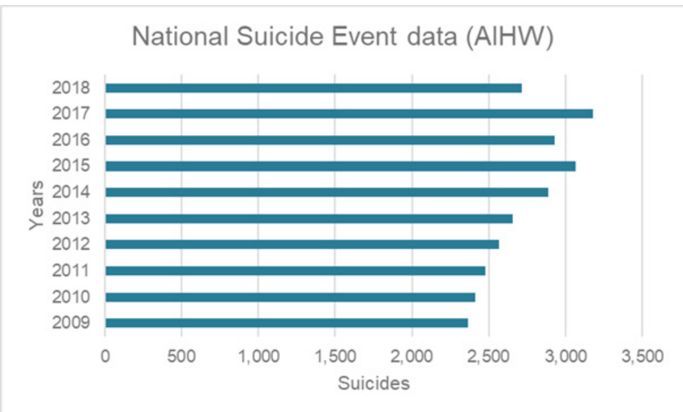

Figure 2. Suicide data (AIHW 2021)

5. Results and Discussion

This scoping review discovers existing suicide prevention building design research ((Berman et al., 2019, Blaschke et al., 2020, Chrysikou, 2019, Connellan et al., 2013) in health and healing spaces. Building design methods of biophilia, social and spatial design can be used for suicide prevention in home designs. Home designs methods can be improved to provide superior comfort and also restorative experience (Abdelaal and Soebarto, 2019, Berg and Joye, 2012, Connellan et al., 2013), with wellbeing as included as a form of preventing suicide ideation and reducing injury events. This suicide prevention research shows design methods that can provide suicide prevention by design strategies such as signage in high-risk areas (Chrysikou, 2019, Connellan et al., 2013, McGregor et al., 2017, Pollock, 2019), means restriction (Pollock, 2019), and including wellbeing design for psychological restoration (Egner et al., 2020).

This research discovers a comprehensive list of suicide prevention methods to be used for home designs. We can provide VM cost/benefit values to consider economic benefits. This research considers community impact considerations for disaster events (Spence et al., 2010) and intensive home use (Manzar et al., 2021) requirements through lockdowns. The research shows positive regenerative design principles provide suicide prevention, that can be used as values/costs in economic terms. This scoping review shows design methods for suicide prevention in homes. Environmental design psychology methods improve wellbeing as qualified and included in previous academic studies. Literature reviewed supports design methods for suicide alleviation by improving mental health in homes. Literature reviewed means and access restriction showing design methods reduce injury and prevent home suicides.

6. Conclusion

This scoping review findings show knowledge gaps for future design research for prevention designs to link economic impact modelling for value benefits. Developing VM and planning to include suicide prevention research into economic modelling to demonstrate future impact as wellbeing value for society. This review of design evidence provides design methods for: Starting suicide from home using environmental design methods of social, spatial and biophilic design. This research is an effort to reduce suicide and injury events in the home and finally, Winston Churchill (1943) once said, "*We shape our buildings and afterwards our buildings shape us*". With consideration of COVID-19 impact to homes, we can now build spaces to improve societies and economies, using research to quantify and qualify solutions.

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Early Career Project Practitioners' Views on Whether their Education Prepared them for Work in Construction: A Qualitative Study

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Abstract
There is a need for new entrants into the project management profession to possess the knowledge, skills, and behaviours that render them work ready and able to transition smoothly into their careers. This study explores the views of early-career project management practitioners on what constitutes work readiness in the context of construction, focusing on the attributes they possessed and those they lacked in their early-career transitions. Semi-structured interviews were conducted with twenty early-career professionals. Participants were asked to reflect on how well their education had prepared them for their early-careers. Thematic analysis revealed that while participants found that their education had helped in preparing them to i) communicate with external stakeholders, ii) lead meetings, iii) exhibit professional conduct and iv) be competent using professional software, they felt that there was still more that educators could do to help prepare graduates for their early-careers. Interviewees recommended that educators focus on i) providing greater exposure to industry, ii) reflecting industry practice in the curriculum, iii) employing more staff with industry experience and iv) providing skills in career mapping. This research may help inform universities on what they can do to better prepare project management graduates to successfully transition into their careers in construction.

Keywords
construction industry, early-career professionals, project management education, project management, work ready.

1 Introduction

There has been global debate over whether universities are producing graduates who possess the skills required in today's fast paced and rapidly changing industries (Pant & Baroudi 2008; Chipulu et al. 2013). It is held that for early-career professionals, merely having completed a university degree is not enough to render them ready for work, with scholars asserting that graduating professionals are required to "develop certain capacities beyond their qualifications which would enable them to deal with the stressful nature of the work environment" (Masole & van Dyk 2016, p.70). Work readiness is a concept recognized as being a key objective of education, and an essential component of performing well at work. It encompasses individuals' possession of a range of attributes that make them prepared for the workplaces in which they aspire to work (Prikshat et al. 2018). As a concept, work readiness constitutes a range of attributes which in turn, encompass a mixture of values, behaviours and skills that facilitate a successful transition into the workplace (Business Council of Australia 2016).

Educators have a role in preparing their graduates to be work ready and industry is quick to recognise the importance of work readiness in its workforce, with employers continuing to advocate for the improvement of work readiness education for their future employees (Cavanagh et al. 2015). There is a need for further investigation to better understand factors influencing early-career transitions into the workplace, to ensure that graduated professionals are embarking on their career journeys equipped with the attributes they require to thrive in the twenty-first (21st) century knowledge-based economy (Finch et al. 2013).

2 Literature Review

There continues to be a knowledge gap in the extant literature with regards to how well-equipped graduating professionals are to perform at work. Extant literature posits that holistic work readiness is better realised through the consideration of key stakeholder perspectives concerning education (Borg, Scott-Young & Turner 2019; Cavanagh et al. 2015). However, the student and graduate voices on the attainment of work readiness attributes remain largely under-researched (Su 2014) and while studies have examined the transition from university to the workplace, the perspectives of early-career professionals are often discounted (Moreau & Leathwood 2006). Early-career professionals (i.e. recent university graduates) are key stakeholders when it comes to their education and in reflecting on their own personal transitions from university into the industry (Borg et al. 2019), and are well-placed to share their stories on how well their education prepared them for the workplace.

There is a need for research which explores the transitions of graduating professionals from academia into the workforce (Holden & Hamblett 2007; Wood, Psaros, French & Lai 2015). Work readiness of early-career professionals is under-researched across many disciplines including project management and construction. Within the context of project management, there has been little focus on careers in the extant literature (Keegan, Ringhofer, & Huemann 2018), which is concerning given that project managers continue to constitute an increasingly important component of management in todays' many industries (Bredin & Soderlund 2013). It is recognized that "most modern work requires significant project management skills and capabilities" (Konstantinou 2015, p.21). Project management graduates form an important and growing portion of the project management talent pool (Borg & Scott-Young 2020a; Borg & Scott-Young 2020b; Lloyd-Walker, Crawford & French 2016; Pant & Baroudi 2008; Ramazani & Jergeas 2015). As work becomes more project-oriented, more well-trained graduates will be required to address the rapidly burgeoning global demand for project practitioners (Borg, Borg, Scott-Young & Naderpajouh 2021). The Project Management Institute (PMI 2017) has predicted a 33% increase in the project labour force over the next decade, hence it is timely to develop a better understanding on the skill-requirements of early-career project manager practitioners.

The construction industry continues to be in constant state of change as a result of impacting variables including economics, labour resources, market forces, emerging technologies and government laws and regulations (Ahmed et al. 2014; Benhart & Shaurette 2014). When transitioning into any role, individuals are known to experience negative feelings such as stress and pressure (Davis 2010; McNamara 2011). For project management individuals working in the dynamic and diverse construction industry, the challenge of the transition is exacerbated by the many challenges of the industry itself. It is therefore critical that early-career project management practitioners in construction are aware of the work readiness attributes that would enable them to smoothly become adjusted to their work. It is held that the diverse nature of the construction industry, makes it "impractical for the industry to have a single voice on their skills and labour requirements" (Amaratunga, Thayaparan & Malalgoda 2012, p. 3). However, without guidance on the skills-requirements of the industry, educators face the challenge of training future construction professionals without clear confirmation from industry on the areas that these future employees will need to be educated in. This study explores the work readiness requirements for early-career project management practitioners in the industry, from the perspective of the practitioners themselves, with the aim of shedding light on the best way to equip future construction graduates for the future.

2.1 Research Aim

The aim of this research was to ascertain the perspective of early-career project managers regarding the work readiness requirements of working within the Australian construction industry. In line with this aim, this study set out to answer the following three research questions from the perspectives of early-career project management practitioners working in the construction industry:

(RQ1) What work readiness attributes do current early-career project management practitioners working in construction possess?

(RQ2) What work readiness attributes do current early-career project management practitioners working in construction lack?

(RQ3) What can universities do to better prepare project management practitioners for their early-careers in construction?

3 Research Methodology

The purpose of the current research is aligned with the interpretivist/constructivist research paradigm, which suggests that it is essential that social action is analysed from the actor's standpoint (Tracy 2012). In alignment with this understanding, this research explores the concept of work readiness from the personal viewpoints and perspectives of early-career project managers working in construction. Stakeholder Theory (Hickman & Akdere 2017), coupled with the underlying theoretical principles of the Resource Based View (Wernerfelt 1984), and Matching Theory (Gale & Shapley 1962), frames the aims and methodology of this research. Specifically, interviewees consisted of early-career project managers who had been working in the construction industry for 1-5 years and who had graduated from one of the highest ranked universities for employer reputation in Australia (Quacquarelli Symonds 2019). It was held that information collected would provide insight into the work readiness values, bahaviours and skills necessary for the successful performance of early-career project managers in the construction industry.

2.2 Data Collection and Analysis

The research entailed the use of semi-structured in-depth interviews to capture early-career project managers' individual voices and work experience accounts. In depth interviews are described as constituting "a meaning-making partnership between interviewers and their respondents"; they are knowledge producing conversations (Hesse-Biber & Leavy 2006, p.128). Thematic Analysis was selected as the method for analysing the data collected following the guidelines of Braun and Clarke (2006; 2013). Inductive thematic analysis entails "coding the data without trying to fit into a pre-existing coding frame or the researcher's analytic preconceptions" (Braun & Clarke 2006, p.83). In contrast to theoretical thematic analysis (whereby the analysis is considered to be more analyst driven), inductive thematic analysis has the strength of providing a richer description of the overall data set (Braun & Clarke, 2006).

2.3 Sample – Demoraphic Profile

This study adopted purposive sampling of research participants. The sample was comprised of 20 early-career project managers who had graduated within 1-5 years of the study and had made the transition from university into the project management discipline. Participants worked in various types of organizations and were involved in various types of projects, including commercial high-rise, residential construction, land and property development, defense force projects, and project consulting services across disciplines including tourism, manufacturing and construction. Forty percent of participants were female. Ages of the participants varied from 20 to 32 years of age. All participants had graduated from their undergraduate degree within the previous 5 years and had transitioned into the project management profession following graduation. Thirty percent of participants participated in graduate programs offered by their organisations, while the remaining 70% did not have access to graduate programs within their organisation. In total, 35 participants who had graduated between the years 2013 and 2017 and who were employed as project management professionals were contacted and invited to participate in the research. Twenty-five participants expressed interest in participating, however only 20 progressed to signing and returning the research consent form and scheduling the interview, corresponding to a participation rate of 57%. While all 20 were interviewed, data saturation was reached at approximately 14 interviews, yet further interviews were conducted to ensure that no new themes emerged from the data set.

4 Findings

4.1 Addressing RQ1: Possessed Work Readiness Attributes

Participants reflected on instances in which they had demonstrated their work readiness in the profession. They were asked to reflect on their perceived areas of strength and what they believed had helped them make a successful start to their careers in the discipline. The themes that emerged included i) communication with external stakeholders, ii) leading meetings, iii) professional conduct and iv) professional software competency.

4.1.1 Communication with External Stakeholders

Participants felt confident in their communication with stakeholders. Underlying their ability to communicate with stakeholders, was a confidence that they had the skills required to communicate effectively in the workplace. Participants felt that communicating with external stakeholders was key to their roles as project management practitioners and it was encouraging to see that participants felt confident in their ability to deliver a task which they saw as fundamental to their roles. *'I came to find that stakeholder management was a really critical skill to have – you should really be able to build those relationships. Too much tension and things can go pear shaped – you need to be able to manage that.' – (Participant (P) 06, male, 30years).*

It is important to note that the theme focuses only on communicating with external stakeholders and not the internal stakeholders or members of the participants' organisations. While results showed that participants were confident in their communication with external stakeholders, there was no observed confidence in the participants' communication with their internal stakeholders, superiors and colleagues.

4.1.2 Leading Meetings

Results showed that participants were comfortable leading and chairing meetings and participants reflected on similar scenarios in which they were tasked with leading a group of people in a project related meeting and their ability to do that effectively. A number of participants attributed their ability to lead meetings to the skills taught as university, while others noted that their previous work experience while combining work and study had prepared them for the task. Results suggested that both university and work experience helped prepare students for the task. Participants were confident in their ability to lead meetings and felt that their skills were also noted by their employers, suggesting that their skills in this area were well developed. *'My boss was shocked that I could lead meetings so well. I felt confident to put the input in, whereas I think he thought that I would not contribute and be in background.' – (P13, female,23 years).*

4.1.3 Professional Conduct

Participants expressed that they were confident in their personal and professional presentation and that they were prepared in how to conduct themselves in the workplace upon making the transition from university to the industry. Results showed that participants were confident in presenting themselves professionally in a number of situations in the workplace, including to both internal and external members of their organisations.

4.1.4 Professional Software Competency

Participants felt that they had a competitive advantage when it came to professional software, specifically Microsoft Project (MS Project), which is a project scheduling software. Primavera was mentioned as a software package they had come across in their studies, but it was MS Project that most participants mentioned as finding useful in industry. *'MS Project subject gave me a leg up at work. I had people coming to me asking me how to use the program.' – P19, female, 26 years*

Participants felt competent in the application and use of the software, with some participants noting that their level of competency was higher than some of their colleagues.

4.2 Addressing RQ2: Lacking Work Readiness Attributes

Participants reflected on situations in which they had felt under prepared to deal with in their early-careers. The themes that emerged included i) career progression, ii) construction knowledge, iii) earning respect and iv) handling bad behaviour.

4.2.1 Career Progression

Findings showed that while graduates felt comfortable with the job application process and securing a job, graduates felt under prepared for the professional steps that followed, specifically with regards to their career planning. Results showed that graduates felt comfortable securing a job but were unsure of how to proceed once they were employed. Specifically, participants highlighted that they did not know how to approach issues such as workplace rights and salary negotiation. *'I feel applying for jobs was definitely taught as well as I think it could have been but once you're in a job and re-negotiation or trying to move on from a job...I just don't think that was ever discussed; how to move on and progress with your career.' – (P01, female, 22 years).*

4.2.2 Construction Knowledge

Participants conveyed that they felt there was a knowledge gap when it came to the specific construction knowledge. When reflecting on situations in which they felt underprepared for, a number of participants attributed this inability to respond well to the situation at hand to a lack in technical knowledge. *'In terms of technical ability and technical skills, I didn't know what I was doing.' – (P17, male, 25 years).*

While participants acknowledged that university taught them a range of technical skills, they noted that there was a breadth of technical skills that seemed to have to come with experience. Specifically, participants felt that they lacked technical skills such as: i) the ability to read and interpret construction drawings, ii) knowledge of constructability and the processes of building and construction, iii) knowledge of the tender process in construction, iv) knowledge of costing and v) contract knowledge. *'I was looking at some of the plans, wall details and plasterboard and not knowing what a stud wall was… it was pretty petrifying.' – (P14, male, 26 years).*

4.2.3 Earning Respect

Participants expressed difficulty in earning the respect of their project teams in their early-careers. Participants acknowledged that respect is something to be earned and results revealed that they did not specifically expected to have this respect upon transitioning into the industry, but results also indicate that the respect was harder to earn than anticipated by the participants. Many participants attributed this difficulty in earning the respect of their project teams to their age and their lack of experience. In fact, age was an issue raised by many participants and they perceived this as a barrier of which they had no control over nor an idea of how to manage the people who saw their age as a barrier to being deserving of their respect. *'Dealing with trade professionals, me being a 22-year-old that doesn't know have the experience they do and they're 50 and have all the experience they have. It's hard to break down that barrier, making them listen to you and earning that respect.' – (P20, male, 26 years).*

Participants did not attribute this apparent inability to earn respect to any particular skill they lacked, but rather as a direct result of people within the workplace not being cooperative. What results indicate is not that participants were not knowledgeable on how to earn the respect of the stakeholders, but that they were not prepared for the barriers to earning that respect, placed on them by no other than their fellow colleagues and consultant teams.

4.2.4 Handling Bad Behaviour

A significant theme that emerged repeatedly through the data was that participants felt surprised by the behaviour of people within the industry and their attitudes and nature towards their own colleagues. Results revealed that participants found themselves working with what they described as *'horrible humans'* (P11, female, 23 years); people who at times behaved *'unprofessional'* (P9, male, 25 years) and *'ruthless'* (P05, male, 26 years). Participants recounted scenarios they faced in which they felt underprepared and unequipped to respond to. Some participants noted that the construction industry is one in which you need a *'thick skin'* (P04, female, 27 years) and you need to *'learn to be more ruthless'* (P05, male, 26 years). Results indicated that not only were participants not prepared for such scenarios but that these scenarios came as somewhat of a shock to them. Both female and male participants found themselves in situations in which people within the workplace had either belittled, harassed or embarrassed them in front of their colleagues.

4.3 Addressing RQ3: Advice for Universities

Participants suggested some areas which educators at the university could have focused on and that in their opinion, had these areas been more integrated into the curricula, they would have better helped them be work-ready and prepared for their early-careers. Results revealed that participants' advice to educators to better prepare graduates for their careers would be to focus on i) exposure to industry, ii) career mapping and development, iii) reflecting industry practice, and iv) staff with industry experience.

4.3.1 Exposure to Industry

Participants stressed that they would have benefited from more exposure to the industry while at university and suggested that this may be an area which university could better focus on to help graduates for their early-careers. Participants described the course as largely *'classroom-based'* with *'no real practical elements'* (P17, male, 25 years). Participanst felt that *'there's no real incorporation of what the industry is into the course*' (P4, female, 27 years). Results suggested that some ways which participants considered would be useful in exposure to industry would be to incorporate work experience. Results revealed that participants felt that the course would benefit from having work experience embedded within the curricula. Participants stressed the importance of exposure to industry and suggested that university embed this into the program.

2.3.1 Career Mapping and Development

Result showed that while graduates felt able to apply for and secure employment upon graduation, they felt unprepared when it came to the next steps in their career development. Participants therefore reflected on educators could do better to better prepare future graduates in this area. Furthermore, a number of participants raised the issue that university had not necessarily educated them about the roles they could expect to step into following graduation. Results revealed that participants were not aware of the day to day role of a contract administrator, project manager, assistant project manager or similar roles they could apply for after graduation.*'I would talk to some of the key roles; like we knew from uni that a contract administrator was one of the basic roles that we could go into and I don't think we did a lot of things that related to that position.' – (P10, female, 23 years).*

2.3.2 Reflecting Industry Practice

Results revealed that participants felt there was a gap in terms of the way things were taught to them at university and the way that these were applied in the industry. Participants suggested that university looks towards teaching the content in a way that mimics how it would be then applied in the industry and the workplace. Participants suggested that educators embed real life industry examples into their teaching and reflect industry problems in their assignments. Participants felt that this would have helped them in the practical application of theory and thus made them more work-ready for when they had to face such similar issues in their workplaces. *'I probably needed to know more of the knowledge we were learning in a practical sense. What it was going to apply to and how we would have to analyse what we were learning.'– (P1, female, 22 years).*

2.3.3 Staff with Industry Experience

A number of participants reflected back on their educators, lecturers and tutors at the university, saying that staff with experience helped in their work readiness as they were able to integrate industry examples within their teaching. Results revealed that participants felt that had they been taught by more staff that had industry experience and who could bring their experiences as examples within the classroom, they would have been better prepared for work.

5 Discussion

The findings show that early-career project management practitioners identified stakeholder communication, leading meetings, professional conduct, professional software competency, career progression, construction knowledge, respect and handling bad behaviour as key components of work readiness in project management professionals within the construction industry. Essentially, the results suggest that the eight attributes (identified as areas of strength and weakness) identified by the early-career professionals are key skill-requirements for early-career project management practitioners in construction. The variety in attributes resonates with the findings of other scholars in that the identified attributes entail a combination of both project-specific technical knowledge and interpersonal/ 'soft' skills (Borg & Scott-Young 2020b). This in turn is consistent with definitions of work readiness as entailing a range of attributes that include values, behaviours and skills (Borg & Scott-Young 2020a; Business Council of Australia 2016; Caballero & Walker 2010). The literature shows that for project managers, soft skill competencies valued by employers across disciplines encompass; leadership, problem solving (Müller & Turner 2010; Hölzle 2010), communication (Skulmoski & Hartman 2010), emotional intelligence (EQ) (Müller & Turner 2010), social skills, negotiation skills, and professionalism (Skulmoski & Hartman 2010). We observe that there are overlaps with the project management skills detailed in previous studies and the attributes identified as necessary for early-career practitioners by the participants of this study. For example, professionalism (Skumoslki & Hartman 2010) is closely related to professional conduct, which was raised by the participants as being essential for early-career project management practitioners. Moreover, in handling bad behaviour, an individual's emotional intelligence, communication and social skills would come into play. These findings suggest that elements of work readiness within the context of project management transcend across the discipline (i.e. communication, emotional intelligence) but others are specific to the industry context in which they are applied (i.e. handling bad behaviour was identified as a desired attribute due to the industry culture as described by participants).

Work ready individuals are assumed to be able to make a successful transition into the discipline and industry in which they aspire to work (Caballero & Walker 2010). In light of this, it is concerning that construction knowledge was identified to be lacking in the skills repertoire of early-career project management practitioners embarking on their careers in the construction industry. The results suggest that the higher education degrees may not have contextualised the theory within industry practice (i.e. in this case the project management theory within construction practice). This echoes the participants' recommendations for educators to focus on more exposure to industry through their courses and the reflection of industry practice in curriculum. Another apparent concern is the lack in confidence of early-career practitioners with regards to their career planning. Edcators have a role in preparing their graduates for the world of work (Borg & Scott-Young 2020a; Cavanagh et al. 2015), yet this study shows that not enough is being done at university to help early-career practitioners plan for their careers.

Through the lens of Matching Theory (Gale & Shapley 1962), graduate work readiness results from the ability of the graduates to successfully exercise their knowledge and attributes, which can only be realised if their possessed knowledge and attributes match those required in the industry in which they aspire to work. In looking at the results from a Matching Theory perspective, there appear to be elements of misalignment between some of the skills possessed by the early-career practitioners and the attributes they have identified as necessary components of work readiness attributes (such as earning respect, handling bad behaviour, being ablet oplan for their career development). From a macro level and Stakeholder Theory perspective, this research observation suggests that both industry employers and university educators may benefit from open dialogue with the early-career professionals for the enhancement of work readiness within the discipline. From the Resource Based View perspective (Wernerfetlt 1984), it becomes clear that as key stakeholder in work readiness, educators need to work towards contributing to an increased work readiness of project management professionals.

6 Conclusion

This research serves as a critical step towards ascertaining the perspectives of early-career project management practitioners' views on the attributes that make them work ready and which they require to navigate their careers. This is the first known study to explore work readiness from the perspectives of early-career professionals within the context of project management and construction, thus contributing to new knowledge and helping shed light on the topic of work readiness in an under researched area. While early-career project management practitioners were found to possess key attributes and traits that enabled them to contribute positively to their industries in their early-career period, this study has identified a number of key attributes that are still areas of weakness in today's young project management practitioners. In highlighting the areas of weakness and strengths in early-career professionals' work readiness, this study suggested areas of focus for university educators in their endeavour to prepare and support early-career practitioners for their work in project management and construction. This study advocates for ongoing and topical discussion of work readiness requirements within a project management and construction context among the key stakeholder groups involved (including educators, employers and working professionals).While the findings of this study cannot be generalised to apply to all early-career project management practitioners in the construction industry, or to all efforts made by universities in the training and support of these professionals, the results can serve as a foundational step in beginning to understand early-career work readiness within the context of project management and construction. The next phases of this research looks towards ascertaining and contrasting the perspectives of other stakeholders on the topic, including those of project management educators, employers, students, and professional bodies.

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Managing to Retain Generation Z in the Construction Industry

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Abstract
The construction industry is subject to the dynamic 21st Century environment characterised by volatility, uncertainty, complexity and ambiguity (VUCA) coupled with the ongoing threat of the Coronavirus Pandemic (Covid-19) threatening the industry's survival. Further challenging the sustainability of the construction industry is the forecasted skills shortage coupled with high turnover rates. These turnover rates are caused by an ageing population which contribute to the loss of company-specific knowledge and experiences, as well as increased job-hopping of Generation Y and Z. This conceptual paper highlights the important role that Generation Z play in the sustainability of the construction industry. By presenting Generation Z as necessary resources for an organisations success, this paper details the responsibilities required of employers, presenting career resilience as the required strategy which Generation Z employees must utilise to thrive in their work environments, and contribute to the success of their organisations. Drawing on the limited research on the youngest and most vulnerable segment of the workforce- Generation Z, this paper links the phenomenon of career resilience with the sustainability of the construction industry highlighting the requirement for employers to take an active role to contribute to the resilience of the industry to address these arising concerns and sustain its workforce in the face of the new era.

Keywords
Challenges, Construction industry, Generation Z, Retention, Sustainability, VUCA

1 Introduction

As industries continue to navigate and survive in the Covid-19 pandemic riddled environment, the work environments of the 21st Century have intensified in both complexity and dynamism pertaining "natural and unique stresses that contribute to environmental and employee stress" (Darling & Whitty, 2019, p.1754). In conjunction with navigating the dynamics of Covid-19, as well as the VUCA (Mack, Khare, Kramer & Burgatz, 2016) environment, the Australian construction industry also faces the challenges associated with the forecasted skills shortage, high turnover rates and talent gaps and technological disruptions (Schwab, 2016; Project Management Institute, 2017; 2018). Whilst some of these disruptions and shocks may be unable to be anticipated or in some instances uncontrollable such as the Covid-19 pandemic, the manner in which employees and their employers respond to these shocks affects the worker experience which may result in deliberations on career path shifts through the development of new skills, exploration of new jobs and career paths or in some instances retirement (Kulip et al., 2012; Seibert, Kraimer & Heslin, 2016). This further adds to the complexities and challenges of the construction industry, amplifying the importance for employees to hone in on their career resilience capacities. Furthermore, there needs to be an intensified focus on the youngest and most vulnerable segment of the workforce- Generation Z (Twenge, 2017) who require a higher degree of guidance both intrinsically and extrinsically through their employers to successfully overcome these shocks and develop a positive work experience in the process.

This conceptual paper draws on existing literature on strategies used to bolster career resilience amongst employees to further contribute knowledge in the under researched areas of both Generation Z workforce (Twenge, 2017) and general career resilience research (Bimrose & Hearne, 2012). Furthermore, this paper discusses the needs and requirements of Gen Z employees, presenting the manner in which existing strategies that are currently being used by organizations can be personalized towards the specific needs of Gen Z with the aim of increasing retention rates. This paper presents the criticality of career resilience as a necessity for retaining Generation Z in the construction industry- who are necessary resources in the challenge of sustaining a talented and adaptable workforce in this fluid and uncertain era.

2 Literature Review

With the ongoing battle to mitigate the threats imposed by the myriad of challenges such as the high turnover intentions amongst younger professionals (Deloitte, 2018), forecasted talent shortages (PMI, 2017) and now the ever-present challenge of imminent changes imposed by the shock of the Covid-19 pandemic (Akkermans, Richardson & Kraimer, 2020), employers in the construction industry must recognize the importance of their younger workforce- Gen Z and their roles in nurturing these critical human resources if they are to not only remain competitive in the industry, but also survive. Additionally, with the significant impacts of the high turnover rates experienced which employers report as resulting in re-hiring and re-training costs of up to 150% of the departing employee's annual salary (Cascio & Boudreau, 2008), the proactive role that employers have in the retention of their employees has never been more critical. Employers must recognize the benefits they stand to gain from actively providing directed support and resources directed specifically at nurturing the development of career resilience amongst their youngest workforce in order to prepare them to deal with the inevitable career shocks and equip them with the necessary skills and capacities to allow them to respond in a manner which will result in positive worker experiences, heightened motivation and satisfaction and thus higher rates of retention of these invaluable resources.

2.1 Generation Z

Gen Z comprise the newest entrants of the workforce and refer to those born from 1995 onwards (Scholtz & Rennig, 2019). With the ageing workforce, Gen Z is anticipated to make one third of labour in 2025 (McCrindle, 2019) further highlighting the importance for employers to invest in the development of this cohort for the sustenance of their human resources and operations. Furthermore, in comparison to their counterparts- Generation Y who were born between 1980 and 1994 (Howe & Strauss, 2000), Gen Z research remains relatively unexplored however research does suggest that there are key differences between value systems and social behaviours of these two generational workforces. In addition, with job hopping becoming more common with newest entrants expected to tenant up to seven job changes by their late 20s (Cascio, Moore & McGlone, 2019), organizations must recognize that in their endeavours to retain their Gen Z workforce there are two critical actions which must be undertaken; i) understanding the values and needs of Gen Z, and ii) implementing adaptable human resource management strategies in line with meeting these needs (Scholtz & Rennig, 2019). Failure to do so may result in detrimental consequences with the most detrimental risk being a failure to retain the resources required to survive (Van Wyk, 2015).

According to existing research, Gen Z place high degrees of value on organizations who offer job security as well as those offering training and development opportunities directed at providing an environment in which employees can continually develop their skills and enhance their employability (Iorgulescu, 2016). Initiatives such as mentoring which provides an opportunity to acquire knowledge and skills from experienced mentors are highly valued amongst younger generations with mentoring regarded as necessary "for talent development, retention and attraction" (Robinson, 2007, p.208). Moreover, Gen Z employees also look more favourably upon organizations offering practices directed at encouraging work life balance, diversity opportunities, fair compensation and opportunities for career advancement (Wayne & Casper, 2012). In adapting their human resource management practices to fulfil the needs of Gen Z and provide the necessary means of support to employees in the face of challenges, employers can take active charge in developing a career resilient workforce who is not only prepared to face challenges and shocks, but one who is motivated and satisfied with their work conditions and environments (Coetzee & Potgieter, 2014) which can be expected to lower turnover intentions and hence increase retention.

2.2 Changing Nature of Work

A career encompasses "the evolving sequence of a person's work experience" (Arthur, Hall & Lawrence, 1989, p.8), with today's careers representing the multi-dimensional work roles experienced by individuals (Super, 1957). The worldwide economic crisis which occurred in 2012 initiated a move away from traditional models of careers which encompassed a shared responsibility of career planning and career management by organizations and their employees (Akkermans, Seibert & Moi, 2018), towards a career paradigm characterized by; self-agency, continual upskilling, employability and key attributes of adaptability and resilience in assisting with the navigation of disruptive factors (Maree, 2017). This is echoed in the high degree of value placed on importance of training and continual development opportunities by Gen Z employees. This new career paradigm necessitates the importance for a high tolerance of uncertainty and stress, as well as the capacity for undergoing transformative change and adaptability in an effort to enhance harmonization with the broader macro environment (Fourie & Van Vuuren, 1998). Therefore, the constant changing nature of careers deems the importance of human resource management (HRM) practices in taking a focus on assisting employees with not only harbouring career adaptability to respond to and overcome challenges, but to also possess career resilience to prepare for, manoeuvre through and reduce the impacts that uncontrollable shocks may impose on their careers (Akkermans et al., 2018).

Whilst a greater degree of responsibility exists within the new employer-employment contract for employees to take ownership of their careers, as highlighted by Waterman, Waterman and Betsy (1994), under this new contract, "it is the employee's responsibility to manage his or her own careers", whilst employers (and HRM personnel) maintain the responsibility of "providing employees the tools, the open environment, and the opportunities for assessing and developing the skills" (p.88). In delivering on their responsibility, employers are able to mitigate the risks associated with high turnover amongst Gen Z. One manner in which employers can further reduce risks of unexpected shocks is through a heightened commitment to provide the necessary support, tools and resources aimed at fostering and nurturing a career resilient workforce (Waterman et al., 1994) to enable them to maintain positive work experiences. With the ever-growing threats and shocks present in current workplaces, career resilience is the key to overcoming what literature has regarded as 'shocks'.

2.2.1 Career Shocks

The increased intensification of the current work environment has contributed to the numerous transitions and shocks faced by employees. Shocks can arise from numerous sources including; (i) interpersonal personal content (i.e., family related), (ii) work context (i.e. organizational environment), or (iii) general context (i.e., environmental or geopolitical environments) all of which affect not only the employee experiencing the shock, but also the organization's ability to retain their workforce, as well as affecting the broader society (Morell, Loan-Clarke & Wilkinson, 2004). In accordance with extant research, a career shock encompasses significant expected and unexpected events which may result in deliberations on career path shifts via development of new skills, exploration of new jobs, changes in career paths or even retirement (Kulip et al., 2012; Seibert et al., 2016). Whilst these career shocks, are unavoidable and in the case of Covid-19, unfathomable, research highlights the importance of both resilience and adaptability in employees generating a positive worker experience from viewing these as opportunities (Seibert et al., 2016), as opposed to threatening events which have a negative connotation and effect on their worker experience. According to Akkermans, et al. (2018), a career shock is "a disruptive and extraordinary event that is, at least to some degree, caused by factors outside the focal individual's control and that triggers a deliberate thought process concerning one's career" (p.4). Furthermore, following the worldwide economic crisis in 2012, the emergence of a new career paradigm characterized by individual agency of one's career and a new psychological contract between employers and employees (Waterman et al. 1994; Birchall & Lyons, 1995), has highlighted the importance of career adaptability and career resilience. These attributes have been classified as being critical in assisting both the employee and the organization in surviving and succeeding in the face of turbulence (Maree, 2017). This focus on implementing strategies which are aimed at instilling career resilience amongst this younger cohort positively benefits the career development of employees, and hence instils confidence in HRM that their workforce is equipped and capable of navigating change, as well as satisfied within their current career tenure.

2.2.2 Career Resilience

The complex phenomenon of career resilience has received a high degree of interest since the 20th Century (Kuijpers & Scheerens, 2006) recently due to its association with taking into account not only the ability to survive perturbations and shocks, but allow the employee to thrive by focusing on the positive trajectory to a new, improved state of working, and hence a positive worker experience. Extant research has reported effects that career resilience (or a lack of) can have on worker experience, most specifically; job satisfaction (Coetzee & Potgieter, 2014), career success (Salisu, Hashim, Ismail & Isa, 2017), staff turnover and retention (Waterman et al. 1994). Originally defined by London (1997, p.34) as "the ability to adapt to change, even when the circumstances are discouraging or disruptive", the concept of career resilience has undergone various formulations, the majority of which regard the phenomenon as an "ability, process and outcome- that is something that people possess…something that is developed…something that can arise as a consequence of experiences" (Burke & Scurry 2019, p.18). With this in mind, career resilience accounts for the transitionary events (be they of a planned and unplanned nature) which challenge the individual and based on the response initiated, fundamentally affects the worker experience. Extant research has deemed the importance of accounting for the contextual factors which initiate a recovery response from individuals, noting that careers do not exist in isolation and in reality, encompass an interaction between an individual's skills and behaviors, their situational factors, and the environmental context (Bryant, 1995). With the level of high turbulence being experienced globally across workplaces (Fourie & Van Vuuren, 1998) and the more recent threats imposed by the Covid-19 pandemic (Akkermans et al. 2020), career resilience is important to directly improve the worker experience and in doing so place organizations in a position which allows for the mitigation of risks associated with a loss of competitiveness and labor shortages (Kuijpers & Scheerens, 2006). Moreover, in a similar vein to the nature of careers which are defined as the "evolving sequence of a person's work experience over time" (Arthur et al. 1989, p.8), the career context too, is constantly evolving, necessitating the requirement for career resilience (Liu, 2003). Extant research in the nature of future careers support the requirement for career resilience, claiming that "career resilience is an essential survival skill in the 21st Century" (Cascio 2007, p.552). Whilst career resilience, in conjunction with the new employee-employer contract places a high degree of responsibility on the employee to develop this capacity, career resilience is not solely a self-reliant concern, noting that organizations have an active role in the provision of resources to employees to assist in their capacity to navigate turbulence and enhance their career resilience to improve their worker experience and intentions to stay loyal to their organizations.

3 Discussion

With the growing complexities faced by the construction industry ranging from the talent shortages, low retention of younger workforce entrants and unrelenting changes to the manner in which work is conducted as a result of the disruptions of Covid-19, the necessity of a career resilient Gen Z workforce has never been more critical. To mitigate the risks associated with the abovementioned challenges, and proactively develop career resilient Gen Z employees to work towards positive worker experiences, this conceptual paper presents strategies that can be directed and employed by employers (see Fig.1 below). These are classified as pertaining a focus on the wellbeing of Gen Z employees which directly affects their personal lives, as well as those which pertain a focus on providing opportunities for career advancement.

3.1 Wellbeing Focused Strategies

3.1.1 Healthy Workplace

Workplaces that foster flexibility, work-life balance and positive and caring relationships amongst workers have the capacity to affect the career resilience of Gen Z employees or alternatively, contribute to their turnover intentions (Bardoel, Pettit, De Cieri & McMillan, 2014). Furthermore, with the increased usage of screens from the enhancement of technological usage to conduct work, employers must recognize their roles in encouraging strategies directed at assisting Gen Z employees to conduct their work without impacting their mental health from excessive technological usage through assisting in the management of stress and improving their mental health and wellbeing (Winwood, Colon & McKewen, 2013). Employers can do this by more widely encourage social media breaks at specific intervals to ensure that employees maintain a balance as opposed to ongoing multi-tasking (Twenge, 2017). Additionally, by encouraging supportive workplaces where Gen Z employees can make relatable connections, contribute in discussions with all levels of management and institute positive mental health and wellbeing (through sharing information, encouraging a climate of civility and contributions), this environment will assist in bolstering the career resilience of Gen Z employees. Additionally, with the complexities and uncertainties posed by the changing workplaces as a result of Covid-19, organizations are recommended to continue to offer mindfulness programs and emotion-regulation initiatives (Knapp, Weber & Moellenkamp,

2017) to ensure that the workplace encourages good wellbeing and provides support for instilling resilience amongst Gen Z.

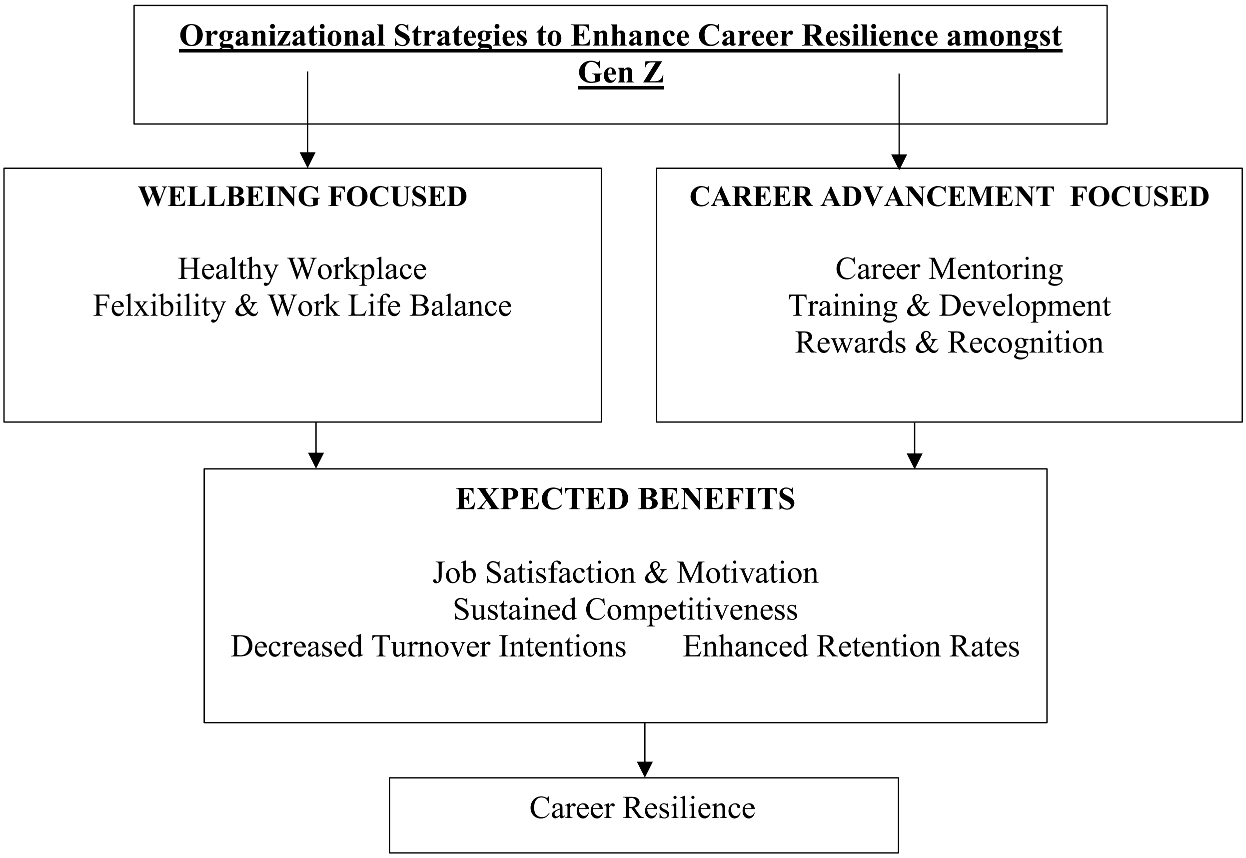

Figure 1. Organizational Strategies to Enhance Career Resilience amongst Gen Z

3.1.2 Flexibility & Work Life Balance

With the Covid-19 pandemic presenting ongoing challenges for employers and employees alike in terms of the manner in which their work is conducted and completed, the requirement for flexible workplace arrangements through technological facilitation has increased in value and importance and has become an expectation (Agarwal & Waghela, 2018). Whilst Gen Z employees value face to face communication to enhance their social interactions, they place an expectation of having the flexibility and convenience of remote working which is maximised by their technological skills and availability of communication via devices such as smartphones, tablets and laptops. Additionally, Gen Z highly value work life balance (Kelliher, Richardson & Boiarintseva, 2019) and support from their organizations to assist them to keep their private and professional lives separate. Through providing this flexibility Gen Z employees can be expected to work hard during business hours and maximise their efficiency through the flexibility to utilise technology and remote working arrangements whilst remaining satisfied that their organizations value their work life balance.

3.2 Career Advancement Focused Strategies

3.2.1 Career Mentoring

According to research, mentoring has been classified as an invaluable tool in assisting employees to enhance their self-efficacy and career development through providing them with guided support from more experienced individuals hence impacting their general resilience and career resilience capacity (Luthars, Avey, Avolio & Peterson, 2010; Arora & Rangnekar, 2015). Mentors have the capacity to provide invaluable insight into coping mechanisms and strategies which Gen Z employees can use when faced with challenges. This allows Gen Z employees who may experience difficulty with facing adversity (which is common due to the VUCA environments) (Twenge, 2017), to change their perception to viewing challenging circumstances as invaluable learning opportunities for their career development. Through offering mentoring opportunities, employers provide direct support resources to Gen Z employees, and directly respond to the Gen Z's needs and desires to work for a company whose HRM strategies support and encourage continual skills development and career advancement. As well as benefitting Gen Z's direct careers, mentoring has been regarded as an invaluable tool "for talent development, retention and attraction" (Robinson, 2007, p.208) thus assisting employers to retain their Gen Z workforce.

3.2.2 Training & Development

Whilst mentoring provides a means by which Gen Z employees can seek guidance and support when faced with difficult circumstances as well as for their general career advancement endeavours, employers can also seek to address Gen Z's priority of career advancement (Iorgulescu, 2016) through technologically aided self-learning opportunities (Francis & Hoefel, 2018). Training and development must be tailored to Gen Z's requirements and needs to maximise the benefits and accessibility. As Gen Z generally prefer short, visually aided self-paced technological learning (Hart, 2017; Scholtz & Rennig, 2019; Gould, Nalepa & Mignano, 2020), employers must ensure that training programs are designed with this in mind. It is therefore suggested that accessibility to online modular learning which are focused and directed at the improvement of specific credentials and skills are made available and are easily accessible via technology (Seemiller & Grace, 2017). With the increased commonality of a working from home (WFH) model as a result of the Covid-19 restrictions, ensuring training programs are technologically accessible is key will assist in both the career resilience and retention of Gen Z employees. This investment in the career advancement of Gen Z will develop their skills and capacity to be resilient in the face of shocks, as well as instil job satisfaction and motivation amongst employees due to a heightened perceived investment in their careers by their employers (Kraimer, Seibert, Wayne, Liden & Bravo, 2011).

3.2.3 Rewards & Recognition

Although Gen Z employees place a high degree of importance on intangible benefits offered by their employing organziations which can take the form of training and development opportunities and mentoring for career growth (Landry, Schweyer & Whillans, 2017), in order to maximise their motivation, employers must provide a combination of financial and non-financial rewards and recognition initiatives. As Gen Z also value being rewarded for their contribution via monetary rewards in the form of salaries reflective of their efforts (Scholtz & Rennig, 2019), organizations must be creative in the rewards offered to Gen Z employees. One important factor that needs to be considered is the criticality in personalizing these rewards to the deserving employee (Landry et al. 2017). With younger generations now seeking meaning and purpose in their careers, this suggests that individualizing rewards to recognize their efforts through a mix of tangible rewards (i.e., extra leave days or travel rewards) and intangible rewards (flexible working practices, training and development initiatives etc.) will demonstrate to Gen Z employees that their contribution is valued within the organization hence increasing motivation and reducing turnover intentions.

3.3 Expected Benefits

Employing tailored strategies to specifically target their younger Gen Z employee cohort has direct and indirect benefits for employers. By providing strategies which cater to the needs and requirements of Gen Z employees such as availability and accessibility to; career mentoring, training and development, rewards and recognition, flexibility, healthy workplaces and encouragement of work life balance, this positive worker experience results in satisfaction within the personal and professional environments of workers which directly contributes to their career resilience. These initiatives are also expected to result in enhanced job motivation and satisfaction amongst these younger employees (Coetzee & Potgieter, 2014). A highly motivated and satisfied workforce who has the required support resources to survive in this VUCA work environment decreases the risks associated with staff turnover thus assisting employers to increase retention rates (Waterman et al., 1994) of these invaluable human resources. This indirectly assists in their ability to maintain a competitive advantage as through their support in developing their coping mechanisms and repositories which dually assists in their growth and experience and thus career advancement prospects (Luthar et al. 2000; Caza, 2007), employers will be a step closer to sustaining a workforce which encompasses the flexibility, nimbleness, and adaptability to achieve the organization’s strategic objectives.

4 Conclusion

This paper highlights the importance and urgency for employers to implement focused human resource strategies to their Gen Z employees for the purposes of addressing concerns surrounding their high turnover rates and thus low retention. As research on both Gen Z workforces and the importance of the phenomena of career resilience remain relatively slim, this conceptual paper draws on existing literature on strategic human resource management strategies and career resilience, integrating this extant knowledge and applying it to the context of Gen Z. This conceptual paper discusses the expected benefits employers can gain by extending their supervisory roles to actively support the development of a career resilient Gen Z workforce and improve their retention of a talented pool of invaluable employees as a result (Kidd & Snewing, 2001). Whilst this paper has provided insight into the manner in which employers can actively act to retain their Gen Z employees, it is conceptual in nature and future studies are encouraged to undertake data-based research to further investigate these insights and further develop to the proposed framework. Additionally, based on the effects of Covid-19 on the manner in which both employers and employees conduct their work, future research is recommended to focus on specific initiatives that can be implemented by employers to inoculate employees from the effects of these disturbances. By implementing specific strategies directed at catering for the needs of Gen Z and supporting the development of their career resilience, employers can expect to contribute to a highly motivated and satisfied younger cohort, contributing to their ability to retain such invaluable assets amidst such chaotic times.

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Requirements Engineering in Complex Infrastructure: Challenges to the Development and Management of Rail Transport Requirements

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Abstract
This paper investigates information requirements development practices in Australian civil infrastructure projects characterised by the use of models, methods and tools to support a strategic approach to asset information lifecycle management. The research study focuses on rail transport infrastructure where the complexity of rail networks as a cyber-physical system-of-systems makes it increasingly difficult for current Requirements Engineering (RE) practices to handle the myriad of requirement types across temporary project supply chains. Consequently, the RE effort needs to continuously consider multiple disciplinary perspectives of the process throughout the asset life cycle. Using both literature and interview surveys, process-oriented challenges to RE are investigated. Findings identify a lack of implementation-ready requirements development and management methods supported by interoperable tool-chains that provide integration and automation in requirements traceability and change management workflows. The paper closes with a discussion on the correlation of our findings with previous studies and the direction of future research.

Keywords
Requirements Engineering, Asset Information Requirements, Asset Information Lifecycle Management, Rail Infrastructure, Challenges.

1 Introduction

Requirements engineering in rail transport projects is increasingly complex. As a part of a greater whole in a linear network, rail transport infrastructure assets are Cyber-Physical Systems (CPS). Different types and levels of requirements about the physical and cyber systems must be developed and managed during the planning and delivery of rail transport projects. Requirement types include, amongst others, high-level capability requirements defining the system architecture capabilities, current and future operational requirements, definitions of system-, sub-system-, and unit- level requirements that span functional and performance requirements, physical requirements, and business case requirements. Government transport agency standards and terms of contract covering Systems Engineering (SE), Digital Engineering (DE), Building Information Modelling (BIM), common classification systems, and supporting ISO standards (e.g., ISO 19650 and ISO 55000), play a key role in enabling more strategic approaches to asset information lifecycle management. Growing maturity in the application of these procedural methods and information schemas has resulted in new service-oriented offerings linking, for example, BIM to Facilities Management, and more recently to the development of spatial Digital Twins (DTs) in support of theOperations and Maintenance (O&M) of rail transport assets.

The recent application of the spatial DT to support O&M is largely driven by the need to manage the growing complexity of the rail CPS. There are a range of use cases for creating a

DT of a rail transport assets, namely to: enable connected and autonomous transport capabilities, manage digital cadastral information, leverage the value of digital asset data created during project delivery (e.g., to locate and maintain assets), and to enable more strategic approaches to asset information lifecycle management. However, due to their scale, functional complexity, dynamic interactions, and emergent properties, rail transport projects are increasingly difficult for RE practices to handle.

Against this backcloth, the authors explore contemporary RE practices in rail transport projects relative to the development of the physical and cyber systems, as well as their virtual replicas and the digital deliverables required to support O&M. We examine the process-oriented challenges encountered by project stakeholders, with the aim of identifying the key barriers to the development and management of asset information requirements during the ‘plan’ and ‘acquire’ phases of the asset life cycle, which ultimately impact on the creation and verification of digital deliverables, and in particular those supporting the digital twin.

2 Background

In the built environment, integrated approaches to requirements engineering (RE) are relatively immature (Chen and Jupp, 2018; Johnson *et al.*, 2021). In rail transport projects, and in particular those implementing a strategic approach to asset information lifecycle management, the network of authorised engineering organisations (AEOs) including consultants and contractors must develop different types and levels of CPS requirements, and manage the complex of interfaces between them.

2.1 Rail Cyber-Physical Systems and Digital Twins

The phrase “Cyber-Physical Systems” (CPS) was coined by Gill in 2006 (Gill, 2006). It is used to describe systems that seamlessly integrate computational elements and physical components with mutual communication (Wiesner *et al.*, 2014; Deka *et al.*, 2018). The CPS approach has long been adopted in information systems in industry sectors like aerospace, automobile, shipbuilding, and healthcare (Akanmu *et al.*, 2013). Relative to a domain-specific level, where many sub-systems are working in parallel, term “Cyber-Physical s*ystem-of-systems*” (CPSoS) was coined to describe the multidimensional and complex network that integrates the cyber world and the dynamic physical world (Broy, 2013; Tao *et al.*, 2018). Complex rail transport projects can be categorised as a CPSoS. Rail CPSoS can be broadly classified into infrastructure-based CPS, vehicle–infrastructure coordinated CPS, and vehicle-based CPS (Deka *et al.*, 2018).

The “Digital Twin” (DT) concept was first introduced by Grieves in 2003 (Grieves, 2014) and differs from a CPS or CPSoS. Definitions and explanations of the DT concept have been proposed and refined by various researchers (Grieves, 2014; Negri *et al.*, 2017; Parott and Warshaw, 2017; Tao *et al.*, 2018). DT technologies were adopted in the spacecraft sector in 2010 and later in complex manufacturing sectors (Glaessgen and Stargel, 2012; Lee *et al.*, 2013). NASA were early pioneers of DT technologies for remote monitoring, controlling and running simulations of spacecraft from Earth (Shafto *et al.*, 2010). In the built environment, the application of DTs are in the early stages, with few fully-realised examples (Lamb, 2019). The creation and verification of a DT of a rail infrastructure and/ or vehicle CPSs is dependent on the timely definition of asset information requirements, asset information classification, and hierarchy management. Asset information needs are predominantly non-geometrical including specifications of: asset performance, uptime, pressure ratings, operating temperatures, set points, manufacturer, asset tag numbers, operating limits and costs. This information is more valuable than having geometrically accurate ‘twins’ of a rail infrastructure asset.

According to these definitions, both CPSs and DTs are aimed at achieving systems integration. However, their emphasis on the implementation of functions is where these two concepts differ. CPSs emphasise sensors and actuators, while DTs consider asset data and models as the main modules (Tao *et al.*, 2019). Although emphasising different elements, it is necessary to understand DTs in light of CPSs as they share procedural similarity and dependency relative to their creation, where the elicitation, specification, implementation, verification, and validation of asset information is essential to their successful delivery. The development and management of asset information requirements must span physical, cyber and virtual systems.

2.2 Strategic Asset Information Management

To support RE in rail transport projects, the International Standard ISO 55000 (2014), and ISO 19650, Parts 1 and 2 (2018a, 2018b) provide procedural methods and much needed consistency in the terminology, concepts, and principles underpinning the development of asset management strategy and identification of supporting requirements. Together, ISO 55000 and ISO 19650 are able to provide a regulated procedural method for the development of a strategic approach to asset information lifecycle management.

The ISO 55000 series consists of three international standards that provide the terminology, requirements and guidance for implementing, maintaining and improving asset management systems. The ISO 55000 series is widely used by utilities, transport, mining, process and manufacturing industries worldwide, enabling them to streamline their expenditure, strengthen their credentials and future-proof their facilities and assets.

The release of ISO 19650 describes the processes supporting digital information management in the context of buildings and civil engineering works, including building information modelling (ISO, 2018a, 2018b). Prior to the introduction of ISO 19650, projects implementing BIM and structured data approaches did not have a consistent information requirements management process across the industry. ISO 19650 provides a procedural method according to four requirements types, including client-side: i) organisation information requirements (OIR), ii) asset information requirements (AIR), and iii) project information requirements (PIR); as well as the: iv) exchange (or employer) information requirements (EIR) of the project team. Information requirements management activities commence with the client's OIR, which are established in a statement about the information needed by an organisation to inform decision-making about high-level strategic objectives (Simpson *et al.*, 2018). The OIR is therefore a critical step in the procedural method as it supports the capture and mapping of information and deliverables contained in the policies or acts of government transport agencies, including their asset management accountability framework (AMAF), which is an integral component of ISO 55000:2014 implementation. Australian government transport agencies widely utilise the AMAF to detail mandatory asset management requirements and provide guidance for managing assets.

Consequently, it is critical that the OIR accurately reflects *what* information is required so as it is able to inform the development of the AIR and PIR. The AIR and PIR will in turn inform production of the EIR, which represents the overall information requirements that span the managerial, commercial and technical aspects of the AIR and PIR, where the owner's requirements for asset registers to support spatial referencing, classification, hierarchical management and location referencing as per the nominated schema, e.g., Uniclass 2015. The EIR is then primarily concerned with the *who*, *how* and *when* of their delivery, and includes the information production processes and procedures, data standards, file formats, timetables for information exchange, and roles and responsibilities of the project team (Simpson *et al.*, 2018). The EIR is used to inform the development of the Digital or BIM Execution Plan (DXP/ BXP). ISO 55000 and ISO 19650 procedural methods together play a central role in the development and management of asset information requirements, as well as the ongoing management of digital information and digital deliverables supporting asset management.

3 Literature Survey of Challenges to RE Processes

This section presents a literature-based survey of the challenges to requirements engineering and information requirements development. The research focuses on process-oriented issues. By reviewing the literature, the intention of the authors is to map the process based challenges to RE challenges and undertake an interpretive analysis. In total, 37 papers from the AECO domains were identified and 20 papers were reviewed after eliminating papers that did not meet the search criteria. The search criteria restricted papers to those using model-based approaches to complex projects with digital deliverables supporting strategic approaches to asset information lifecycle management.

3.1 Challenges to Requirements Engineering Processes Identified in the Literature

The early involvement of all stakeholders is essential for requirements elicitation, prioritisation, negotiation and communication processes. The absence of key stakeholders during the early design phase brings challenges to all activities in the requirements development process due to knock-on effects to downstream requirements-dependent tasks (Navendren *et al.*, 2015; Jupp and Awad, 2017; Heaton *et al.*, 2019). The continuous changes to AECO requirements and lack of adequate change management processes is one of the most well-documented challenges reported by researchers over the last decade (Yu *et al.*, 2010; Nekvi and Madhavji, 2014; Papinniemi *et al*, 2014; Patacas *et al.*, 2016; Koltun *et al.*, 2017; Junior *et al.*, 2019). These general challenges to RE processes are categorised and ordered in Table 1 according to author.

Table 1. Requirements Engineering Process Challenges

Code	Challenge	Source
LS-RE-PC01	Missing stakeholders and lack of collaborative work amongst the team during early design phase	(Navendren *et al.*, 2015; Jupp and Awad, 2017; Heaton *et al.*, 2019)
LS-RE-PC02	Missing links between requirements captured in the user requirements' document and their functional specification	(Berkovich *et al.*, 2014)
LS-RE-PC03	Change of requirements/ evolution of client needs, Lack of change management processes	(Yu *et al.*, 2010; Nekvi and Madhavji, 2014; Patacas *et al.*, 2016; Koltun *et al.*, 2017; Junior *et al.*, 2019)
LS-RE-PC04	Highly distributed requirements development with different levels of abstraction	(Penzenstadler and Eckhardt, 2012)

3.2 Challenges to Information Requirements Development Processes

A series of challenges specifically related to information requirements development processes were then identified. These challenges are categorised and ordered in Table 2 according to author.

Table 2. Information Requirements Development Process Challenges

Code	Challenge	Source
LS-IRD-PC01	Incomplete information requirements documentation, decomposition, analysis, and allocation	(Kelly *et al.*, 2013; Aaramaa *et al.*, 2015; Johnson *et al.*, 2021)
LS-IRD-PC02	Lack of common language supporting information requirements development processes	(Jallow *et al.*, 2014)
LS-IRD-PC03	Unstructured and late delivery of data and information to the FM phase of buildings.	(Patacas *et al.*, 2015)
LS-IRD-PC04	Lack of application of standards or guidelines supporting information requirements processes	(Patacas *et al.*, 2015; Cavka et al., 2017; Jupp and Awad, 2017)

The specification and allocation of OIRs combined with the consistent management of AIRs and EIRs throughout the project amplify traditional requirements change challenges. Other issues surround deficiencies in the requirements specification process resulting in unclear, incomplete (Aaramaa *et al.*, 2015) or conflicting requirements (Scott *et al.*, 2016; Junior *et al.*, 2019), the lack of process standards (Patacas *et al.*, 2015; Cavka *et al.*, 2017; Jupp and Awad, 2017), unstructured and late delivery of data and information to facilities management (FM) phases (Patacas *et al.*, 2015), and absence of a common language for AECO requirements (Jallow *et al.*, 2014).

3.3 Key Challenges to Rail RE and Information Requirements Development

The complexity of rail transport RE processes is emphasised due to the number and type of system requirements, stakeholder requirements management interactions, and supporting requirements software tool-chains. RE challenges therefore increase in rail projects that must deliver a strategic approach to asset information lifecycle management as complexity resides in physical and cyber assets, their virtual replicas and their real-time behaviours in operations.

In projects with strategic approaches to asset information management, challenges to rail transport RE processes stem from the 'plan' phase of the asset life cycle and can be linked to a lack of owner-developed asset information requirements supporting current and future operational scenarios, as well as a deficiencies in the detail of required asset information to support asset management systems (Kasprzak, 2013). Whilst the asset management sector undergoes this digital transformation, it remains that few owners have defined their actual information needs and how asset information will map to asset management systems.

In the transition from the 'plan' phase to the 'acquire' phase of the asset life cycle, requirements specifications must make an important transition from system level to project level documentation formats. RE efforts may be compromised during this exchange process due to the lack of detail about sub-system and unit level asset information requirements, which affect the downstream information management capabilities of the project team. In what is largely a text-based exchange, insufficient specifications and documentation of the level of information (need), level of detail, and level of integration between systems, sub-systems and unit level design components all compound these difficulties.

From a process standpoint, RE complexity remains a critical challenge due to the many interdependent activities enacted in the elicitation, description and documentation of organisational and asset requirements types, as well as the decomposition, analysis and allocation of requirements across collaborating AEOs. The dynamic nature of complex rail transport projects also results in an intricate network of requirements change management activities and challenges to this stem from deficiencies in RE tool-chains, lack of software interoperability, imperfect or incomplete information exchange, and poor stakeholder interface management across the asset life cycle. Complexity in RE processes is therefore also embedded in the social challenges surrounding the presence, power and influence of project team members involved in (or absent from) requirements development and management activities.

Requirements integration risks therefore persist in rail transport projects and evidence of bespoke RE tool-chain integration initiatives in rail transport projects exist (Roodt et al., 2020). However they are predicated on the key assumption that information requirements are consistently developed in accordance with industry agree data schemas providing a standard for asset system hierarchy (Chen and Jupp, 2019). Such approaches also demand that the value of requirements assurance, verification and validation processes extend beyond asset handover.

RE complexity exacerbated by a lack of maturity in collaborative information requirements development processes and the co-engineering of physical and digital assets. The maturity of integrated RE procedural methods are a critical barrier to advancing enterprise platform RE processes.

4 Interview Survey of Challenges to RE Processes in Industry

Following the literature review, the research collected primary data to investigate the process related challenges encountered by project teams when developing and managing complex and interdependent information requirements. An interview survey (Hox and Boeije, 2005) approach was adopted, and data collection involved semi-structured interviews with Australian industry experts in the rail infrastructure domain who have participated in public rail project. The semi-structured interviews ensured that multiple topics surrounding the research problem could be covered.

4.1 Interview Questions and Participants

Key interview themes included the following question areas: (1) experience in developing and managing requirements of physical assets and digital deliverables, and (2) Current challenges to developing and managing different requirements types. Ten participants were interviewed across five companies (see Table 3). Interviews took place between February 2020 to May 2020. Each interview took approximately one hour, and recordings were subsequently transcribed and verified.

Table 3. Interviewees

Organisation	Role	# Interviewees
Developer	Digital Engineering Director/ Lead	2
	Senior Project Manager	1
	Systems Architecture Principal Engineer	1
Consultant	Systems Engineer/ Rail Systems Engineer	4
	Digital Engineering Lead	2
	Total Participants Interviewed	10

4.2 Interview Findings

Interviews were transcribed and analysed using the same taxonomy as identified in literature review. Findings identified a variety of challenges relating to process maturity issues. Analysis also revealed insights related to the adoption of more integrated and systems-based approaches to requirements engineering. A summary of findings is provided in Table 4 and discussed in the following sub-sections.

Table 4. Process Challenges to Requirements Engineering and Information Requirements

Code	Challenge	Phase
INT-RE-PC01	Disconnect in workflows and tool-chains linking requirements types and levels	Plan > Acquire
INT-RE-PC02	Lack of requirements change management process	Acquire
INT-RE-PC03	Lack of standard process for physical, cyber and info. requirements validation	Acquire
INT-IR-PC01	Delays in information requirements development process	Plan > Acquire
INT-IR-PC02	Lack of process standards supporting information requirements development	Plan > Acquire
INT-IR-PC03	Lack of agreed and consistent language describing information requirements	Plan > Acquire

4.2.1 Challenges to Requirements Engineering Processes

Process maturity refers specifically to requirements engineering related processes and the integration of those processes with traditional AECO project management processes. A number of significant challenges were identified by rail infrastructure interviewees, i) disconnection in the workflows that support system architecture and project level requirements, ii) lack of requirements change management processes, and iii) lack of validation process supporting physical and virtual requirements.

Disconnect in workflows and tool-chains linking requirements types and levels*:* In rail infrastructure, network level and system architecture requirements should guide the development of project level design requirements. However, a disconnect was reported by interviewees between the planning of the system architecture and the elicitation of project level requirements at the unit design level as reflected in the following response from the Systems Architecture Principal Engineer.

"…There is disconnect between the planning of the system architecture and how requirements are not derived from a well-planned definition of the system network so as to inform and spill into a project level…" --- *Systems Architecture Principal Engineer*

Lack of requirements change management processes: Change of requirements keeps happening during the development and delivery of rail infrastructure. To minimums delivery risk, it is important to inform those project level changes to network level. However, this process is lack at the moment as captured by the following responses from the Systems Architecture Principal Engineer.

"…changes occur at the project level without informing the upper level – the network level – to evaluate the impact on the data of service that is expected at that given time in the future…"

--- *Systems Architecture Principal Engineer*

Lack of standard process for physical, cyber and information requirements validation: In sectors such as aerospace and automotive industries, requirements validation - ensuring specified requirements meet the customer needs – is recognised as a critical activity in the requirements development process. A lack of robust requirements validation in rail infrastructure was highlighted by all rail interviewees.

"The behaviours that came from the Defence sector, where there is a lot of rigor in validating the mathematical information, is not being shared in construction industry."

--- *Systems Engineer*

4.2.2 Challenges to Information Requirements Development Processes

There are also some challenges specific to information requirements development processes identified, including i) delays in information requirements development process (elicitation and description and documentation and decomposition activities), ii) lack of process standards supporting AECO requirements development and management, and iii) lack of agreed and consistent requirement language

Delays in information requirements development process: The information requirements should be recognised during early planning phase and then fed into the design phase. However, the reality on many rail infrastructure projects is that this occurs during the detailed design and even construction phases.

"…The rail systems are so fragile and sensitive… This industry is always at risk of making decisions that have side effects and unknown emergent properties and consequences that are often picked up far too late…" --- *Systems Engineer*

"The current rail industry is very, kind of, physically focused. The digital twin should be developed in parallel with physical rail. But it's very difficult to get the focus from the key stakeholders on the information requirements at the early stages of development…because the maturity of the industry is actually quite low with regards to the sort of requirements definition up front to feed into the design. It's very much geared around detailed design."

--- *Digital Engineering Lead*

Lack of process standards supporting information requirements development: The use of industry standards typically indicates the maturity level of the industry. In rail infrastructure, there is a lack industrial-wide standards and guidance supporting structured processes and the management of information requirements throughout the lifecycle of the asset.

"…different projects adopt a digital engineering approach in different levels of maturity… there is a lack of standards or structured guidance… and consistency across these ap-proaches is really important…" --- *Senior Project Manager*

"…people require information at different levels [of detail] in terms of how the systems wide requirements map with the project requirements and the functional requirements…"
--- *Senior Project Manager*

Lack of agreed and consistent language describing information requirements: Consistent requirement language supporting effective and efficient communication and collaboration among multiple stakeholders of a project was noted as lacking across the sector. The lack of a common or standard requirement language used across different rail infrastructure projects was lamented by those engineers with systems backgrounds.

"…there is no common set of requirements that go down…" --- *Rail Systems Engineer*

5 Analysis and Discussion

To locate the procedural pinpoints of RE identified in the literature and interview surveys, each challenge was mapped to corresponding phases using an adapted 'V-model' of the asset life cycle with the classic 'V' model reflected to represent the development phases of a CPS's digital twin, see Figure 1. The lower 'V' reflects the classic systems engineering process of the CPS, while the mirror reflection of the 'V' above represents the DTs modelling and simulation (Hatakeyama *et al.*, 2018).

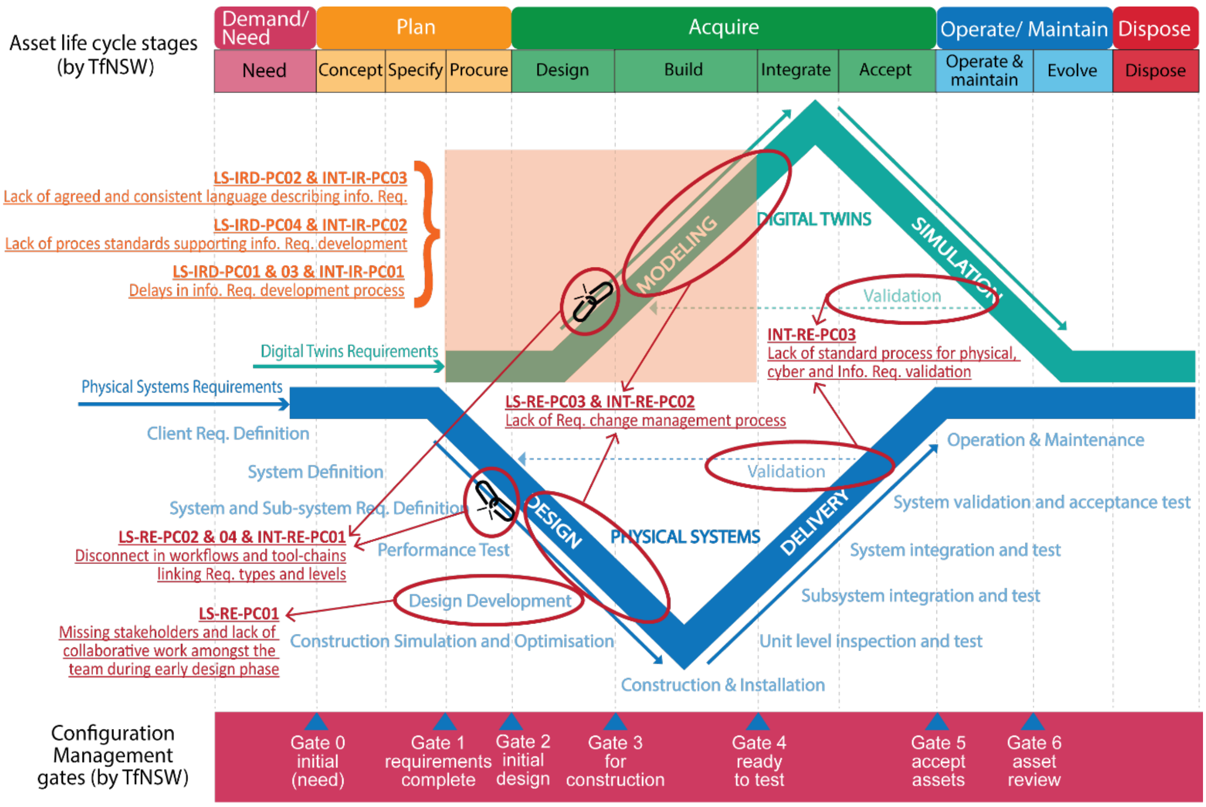

Figure 1. Challenges to RE and information requirements development

Challenges specifically related to information requirements development (and relating to ISO 19650 procedures) are mapped onto the reflected 'V'. As shown in Figure 1, the development process of asset information requirements can be delayed and effectively shifts the reflect 'V' capturing the digital deliverables procedures to the latter stages of the classic 'V' development process of the CPS itself. Figure 1 also shows that the majority of challenges are located in the 'specify' and 'design' stages of the asset life cycle, with their knock-on effects causing impacts on downstream verification activities. Further, although verification issues identified are mapped to the 'integrate' stage, these process challenges can largely be addressed in the earlier 'specify' stage within the PIR and EIR specifications.

A comparison of the challenges reported in the literature with those identified in the interview survey reflects a number of overlapping issues. However, key differences can also be found. Process challenges relating to requirements validation processes have not been previously documented in the literature. Furthermore, the absence of key stakeholders and a lack of integrated workflows across the different AEO participants in the 'design' stage was not reported as a key challenge by interviewees. These differences will be explored in follow-up interviews to analyse their significance in rail transport projects.

Information requirements supporting the physical, cyber and digital assets must be shared and exchanged between multiple disciplines so as to create a common and integrated view of the targeted deliverables (Wiesner *et al.*, 2017). The implementation of strategic approaches to asset information lifecycle management demands continuity in RE processes spanning the 'plan' and 'acquire' phases. However, our findings show that robust procedures and tool-chains linking RE phases across requirements elicitation and analysis, prioritisation, communication and negotiation, change management, traceability and validation activities are not well-supported by a continuous workflow shared by participating AEOs.

6 Conclusion and Future Work

The paper highlights a number of key challenges to RE in rail transport projects, where continuous workflows and integrated RE tool-chains spanning the asset life cycle impacts on the development and management of asset information requirements and the effectiveness of strategic approaches to information lifecycle management. Whilst regulated procedural methods are addressing the complexity of asset information requirements development and management, greater levels of maturity will provide greater capability in the verification of digital deliverables and ultimately supporting the efficacy of DT creation. Existing studies of rail transport and complex building projects reported in the literature highlight the impediments to mature methodologies and integrated tool-chains to support RE. The interview findings presented demonstrate the need for greater levels of requirements interfaces and change management. Whilst together with ISO 55000 and ISO 19650 provide much needed guidance to building and civil engineering projects in this area, there remains a lack of implementation-ready OIR and AIR development and management methods supported by integrated tool-chains that provide continuity and automation in requirements traceability and change management workflows across collaborating project team members. Future research will focus on verifying the findings of this study and examining the prioritisation of challenges identified in both literature and interview surveys by using a more quantitative approach (e.g., survey questionnaires).

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Attitude of Stakeholders Towards the Adoption Of Green Building in Ghana: the Perspective of Construction Professionals

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Abstract
Green building as one of the lexicons of sustainable construction could be explained as building in standards that take into consideration the environment and the people within. However, this innovative way of construction has encountered more challenges in its implementation in the industry. Despite the established benefits of green building to the environment and its occupants, the method is still underexploited in the industry. Several factors have been identified as hindrances towards its implementation. Nevertheless, little or no attention has been given to the inherent psychological root of these stated barriers. Using the Construction professionals as the unit of analysis, the study explored the attitudes of stakeholders towards the adoption of green building into the Ghanaian construction industry using a quantitative approach with a survey questionnaire as the data collecting tool. The study identified that construction professionals in the Ghanaian construction industry were open-minded towards the adoption of the green building concept due to its environmental friendliness, resource efficiency, and cost-effectiveness in the long run. Incorporating the green building concept in the construction industry is a major concern for both academicians, construction professionals, and the government. Hence this study should be helpful to decision-makers to understand and implement policies that suit the attitudes of stakeholders.

Keywords
Attitude, Construction professionals, Ghana, Green building, Stakeholders.

1 Introduction

According to Asamoah and Decardi-Nelson (2014) despite the support and benefits, the industry gives to the country's economy and social development, the industry is also characterized by unprofessional practices. Aside from the inefficient usage of resources, some activities by the construction industry have been recorded as unsustainable. Activities such as sand mining, deforestation, water pollution can be tagged as some of the unprofessional practices by the construction industry hence resulting in resource depletion. These actions by the construction industry propelled Murota (1996) to state that, the rapid development of developing countries using the conventional method of construction could quicken global warming and hence worsening the resources problem. An attempt to solve these characterized unprofessional practices in the industry consequently promoted the concept of sustainable/green building. According to Yu et al (2017), the previous researcher in an attempt to improve the sustainability of the construction industry has offered different approaches including green innovation of construction methods. According to Erten et al. (2011) green building is defined in construction as providing determined standards about subjects including sustainable land planning, usage of low embedded- energy material, saving water and energy, indoor quality, presenting healthy and comfortable medium, and control of wastes. In the case of Ghana, several types of research have been conducted on the adoption of green practices into the building construction industry. Ghana is noted among the few developing countries putting effort to achieve major progress in Green Building Technologies (GBTs) adoption and development (Darko et al., 2017). In an attempt to achieve sustainability, the Ghana Green Building Council which is mainly responsible for the implementation of GBTs in Ghana was established in 2009 (GHGBC, 2010). Nonetheless, several challenges have been identified by the researcher as factors hindering the smooth implementation of sustainability or green practices in the Ghanaian Construction Industry. Chan et al. (2018) in their study identified 20 critical barriers to the adoption of GBTs in Ghana. The high cost of GBT's, lack of government incentives, and the lack of financing schemes were the three major barriers according to the ranking of the variables. Ametepey (2015) in his study equally included that, the fear of high investment cost on the implementation of sustainable construction has been well documented. These challenges despite the existence of green building benefits propagated in the construction industry hinder its adoption in developing countries. According to Addy et al. (2020), Ghanaian construction stakeholders struggle to incorporate the green building concept in planning, designing, and constructing new buildings as well as retrofitting existing structures. Could this struggle be a result of an inclined perception or belief? Or could it be stated that construction stakeholders are considered cost minimizers or profit maximisers hence concentrate only on the initial cost neglecting the life cycle cost of the building which is of more importance? However, Barros (2010) was of the view that in the real world, building construction stakeholders might not act as cost minimizers or profit maximisers but just choose acceptable solutions-satisfiers. This statement, however, contradicts the situation in the Ghanaian construction industry since the currently acceptable solution satisfier is sustainable/green building solutions worldwide. Human decision-making and behaviours specifically are powerfully influenced by context, and particularly subjected to emotions, cognitive biases, and social influence (Kahneman and Tverty,1979: Thaler and Sunstein, 2008). Nonetheless, the majority of studies conducted on green buildings are "its challenges and benefits" but very little attention has been given to the actual attitude of stakeholders to the adoption of the green building concept. According to Adjen's (1985) proposed theory, attitude is a major factor that influences one's behaviour. Therefore, the study aims at assessing stakeholders' attitudes towards green building adoption based on the theory of planned behaviour as these attitudes contribute greatly to determining stakeholders' behaviours.

2 Literature Review

2.1 Construction Stakeholders

Freeman et al. (2003) defined stakeholders as parties contributing to a decision-making process and/or being impacted by it. Freeman (2004) also explained stakeholders as a group of individuals who can be affected and is affected by the achievement of the organization's objectives. Moloney (2006) added by suggesting that a person or group that makes a profit from an organization is a stakeholder. These definitions are however broad but narrowing down to the construction industry, a stakeholder can be explained as an individual or group whose activities critically affect the success of a project. As a labour-intensive industry, the construction industry was noted for its wide range of stakeholders. Stakeholders in the construction industry are; clients, Project managers, Contractors, Artisans, Subcontractors, Suppliers, Architect, and Consultants. Osei (2013) buttresses the statement by classifying this wide range of stakeholders in the Ghanaian built environment sector into four. According to the classification, the four range of stakeholders are Users/customers, demand-side operators, Supply-side operators, and finally the regulators. Several researchers have other classifications for these stakeholders such as internal/external, outsider/inside, and finally direct/indirect (Winch and Bonke, 2002; Newcombe, 2003; Smith and Love, 2004). These classifications are based on the level of input of the various stakeholders involved in the construction project. The successful performance of the construction project is dependent on these identified stakeholders. Service suppliers and demand-side stakeholders are most classified as the internal/inside/direct stakeholders of constructions. Any wrong move by any of these key stakeholders could be very detrimental to the success of the project.

2.2 Green Building Concept

The paradigm shift from the conventional method of construction to sustainability construction is a result of the negative influence of construction on the environment, the people within it, and finance. According to Howe (2011), about 81 million buildings in the United State, a majority of which, operate on energy inefficiency, generated high amounts of waste in their construction and overall emits large quantities of pollutants and greenhouse gases. On the other hand, the green building seeks to correct and improve on all these negative sides of conventional buildings. The green building concept seeks to incorporate a broad variety of ideas and best practices (US Green Building Council, 2009). EPA (2013) equally defined green/sustainable building as the practice of creating and using healthier and more resource-efficient models of construction, renovation, operation, maintenance, and demolition. This method of construction focuses on the optimization of resource utilization and increasing resource efficiency (US Green Building Council, 2009). The Green/sustainable construction method seeks to incorporate a natural and less harmful means of construction into the industry taking into consideration the environment, the people within it, and their finance. However, according to Darko et al. (2018), the definition of a green building varies according to the globe as it depends on the requirement of national and regional building industry development. Socio-cultural setup, economy, materials, and technology availability and affordability greatly influence sustainability building (Singh et al., 2009). Even though the definition of green/sustainable varies across countries, the fundamental concept of the green building remains the same. The main objectives of green/sustainable buildings are to ensure the efficient usage of resources, protecting and improving the productivity of occupants, and reducing the negative effect of the conventional method of construction on the environment.

2.3 Attitudes of Stakeholders towards Green Building Construction

Blackwell et al. (2006) described the attitude as favourable or unfavourable cognitive judgments, emotional experiences, or behavioural patterns that are continuously retained by individuals for certain circumstances or ideas. According to modern psychologists, attitude is believed to be a type of inherent psychological property comprising cognitive, affective, and conative tendencies that exhibit acts of consistency and persistence (Gifford, 2007). Attitude could therefore be explained as the individual's conviction to undertake something. The theory of planned behaviour equally explains attitudes as the judgment people make about the behaviour they dislike and like (Fang et al., 2017). White et al. (2009) added that attitude refers to an "individual's overall positive or negative evaluations on the behaviour."

In the construction industry, the attitude of stakeholders towards green building adoption is not very clear as the concept is clouded by uncertainties. The uncertainty of stakeholders towards the adoption of green building is shown during the initial stages of the project. Sustainable measures according to Rafindadi et al. (2014) are accompanied by confusion in various ways. These uncertainties are mostly associated with developing countries. The active delivery processes of sustainable project planning, design, construction, and operations have recently been reported to be inherently more dynamic and have more stakeholder interactions than their conventional counterparts' delivery processes (Lapiski et al., 2006, FIDIC, 2012). In all phases of the Project Life Cycle (Ward and Chapman, 2008), stakeholders are considered to be a significant source of uncertainty. Klotz and Horman (2010) added that this is due to the dynamic systems with which they are mostly unfamiliar within implementing sustainable projects. According to Ness et al. (2007), two types of uncertainties have been identified such as stochastic uncertainty which referred to the natural variability of the system while fundamental uncertainty is the inability to predict due to lack of knowledge about the system. The uncertain attitude of stakeholders towards the adoption of green buildings could be any of these two types of uncertainty. These uncertainties have resulted in the fear of high financial investment. However, the claim of the high cost associated with the implementation of sustainable technologies and practices according to (Bartlett and Howard, 2000 and Rehm and Ade, 2003) are a mere illusion per other researchers. This assumption contributes significantly to the attitude of fear and uncertainty by stakeholders in the adoption of the green building concept. These uncertain and fearful attitudes of stakeholders can affect their intention towards the adoption of the green building concept in the construction industry. Attitude based on the theory of planned behaviour is noted to have a significant influence on the behaviour intention of people. Could the uncertain attitude of stakeholders towards the adoption of green building construction be the major hindrance towards its campaign especially in developing countries?

3 Research Methodology

Based on the theory of the Planned behavioural model on attitudes, eight (8) attitudes were identified as potential attitudes of construction stakeholders towards the adoption of green building in the Ghanaian construction industry. A quantitative research approach was adopted for the study with a questionnaire as the main data collection instrument. This tool of data collection was adopted due to its ease of objectivity (Chan et al., 2018). A pilot study was conducted with a drafted questionnaire survey where five sustainable researchers were selected to review the drafted potential attitude of stakeholders. Drafted questionnaires were revised based on the comments of reviewers. Based on the pilot study, three questions on potential attitudes were rephrased whiles two other variables were removed. The questionnaire survey was a closed question with target respondents required to rank the variables on a five-point Likert scale. The Likert scale ranged from 1 to 5 and represented strongly disagree, disagree, neutral, agree, and strongly agree. Respondents were further encouraged to outline potential attitudes that were not stated in the questionnaire.

The population for the study was construction professionals within the built environment in the Ghanaian construction industry. Due to the difficulty in accessing the sample frame, the study adopted non-probability sampling techniques which are purposive and snowball sampling techniques. Selecting a representative sample according to Patton (2001) could be done using non-probability sampling techniques as it consequently reduces bias associated with this sampling technique. Wilkins (2001) used this approach in construction management study and is best used when there is difficulty in selecting a random sample from the population set as evidenced in this study. Participants willing to undertake the research study are classified as the target respondents. Target respondents for the study were construction professionals with either practical or research knowledge in green/sustainable buildings. Target respondents included Project managers, contractors, quantity surveyors, architects, civil engineers. A total of 206 responses were gathered at the end of the survey. The respondents were made up of 32 project managers, 47 construction managers, 56 Quantity surveyors, 61 Architect, and 8 Civil engineers. Based on the responses, 121 of the respondents indicated having experience with green buildings. Nonetheless, out of the 121, 67 of the respondents indicated research experience whiles 54 of the responses indicated practical experience.

4 Findings and Discussion

Statistical Package for Social Science (SPSS) V 26 was used to analyse the data set. One sample t-test, Kendall's W and mean score were used in the analysis of the data. Based on this the study could be said to adopt a three-stage data analysis. The first stage of the analysis was the use of One sample t-test to assess the significance of the potential attitudes of construction professional stakeholders towards the adoption of green building in the Ghanaian construction industry. According to Zhao et al. (2012) and Ahadzie (2007). One sample t-test used in analysing data is adopted in examining the relative significance of the variables. Each variable standard deviation, mean, and significance value is used to determine the outcome of the survey. The test value of the population's mean and significance value was hypothesized at 3.5 and 95 respectively (Ling, 2002; Ahadzie et al., 2008; Kissi, 2013). Table 1 indicates the variables above the hypothesized mean and hence suggesting that all 8 variables were important concerning their attitude towards green building adoption. Again, it was observed that the standard deviation of the various variables was less than 1. This indicating little variability and high consistency of target respondents' opinions (Field, 2005). In confirming this, Kendall's coefficient analysis was conducted to verify the reliability of the five-point Likert scale by measuring the internal consistency among the various variable. Amongst a set of rankings, an overall agreement can be ascertained with the aid of Kendall's coefficient of concordance (Chan et al., 2009). The Kendall's W for the study was 0.092, indicating a low degree of agreement amongst the set of rankings. Again, the p-value of all the variables was less than 0.05 for the two-tailed test. This shows that the variables are considered statistically significant towards the adoption of green building in the Ghanaian construction industry.

Table 1. Test Statistics

Test Statistics	
N	128
Kendall's W[a]	.092
Chi-Square	82.559
df	7
Asymp. Sig.	.000
a. Kendall's Coefficient of Concordance	

Table 2. One-Sample Test

One-Sample Test					
	Test Value = 3.5				
	t	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
				Lower	Upper
I am confident that, adopting green building practices is more convenient	6.842	.000	.437	.31	.56
I believe that green building practices are favorable due to their benefit	10.427	.000	.621	.50	.74
I appreciate the concept of green building and adopting it will be more desirable	10.027	.000	.626	.50	.75
I think green buildings are more efficient hence should be adopted	11.936	.000	.699	.58	.81
I believe the adoption of green building is better as it is more cost-effective in the long run.	8.611	.000	.553	.43	.68
As a stakeholder, I believe the adoption of green building is significant to the environment	12.198	.000	.777	.65	.90
I like the idea of designing and constructing a green building	11.754	.000	.704	.59	.82
The idea of living in a green building is intriguing	6.791	.000	.417	.30	.54

The mean score on the various variable was adopted in ranking the variables in order of importance and the result was displayed in Table 3. The average weight of the various variable was given based on this method. As shown in Table 3, all variables had a mean score greater than 3.5.

Table 3. Mean Score

	Mean	Std. Deviation	Std. Error Mean	Ranking
As a stakeholder, I believe the adoption of green building is significant to the environment	4.28	.914	.064	1st
I think green buildings are more efficient hence should be adopted	4.20	.841	.059	2nd
I like the idea of designing and constructing a green building	4.20	.859	.060	3rd
I appreciate the concept of green building and adopting it will be more desirable	4.13	.896	.062	4th
I believe that green building practices are favorable due to their benefit	4.12	.855	.060	5th

I believe the adoption of green building is better as it is more cost-effective in the long run.	4.05	.922	.064	6th
I am confident that, adopting green building practices is more convenient	3.94	.916	.064	7th
The idea of living in a green building is intriguing	3.92	.882	.061	8th

Several studies have empirically indicated the role of attitude in the predictions of various types of behaviour (Armitage and Conner 2001; Johnson and Hall 2005; Goh and Sa'adon 2015). Nonetheless, to ascertain the role of stakeholders' attitudes in the prediction of their behaviour towards the adoption of green buildings, the attitude of construction professionals towards the concept needs to be ascertained.

The first ranked "attitude" according to professionals was "As a construction professional, I believe the adoption of green buildings is significant to the environment". According to Hungerford et al. (1990) in the field of social psychology, studies on the influence of attitudes on behaviour have shown that educationalists believe that in a behavioural change system if people obtain relevant knowledge that helps prove the environment, they may gain further environmental awareness and a positive attitude towards the environment and therefore exhibit a greater level of pro-environment behaviour. Schultz and Zelezny (2000) also indicated that "attitudes of environmental concern are rooted in a person's concept of self and the degree to which an individual perceives him or herself to be an integral part of the natural environment". From the ranking of the attitudes, it is seen that construction professionals perceive themselves to be an integral part of the environment hence are looking for a good interest in it. This indicates that construction professionals believe in the environmental benefit of green building adoption in the Ghanaian construction industry. That is to say, construction professionals have a feeling of favouritisms for green building as it is more beneficial to the environment. The second-ranked attitude was, "I think green buildings are more efficient hence should be adopted". US Green Building Council (2010) indicates that green building is an outcome in design philosophy that focuses on the maximum utilization of resources hence increasing the efficiency of resource utilization. Again, one of the basic objectives of green building as indicated by NCRE (2010) is the efficient use of energy, water, and other resources. Construction professionals based on their knowledge of green building was of the view that they like the idea of adopting green building due to the degree of efficiency. Thirdly, Construction professionals also indicated that they like the idea of designing and constructing green buildings in the industry. US Green Building Council (2010) explained green building as a new concept involving a broad spectrum of a solution to existing construction methods. The concept is still regarded in the Ghanaian construction industry as its awareness and knowledge acquisition have not properly diffused into the industry. Anzagira et al. (2019) added that, although a green building is no longer a novel in developed countries, given the state of green building practices in SSA, the GBC appears to meet these criteria because it is relatively new in most developing countries, including Ghana. Based on the newness of the concept and its broad composition alongside the benefits and comfort to users and the environment at large, construction professionals are enthused with the idea of designing and constructing. Fourthly, construction professionals again agreed on the cost efficiency of green building, especially in the long run. Buildings are responsible for about 48% of total energy consumption according to US Energy Information Administration and Energy Agency (Singh et al., 2009; International Energy Agency, 2010; US Energy Information Administration, 2010). However, Singh et al. (2009) further indicated that incorporating energy efficiency in the building has the potential of saving 40-50% energy in buildings. These energy savings contribute tremendously to cost reduction during the usage of the buildings hence leading to cost efficiency in the long run. Also, construction professionals again indicated that they do appreciate the concept of green building and finds the concept desirable. The tangible and intangible benefits of green building practices make the concept desirable. It is however not surprising that construction professionals based on their knowledge of green building find the concept favourable and desirable hence should be adopted. All the eight list possible attitudes of stakeholders towards green buildings adopted were strongly agreed to by respondents. Construction professionals were of the view that the concept of green building is favourable and convenient hence are of the idea that the concept should be adopted in the construction industry. The responses from the respondents indicate that construction stakeholders especially the professionals have open minds and attitudes towards the adoption of green buildings in the construction industry.

The positive mindedness of construction professionals towards the adoption of the green building concept in the Ghanaian construction industry is encouraging. It is stated empirically that attitudes play major roles in the prediction of various types of behaviour (Armitage and Conner 2001; Johnson and Hall 2005; Goh and Sa'adon 2015). Nonetheless, despite the positive attitude of construction professionals towards the adoption of green building, the adoption of the concept in the Ghanaian construction industry is still at its infant stage. According to Ajzen and Fishbein (1980), although attitudes could affect a person's intention and actual behaviour, the correlation between attitudes and behaviour is often weak. It must therefore be noted that according to Ajzen and Fishbein (1980) attitude is one of the major factors that could predict a person's intent or behaviour. Since construction professionals have a positive attitude towards green buildings, it is recommended that these attitudes be continuously fed by equipping professionals with the necessary knowledge on green building. Also, a study should be conducted on the possible social norm in the Ghana Construction company. This will help ascertain the level of influence these elements have on the prediction of intention and behaviours.

5 Conclusion

The study reports on the attitude of construction professionals towards the adoption of green building in the Ghanaian construction industry. These attitudes identified were measured from the perspective of various construction professionals such as the quantity surveyor, contractor, project managers, civil engineers, and architects. Findings from the study suggest that construction professionals have a positive mindset towards the adoption of the green building concept in the Ghanaian Construction industry. Construction professionals were in support of the green building concept based on the positive effect it has on the environment, resources, and cost. The construction professional's open-mindedness towards the green building concept is very encouraging and promising. However, could it, therefore, be concluded that the opened mindedness of construction professionals in the Ghanaian construction industry is not enough ticket to drive the agender of green building. The construction professionals despite being a key primary stakeholder are just implementers of clients' "wants" hence can do very little with their strong-mindedness on the concept.

Based on the findings of this study, a further study into the attitude of the demand-side operators in the Ghanaian construction industry on the adoption of green buildings should be encouraged. In addition to that, further study into the attitudes and perceptions towards economic incentives and wellbeing drivers should be conducted.

The outcome of this study will help researchers focus on other factors that could be affecting the behaviour of stakeholders towards the adoption of green building. The attitude being a key factor in behaviour prediction, this study will enlighten the various environmental protection agencies to focus their attention on some green policies that are within the practicality of professionals to implement during construction looking at their attitude towards the environment.

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BIM Based Cost Planning for Quantity Surveying Students: A Case of WelTec

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Abstract
Essential building information modelling (BIM) skill competency by quantity surveying (QS) graduates is highly desired by construction industry employers. There is a growing BIM popularity in New Zealand, QS professional body and practice. However, there remains a constant BIM learning and teaching gap in academia. The rapid increase in infrastructure development and construction sector contribution to gross domestic product (GDP) invariably leads to huge BIM graduate attribute demand. Wellington Institute of Technology (WelTec) in a bid to improve QS graduate competencies implements BIM learning and teaching. This study examines the effects of BIM learning and teaching practices on student perception. An extensive literature review was carried out on different BIM pedagogy. A simulation based pedagogy was utilised to give students real-life hands-on BIM learning. Survey questionnaire was administered to QS students to derive impacts on perceived learning. Data was analysed using descriptive and relative importance index (RII) of examined BIM learning and teaching variables. The results revealed that introducing BIM to QS students had a positive impact on their learning in several aspects such as quantification, cost estimation and scheduling. The result also found that understanding of design drawings was improved including an immense increase in productivity in carrying out QS task. The implication drives inclusion of more BIM learning and teaching in relevant QS courses and other construction related courses.

Keywords
Building information modelling (BIM), Quantity Surveying (QS), Students, Cost Planning, Competencies

1 Introduction

BIM is a coordinated set of processes, supported by technology, that add value through the sharing of structured information for buildings and infrastructure assets (BIMINNZ, 2019). "BIM is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle; defined as existing from earliest conception to demolition. A basic premise of BIM is a collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder." (NBIMS, 2019). The fifth dimensional characteristics of BIM is related to cost. This dimension generates immediate cost budgets and general financial representation of the BIM model. This dimension of BIM decreases the time required for quantity take-off and estimation drastically. It also helps in reducing the errors and let the cost consultant or Quantity surveyor to spend their time efficiently for other value improvement activities (Karmeedan, 2010). According to Ashar et al (2012), BIM is not only software; it is both technology and process. The technology part of BIM helps project stakeholders to envision what is to be built in a simulated environment to identify any possible design, construction or operational concerns. The process part helps the stakeholders with close collaboration and encourages the integration of their respective roles. As opined by Jayasena and Weddikkara (2012), BIM is an IT solution for integrating software applications and Information technology tools to design a building in a common platform. This platform will not be dependent on the software that is to be used. As mentioned by Woo (2006), BIM is a building design and documentation methodology which allows all the graphical and non-graphical building information for a construction project to be readily available using a relational database that store, access and retrieve all the information about building components.

The usage of building information modelling (BIM) in the New Zealand construction industry is increasing gradually. According to 2018 BIM in New Zealand report, the use of BIM in cost estimation in New Zealand will increase from 46% to 54% in 2019. Collaborative working environment is considered one of the main drivers of BIM adoption by construction stakeholders (Enegbuma et al., 2014). There is an increasing demand for quantity surveying professionals with the knowledge of BIM in New Zealand. Quantity Surveyors have a pivotal role in the cost management services for the construction industry. Wong et al, (2014), highlighted that QS oversee the cost management for a project right from the inception till the completion which is from the feasibility study stage to the construction completion and handing over stage. QS with the knowledge of BIM is an essential requirement for the successful completion of a project using BIM. According to Stanley and Thurnell (2013), the use of BIM in New Zealand for quantity surveying practices are not as advanced as internationally, however, it is evolving. The use of 5D BIM for cost modelling is limited and is restricted to certain specific features of cost modelling such as quantity measurement take-offs for cost planning usage. In New Zealand, National BIM Education Working Group (NBEWG) started in December 2014 through BIM Acceleration Committee (BAC). BAC is a committee which cooperates with industry and government to coordinate with all the parties to motivate and accelerate the use of BIM in New Zealand. NBEWG found that there is no room for implementing BIM into education especially into the diploma programmes due to the lack of flexibility in the curricula, Puolitaival et al (2017). As part of a 2-year diploma, WelTec is providing New Zealand Diploma in Construction with strands in Construction and Quantity Surveying. It will be advisable to introduce BIM in this programme especially the 5D aspect of BIM which covers the costing and measurement take-offs of the models. Hence, it is vital to explore what factors influence BIM use by quantity surveying students, impact of BIM on quantity surveying learning and suitable framework for BIM education for quantity surveying students. This study aims to examine the influence of BIM on learning for quantity surveying students of WelTec.

2 BIM and Quantity Surveying

According to Ismail et al. (2016), by applying BIM in cost estimation would probably improve input data and improve the knowledge of quantity surveyor/estimator. This finally will lead to producing more reliable cost estimates. Wong et al. (2015), highlighted the changes in the requirements of clients and the discontentment in the performance of quantity surveyors are the factors driving the quantity surveyors to pursue advanced effective methods as compared to the existing methods. Olatunji et al. (2010) mentioned that BIM measurement which links with the estimate is possible however it will be challenging to filter the data of BIM to adhere with the standard methods of measurement. Kulasekara et al. (2016) observed that application of BIM in Quantity Surveying will have numerous benefits for quantity surveyors to offer fruitful service in both pre-contract and post-contract phases by the meaning of reducing time, cost and improving buildability of project. Ali et al. (2016) stated that a framework can be developed to equip the quantity surveying students with the necessary knowledge and practical skills required to learn BIM in terms of quantity surveying activities. This has a direct impact on the BIM learning needs of WelTec quantity surveying students, it is therefore, advisable to develop a framework to include in the curricula.

Zima (2017) found that the data provided into the BIM model have a significant impact on the calculated cost of a construction project. The method of modelling and building elements along with the data contents have a big influence on the BOQ preparation process and subsequently, it will affect the cost estimation substantially. Olatunji et al. (2010), stated that BIM measurement represents an approach that could have marked an impact on preconstruction processes like quantity take-off and cost estimation. McCuen (2008) opined that BIM can be utilized by estimators for their gain if they have sufficient understanding of BIM from the 5th dimensional function and quantification automatically by getting more rapid quantities and estimates. Wu et al. (2014), found that the capability of BIM in automating the measurement is the key benefit which clearly speeds up the traditional estimating process. BIM provides a better effective operation solution for quantity surveyors in cost estimating activities with the ability to associate relevant quantities and cost data to the digital building model which can be updated whenever there is a change in design. According to the research done by Thurairajah and Goucher (2013), there is an overall lack of eagerness to use BIM for developing its service offerings on top of quantification and cost estimate, such as lifecycle cost estimates and carbon assessments.

3 BIM Pedagogy

Pedagogy is defined as ‘any conscious activity by one person designed to enhance learning in another' (Mortimore, 1999; Eadie et al., 2016). As BIM proves increasingly useful and the necessity for the quantity surveying students to have a basic knowledge about BIM in terms of quantity surveying activities. Pedagogical practices need to be considered in developing the curriculum of tertiary education in quantity surveying to meet the required competencies for the fresh graduates. According to Eadie et al. (2016), the construction industry will change as BIM develops across platforms, cloud, tablet, mobile phone etc, which will, in turn, makes it challenging for the pedagogical characteristics of BIM. Teaching methods need to be adapted as per the requirements of the industry. Babatunde et al. (2018), found that quantity surveyors both in the industry and in the education sector, including students need to progress their knowledge and skills in BIM and apply BIM into their day-to-day practices. According to Sabongi (2008), the future of BIM is not that optimistic as the development of new courses and making it fit in the syllabus will be time-consuming. Kymmell (2008) and Barison et al. (2009), also arrived at the same conclusion that there are three types of possible obstacles to the introduction of BIM in the curriculum. They are difficulties in learning and using BIM software, misunderstanding of BIM process and issues associated with the circumstances of the academic situation. Promoting resilience in construction management related courses are critical and Ershadi et al. (2021) explored the application of academic resilience intervention (ARI) measures namely site visit, guest lectures, internship, role model, self-assessment, mentoring group discussion, code of conduct, educating concepts, case studies and role playing in promoting an improvement in the curriculum and student learning experience.

According to Russel et al, (2014), presentations with case studies and subsequent discussions can enable students to learn and think about real-world scenarios and solutions. Gier (2008) also found that courses aided with BIM will need teachers to act as coaches and facilitators than as guardians of knowledge and wisdom. Education providers or teachers should design the course activities carefully with the study materials to groom the students with self-construction of information and knowledge. The learning can be enhanced by collaborative approaches such as team assignments, knowledge-sharing platforms and web-based platforms (Shenton et al., 2014). Suwal et al. (2013), highlighted that BIM education should not be limited to the teaching of how to use BIM application, instead of that it should emphasis in increasing BIM competencies of the learner with BIM concepts and technologies. According to Wu and Luo (2015), BIM education is challenging for the construction education sector as it is under two types of challenges such as it has to meet the educational objectives stipulated by the qualification and assessment requirements, also it has to meet the professional aim of developing skilled future workers for the industry. Ershadi et al. (2021) study on building resilience through teaching practice ranked case study as 4th place and highlighted the importance of having a good role model in a practitioner for increased student learning and interest in subjects like BIM-based cost planning.

Traditional learning follows a stand-alone BIM course beneficial for the students to gain exhaustive experience of the use of BIM. As mentioned by Suhaida et al. (2019), the stand-alone approach will provide a much better understanding of the quantity surveying students for taking off quantities and preparing estimates using BIM. Some research proposed that studying 2D and 3D CAD is not necessary for studying BIM because students will not be required to use CAD once they understand how to make use of BIM tools (Sacks and Barak, 2010; Russell et al., 2014).

Badiali et al. (1998), opined that Problem-Based Learning (PBL) is a method of learning which have different types. They typically start with a situation and end with a charge to the group who is solving the problem. A good PBL is one in which learners can only be successful when they think, solve the problem, and defend their solution for the problem.

According to Chetan et al. (2018), gamification has not only encouraged learning but has also obvious to increase the engagement of students with the subject. It also improves the marks in the examination. It is observed that the formal method of teaching supported with gamification provides better engagement from students which in turn gives them the opportunity to interact with the content, of course, to understand it more easily.

Zigmont et al. (2011), presented a strong case for simulation which is linked to life-long learning achievement through simulation, but the teacher needs to consider the people and their experiences along with their circumstances. Simulations give an occasion to experience and makes the learners understand in a better way. This will have an impact on adult learning in a positive way. BIM learning through simulation will similarly help the learners to understand the methods and activities in a real-life experience method. Oludele et al (2014), justifies that by simulating an expert systems technology in a user-friendly manner will provide a good estimate in lesser time while Luo and Wu (2015), attributed using project-based learning through simulation as effective in BIM learning.

4 Research Methodology

In order to assess the effect of BIM on learning amongst Quantity Surveying students of WelTec, a simulation-based class for BIM which will be followed with a survey questionnaire was developed (Creswell and Creswell, 2018). This questionnaire was be distributed to the students. The answers to the questionnaire were collected and analysed to assess the impact of BIM learning among the students. A quantitative approach is selected because the class will be having 30-40 number of students from combined 1st and 2nd year quantity surveying students.

The expected response rate was 80%. The data received will be analysed using the relative importance index (RII) method.

The simulation method will be given so that there will be an opportunity for the quantity surveying students of WelTec to have a hands-on experience to practice at least one project to measure the quantities and provide estimation using BIM. This is the part of research in which the students get a real-life experience of working with a project model on BIM from a quantity surveying point of view. To apply the simulation familiarity for the students, it is advisable to invite some industry/academic experts to the WelTec campus (Zigmont et al., 2011; Oludele et al., 2014; Luo and Wu, 2015). A guest lecture was planned for this purpose conducted in the computer lab where all the students have access to computers. A BIM expert visited WelTec campus to give a guest lecture and a detailed simulation experience on BIM for the QS students. He introduced the software Vico Office, Revit, Navis Works Manage to the students. There were over 40 students in attendance of the guest lecture.

During the simulation-based class, some building models were analysed by the guest lecture. Students were allowed to use the model by themselves in their respective computer with each software introduced by the guest lecture. It was an interesting class for the students as it gave them an idea about different features of BIM models. To further link learning to practice, the students were briefed with all the software that was supposed to use in the class and later given the opportunity to prepare their own quantities. Students generated the bill of quantities. Then they practised the scheduling feature of BIM by providing start and end date of construction and then observed the status of the project at different time. During the guest lecture, the lecturer explained how BIM can be used in post-contract activities like the extension of time claim, variations, progress payment and final account settlement. The students were encouraged to try measurement of quantities of the same model by using BIM and as well as with manual measurement from the 2D drawing. This exercise helped the students in finding exactly what is the difference that the introduction of BIM making in quantity surveying activities. This facilitated the students in recognizing the impact of learning of BIM in their learning.

The survey questions are divided into six sections in which the first five sections are considered as independent variables and the last section which is named as “BIM competencies” is considered as a dependent variable section (Creswell and Creswell, 2018). For the dependent variable section, the questions were developed based on the programme document of WelTec. This was done to ensure the BIM competencies met established learning outcomes for the QS programme. Questions inquired into knowledge from simulation-based class about using BIM effectively in procurement and tendering, if the simulation-based classes helped students in their learning, improvements in their hands-on experience with BIM models, improvements in the communication between the parties involved in a construction project and if preparing the schedule of quantities/bill of quantities is easier with BIM and gives confidence in producing such document.

Relative index analysis was selected in this study to rank the criteria according to their relative importance for the variable sections. The formula used to find the relative index is given in Eq. (1):

$$\mathrm{RII} = \sum \frac{w}{H \times T} \tag{1}$$

where w is the weighting allocated for each student who responded to the questionnaire on a scale of one to five with one indicating the minimum and five the maximum. H is the highest weight and T is the total number of the sample. Based on the ranking (R) of relative indices (RI), the weighted average will be determined. According to Akadiri (2011) and Rooshdi

(2018), five significant levels are converted from RI values are high (H) ($0.8 \leq RI \leq 1$), high-medium (H–M) ($0.6 \leq RI \leq 0.8$), medium (M) ($0.4 \leq RI \leq 0.6$), medium-low (M-L) ($0.2 \leq RI \leq 0.4$) and low (L) ($0 \leq RI \leq 0.2$).

5 Results and Discussion

Demography

The number of respondents was 43.33% female respondents and 56.67% male respondents. These distributions are presented in Table 1. This reflects an even distribution among the respondents. There were different age group students who attended the BIM simulation-based guest lecture. There were 9 students in the age group of 18-24 age. In the age group 25-34, there were 12 students and in the age group of 35-44 there were 9 students. The percentage of both 18-24 age group and 34-44 age group against the total number of respondents were 30%. But the percentage of 25-34 age group was 40%. This shows an estimate of predominantly aged 25-34 graduating into the workforce with BIM based costing competencies. Only 4 students out of 30 respondents are working in the construction industry. 13.33% is the percentage of respondents working in the construction industry. Out of four students working in the construction industry, no one is using BIM. Thus, the percentage of BIM using respondent is 0%. This highlights not only the slow rate of BIM adoption but the skill gaps needing to be filled by academia for graduate competencies. Although, the organisations the respondents work in contributes to the measure of BIM maturity in the wider New Zealand construction industry. Out of 30 students, all responded that they are aware of Navisworks, ArchiCAD and Revit and this resulted from the simulation learning in class. 96.67% of the respondents prefer simulation-based learning style for learning BIM. One of the respondents responded as not aware of the preferred learning style for BIM learning. 3.33% of respondents are not aware of the preferred learning style for BIM learning and this could be attributed to possible areas to improve in in-class simulation pedagogy.

Table 1. Demographic distribution

Measure	Description	Percentage
Gender	Male	56.67
	Female	43.33
Age Group	18-24	30.00
	25-34	40.00
	35-44	30.00
Working in Industry	Yes	13.33
	No	86.67
BIM Software Use	Navisworks	100.00
	ArchiCAD	100.00
	Revit	100.00
BIM Learning Pedagogy	Lecture	0.00
	Simulation	96.67
	Unsure	3.33

Relative Importance Index

From the ranking assigned to each question, it was possible to identify the most important questions or factors in the awareness section shown in Table 2. It was ranked higher for the question stating that BIM simulation gave awareness to the respondents about using BIM in quantity surveying activities. The same ranking was evident for the question about BIM simulation-based lecture provided knowledge on the schedule of project tracking very easily using BIM. The question with the last ranking was given to the statement which mentioned that adequate awareness and knowledge of BIM is essential for the construction industry. The respondents feel that it is not necessary to have adequate knowledge and awareness of BIM to have sufficient achievement in the construction industry. Levels of RII for this section were high for all the questions. These rankings are consistent with the findings of Ismail et al. (2016) which reported on the need to producing more reliable cost estimates from improve awareness and knowledge in QS competency.

Table 2. Awareness RII

Awareness Measure	RII	Ranking	Levels of RII
BIM awareness in QS post simulation learning	0.900	1	High
Schedule tracking in QS post simulation learning	0.900	1	High
BIM dimension in QS post simulation learning	0.887	2	High
5D cost component in QS post simulation learning	0.880	3	High
Precontract requirement in QS post simulation learning	0.827	4	High
BIM limitation in QS post simulation learning	0.813	5	High

From the learning ranking allocated to each question in Table 3, it became possible to identify the most important questions or factors in the learning section. It was ranked higher for the question stating that the respondent is eager to learn more about BIM after attending the simulation-based class because the respondent is keen on mastering latest technologies. This result is consistent with the findings of Zigmont et al. (2011) and Oludele et al. (2014) which found that simulation promotes interest in BIM learning among students. Last ranking question with least ranking was given to the statement which mentioned that adequate awareness and knowledge of BIM is essential for the construction industry. The respondents feel that it is not necessary to have adequate knowledge and awareness of BIM to have sufficient achievement in the construction industry. These findings are similar to Ershadi et al. (2021) study which ranked guest lectures as 4th place and having a high significant impact on resilience for construction management related course learning outcomes.

Table 3. Learning RII

Learning Measure	RII	Ranking	Levels of RII
Eagerness to learn with QS post simulation learning	0.947	1	High
Clarity of drawings with QS post simulation learning	0.940	2	High
Lecturer expertise with QS post simulation learning	0.927	3	High
Active learning with QS post simulation learning	0.920	4	High
Sample BIM models in QS post simulation learning	0.900	5	High
Collaboration with QS post simulation learning	0.887	6	High

According to Table 4, pedagogy choice was ranked higher for the statement which is given that including a properly structured BIM course in the syllabus will help the respondent in developing knowledge in BIM which in turn will help the respondent in working with real BIM projects in future. This was consistent with the findings of Peterson et al (2011) and Woo (2006) which recommended the need to provide more learning materials and consideration in assessment task. The statement about the introduction of BIM throughout the existing course instead of introducing as a new course was received with low points.

Table 4. Pedagogy RII

Pedagogy Measure	RII	Ranking	Levels of RII
Structured BIM course with QS post simulation learning	0.960	1	High
Realistic project situations with QS post simulation learning	0.940	2	High
Workload reduction with QS post simulation learning	0.940	2	High
Hand-on practice with QS post simulation learning	0.907	3	High
Teacher-student contact with QS post simulation learning	0.860	4	High

Books and references with QS post simulation learning	0.840	5	High
Cooperation with QS post simulation learning	0.840	5	High
BIM introduction with QS post simulation learning	0.787	6	High-Medium

The statement on BIM enhances better communication between client and designer received more points and hence ranked first in Table 5. This is consistent with the findings of Zima (2017) which attributed growth in cost calculation and how layers of cost information can be shared between project teams. The respondents gave the least points on the statement that the number of disputes in a construction project can be reduced by introducing BIM as it provides more transparency in different aspects of construction such as design, schedule, and cost management.

Table 5. Communication RII

Communication Measure	RII	Ranking	Levels of RII
Enhanced communication with QS post simulation learning	0.953	1	High
Client-Contractor communication with QS post simulation learning	0.920	2	High
Better understanding with QS post simulation learning	0.907	3	High
Eliminating errors with QS post simulation learning	0.907	3	High
Dispute reduction with QS post simulation learning	0.900	4	High

The declaration which states that respondent who uses BIM for measurement found that it saves a lot of time comparing the manual measurement from drawings that the respondent learned in the class received more points and ranked first in Table 6. This is consistent with the findings of McCuen (2008) and Suwal et al. (2013) which found that BIM growth was improved with increased learning. When asked whether BIM can be to produce elemental estimate/preliminary estimate quickly, the ranking was lower and hence ranked 6. All the questions/statements in this section received with high grading for levels of RII.

Table 6. Skills RII

Skill Measure	RII	Ranking	Levels of RII
Time savings with QS post simulation learning	0.960	1	High
Error reduction skill with QS post simulation learning	0.953	2	High
Productivity gains with QS post simulation learning	0.933	3	High
Post contract with QS post simulation learning	0.873	4	High
Ease of SOQ with QS post simulation learning	0.847	5	High
Quick estimates with QS post simulation learning	0.807	6	High

Three measures in the questionnaire received the first rank in RII in Table 7. Majority of the respondents answered positively on the question asked if BIM simulation assisted them to gain knowledge in evaluating and presenting feasibility information and preliminary estimated to clients.

Table 7. Competency RII

Competency Measure	RII	Ranking	Levels of RII
Knowledge gain with QS post simulation learning	0.933	1	High
QS role with QS post simulation learning	0.933	1	High
Construction activities with QS post simulation learning	0.933	1	High
Tender with QS post simulation learning	0.927	2	High
Resources with QS post simulation learning	0.907	3	High
QS documentation with QS post simulation learning	0.893	4	High
Component pricing with QS post simulation learning	0.880	5	High
Communication with QS post simulation learning	0.880	5	High
Administration with QS post simulation learning	0.853	6	High

This is consistent with the findings of Puolitaival et al. (2017), Stanley and Thurnell (2013), McCuen (2008) and Thurairajah and Goucher (2013). Hence, it received with first rank through RII analysis. Respondents also responded to the statement with higher points that BIM will improve the quantity surveying role of the respondent as respondent can use their time at work efficiently by spending for developing value management and other specialized competencies of a quantity surveyor. Another questionnaire measure which received the highest points was that BIM implementation will help the construction team to manage programming and construction activities of a project more realistically.

6 Conclusion and Recommendations

Based on the research, it is evident that quantity surveying students of WelTec observed that BIM simulation has a positive impact on their learning. As stated by Lee and Hollar (2013), there will be a massive demand for people who have the necessary BIM skills and expertise for entry-level employment in the construction industry. It will be advantageous for the WelTec students to have BIM knowledge and skills with them when they are looking out for jobs after they complete their studies at WelTec. As the end part of the survey carried out based on the programme document of the diploma course in quantity surveying at WelTec, it provided an in-depth analysis of the course's expected outcome along with the BIM learning. Usage of BIM is gradually increasing in New Zealand, and it will be of immense benefit if the students are provided with enough hands-on experience in BIM which will enable them to perform better in their future jobs. This research revealed that the students prefer simulation-based learning which will help them in understanding the topics with better clarity. The awareness of BIM for the students can be improved by improvising the teaching techniques by providing the teachers with more expertise in BIM and simulation-based teaching. The learning of BIM for the quantity surveying students' needs to be enhanced by providing interactive and simulation-based teaching with expert teachers. The simulation-based BIM classes can be introduced in the learning with a properly structured curriculum this will enhance the pedagogical requirement for the quantity surveying diploma course at WelTec. Understanding of BIM can be utilized in improving the communication between all the parties involved in the construction project. The overall result of this research confirmed that BIM has a positive impact on learning among the quantity surveying students. There were some noticeable drawbacks with the assessment of this research. The main limitation is the small class sizes and the lack of historical data on the impact of student learning of BIM. Further study with more students and if possible, with different institutes is suggested for future research.

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Technical challenges for automated indoor construction progress monitoring

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Abstract
Inefficient progress monitoring is a major factor triggering time and cost overruns in building projects. Traditional manual progress monitoring is labourious and error prone. Automated progress monitoring is achieved by means such as imaging technology, tracking and positioning devices, machine learning algorithms, building information modelling. Automated progress monitoring focusses on exterior elements such as columns, beams, and outer walls. Few studies on automated indoor construction progress monitoring (ICPM) have been conducted even though the cost share of interior finishes and services is about 40%. Therefore, this paper intends to explore the technical challenges constraining automated ICPM. Initially, a systematic literature review was conducted on automated ICPM studies followed by semi-structured interviews with subject matter experts to corroborate the literature findings. The data collected were analysed using content analysis. The findings revealed that the technical challenges for automating ICPM can be divided into three categories, as challenges related to indoor objects, lighting conditions and data capturing devices. Indoor objects with achromatic colours constrain feature extraction. Low lighting indoors cause difficulty in detecting objects. Global positioning systems based data capturing is hindered by blockage of satellite signals indoors. Recommendations to improve automated ICPM can be built upon the current technological advancements.

Keywords
Automation, Interior Construction Environment, Indoor Construction Projects, Progress Monitoring, Technical challenges

1 Introduction

Majority of the building construction projects undergo time and cost overruns. Generally, construction projects suffer about 20 percent schedule overruns and up to 80 percent budget overruns (Agarwal et al., 2016). The failure to accurately and efficiently monitor project progress results in time and cost overruns (Marco et al., 2009). Progress monitoring determines inconsistencies between as-planned and as-built status (Golparvar-Fard et al., 2011, Mantel and Meredith, 2003). The traditional methods necessitate data extracted from drawings, site reports and subjective judgements of different construction personnel. Hence, the traditional approaches are erroneous, labour intensive, time-consuming, and visually difficult (Yang et al., 2015, Golparvar-Fard et al., 2015). The adoption of state-of-the-art approaches has accelerated automation in progress monitoring process while improving accuracy with real time remedial action implementation (Omar and Nehdi, 2016).

Automated progress monitoring process encompasses site data collection, information extraction, as-built and as-planned state comparison and visualisation of the results (Kopsida et al., 2015, Omar and Nehdi, 2016). Among the state-of-the-art as-built data acquisition techniques, computer vision (CV) based approaches are predominant. CV-based methods replicate human vision by acquiring, processing, and understanding images obtained from cameras (Szeliski, 2010). Many platforms use CV to perform low-cost automated measuring of onsite progress (Ahmadian Fard Fini et al., 2021). The 3D point clouds obtained from laser scanning is a volumetric data capturing technique (Shahi et al., 2013). Another category of data acquisition is radio wave-based object tracking identification such as barcodes, radio frequency identification (RFID), and ultra-wide band (UWB) (El-Omari and Moselhi, 2009, Shahi et al., 2012). The geo-spatial based technologies, namely global positioning systems (GPS) are also used to capture position data (Kang and Tesar, 2004, El-Omari and Moselhi, 2011). Progress monitoring systems mainly employ as-planned 3D building information models (BIM) and the schedule (4D BIM) with machine learning (ML) algorithms to determine schedule discrepancies (Braun and Borrmann, 2019, Park et al., 2018). 5D BIM enables both cost and schedule management (Smith, 2016). Visualising the progress deviations using 3D walk-through models has been realised by incorporating augmented reality (AR) (Golparvar-Fard et al., 2011, Roh et al., 2011).

The aforementioned automation approaches have profoundly been focussed on the exterior construction environment, while the focus on indoor sites has been scarce (Ekanayake et al., 2021, Deng et al., 2020, Kropp et al., 2018). There are significant differences between the exterior and interior construction environments. The exterior environment mostly consists of columns, beams, and outer walls, while the interior comprises of services including electrical and plumbing, drywalls and finishes (Hamledari and McCabe, 2016, Hamledari et al., 2017). The scope of interior construction progress monitoring (ICPM) covers the the fit-out, refurbishment, renovation and retrofitting projects (Ekanayake et al., 2018). Many factors linked to indoor environments render ICPM challengeable, causing complications in data collection, algorithmic processing and modelling (Deng et al., 2020, Ekanayake et al., 2021). Exploring the technical challenges constraining automated ICPM is imperative in determining future directions to automate onsite progress monitoring as a whole. Although the previous studies on automated ICPM have discussed about the challenges during the ICPM process, having an in depth understanding is necessary to device solutions to overcome them. To attain this aim, initially a systematic literature review on the extant studies of ICPM was conducted and these literature findings were substantiated through expert opinion interviews.

2 Methodology

The methodology consists of 2 stages. Initial stage was to conduct the systematic literature review. Since ICPM is an emerging area, the literature findings were corroborated and modified through expert opinion interviews in the second stage.

2.1 Systematic literature review

The systematic literature review was undertaken in the 3 steps of literature search, literature selection and data abstraction to collate the studies on automated ICPM and thereby explore the technical challenges constraining automated ICPM. This technique was adopted from Antwi-Afari et al. (2019), Zhou et al. (2013) and Snyder (2019). The study used major research databases and libraries such as Web of Science, Scopus, American Society of Civil Engineers with peer reviewed articles relevant to this study. Using several research databases to search articles minimises the bias. A systematic search based on "article title/abstract/keyword" to access previous publications in the area, “automated interior construction progress monitoring” was conducted. Initially, 45 articles were retrieved. Rayyan (Ouzzani et al., 2016), an online tool for organising literature was used with EndNote X9. Once the titles and abstracts were screened, and the duplicates were removed, 31 peer reviewed articles spanning from year 2005 to year 2021 were retrieved for full-text screening. This paper followed a data abstraction method recommended by Snyder (2019), which provides a systematic guidance on extracting information from articles of a small sample size. It enables summarising the facts in the form of descriptive information to organise and understand the common themes among the previous studies.

2.2 Expert opinion interviews

The experts are consulted through qualitative interviews to capture their opinion and in-depth understanding on the subject matter (Dawson, 2007). Since automation application in ICPM is relatively new, the number of experts in the relevant area is limited. The construction professionals, who have contributed to automated construction progress monitoring research with their expertise in the areas such as BIM, imaging technology, tracking and positioning technologies were considered as the subject matter experts. As the data sampling technique, purposive sampling was selected since it focusses on a small sample which facilitates capturing respondents appropriate to the study based on the researcher’s own knowledge and opinion. It also accomadates resource and time constraints (Patton, 2002). Data saturation (Patton, 2002) was reached without adding any new insights by 5 interviews. These interviews were conducted as semi structured, because they facilitate gathering information through structured questions while remaining flexible to discuss any other important information (Berg, 2004). The profile of the respondents is presented in Table 1. Some of the interview participants were met in person, while the others were contacted via Zoom due to COVID restrictions.

Table 1. The profile of the respondents

Respondent	Profile description
R1	A structural engineer of 5 years of experience with the expertise in BIM, laser technology and AR
R2	A civil and computer science engineer with 7 years of experience with the expertise in BIM, GPS and RFID technologies
R3	A BIM coordinator and robotics consultant at a construction company with 4 years of experience.
R4	A digital facility modelling expert and a Director at a construction company with 26 years of experience.
R5	Imaging technology expert and a consultant at a construction company with 23 years of experience

Respondents were inquired based on 2 main questions; *what is the extent of automated ICPM in construction projects*; *why do they think automated ICPM is challenging technically in the current setting*. They were presented with the tabulated litetaure findings (Table 2) and asked whether they agree with the findings. They were requested to comment on each and mention any additional challenges missing from the list. The data collected was analysed using content analysis since it enables interpreting meaning from qualitative data categorised under the themes (Denscombe, 2014, Hsieh and Shannon, 2005). The opinions, views and comments capturd from the interviws were analysed under the 3 main themes indoor objects related, lighting related and data capturing related challenges.

3 Findings and Discussion

3.1 Literature findings on technical challenges for automated ICPM

Based on the literature findings, the authors have organised the technical challenges for automating ICPM into three categories, as challenges related to indoor objects, lighting conditions and data capturing devices collated from 20 studies. These were referred to as technical challenges, since the data collection from the as-built scenes and algorithmic processing to extract information to make inferences are constrained by aforementioned conditions. Moreover, technical solutions are required to overcome the said challenges (Ekanayake et al., 2021). These literature findings are presented in Table 2.

Table 2. Literature findings on technical challenges for automated ICPM

Literature findings	**Sources**																			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Indoor objects related challenges																				
Detection of the region of interest (ROI) is constrained by the presence of temporary equipment and material					●								●							
Movements of construction personnel create clutter in images								●												
Feature extraction of slender objects and small objects is challenging													●			●				
Indoor objects with less texture and achromatic colours constrain object classification													●		●					
Changes in the interior walls cause capturing overlapping images													●							
Lighting related challenges																				
Detecting the ROI can be hampered by changing indoor lighting		●	●																	
Missing artificial lights, back-lights and shadows constrain object detection													●							●
Non-uniform illumination cause ineffective shape													●							

extraction of indoor elements																				
Data capturing devices related challenges																				
Concrete and steel enveloped indoor environments interrupt GPS readings												●							●	
UWB devices are less effective as the signals are obstructed by indoor building materials														●						
RFID devices can determine the presence of objects, but they are limited in localisation									●			●					●			
Fixed cameras get hindered by the limited field of view							●													
Continuous relocation of data capturing devices is exhausting			●				●													
Unsupervised device movements lead to uncertainties in capturing different perspectives ofobjects											●									
Point clouds generated by laser scanners for reflective surfaces such as metallic pipes can be incomplete						●				●										
Detecting transparent indoor elements like glazed doors and windows, which cannot reflect laser beams is challenging	●									●										
Inaccurate point clouds are generated due to occluding indoor building elements																		●		

Sources: *1-(Pu and Vosselman, 2007); 2-(Ibrahim et al., 2009); 3-(Bosché, 2010); 4-(Bohn and Teizer, 2010); 5-(Roh et al., 2011); 6-(Golparvar-Fard et al., 2011); 7-(Dai et al., 2012); 8-(Kropp et al., 2012); 9-(Shahi et al., 2012); 10-(Turkan et al., 2012); 11-(Kropp et al., 2013);12-(Shahi et al., 2013); 13-(Hamledari and McCabe, 2016); 14-(Ham et al., 2016) 15-(Kropp et al., 2016); 16-(McCabe et al., 2017); 17-(Kropp et al., 2018);18-(Pučko et al., 2018); 19-(Ibrahim et al., 2019); 20-(Deng et al., 2020)*

These literature findings were then presented to the subject matter experts.

3.2 Findings from the expert opinion interviews

3.2.1 Indoor objects related challenges

Corroborating the literature findings, the interview respondents offered more insights. All the respondents agreed on including the clutter caused by human involvement under indoor objects related challenges. R5 pointed out that compared to exterior sites, when a renovation of an occupied building is carried out, in addition to construction personnel, clutter may occur due to building occupants accidentally entering the renovation site. Drywalls are one of the main elements in an interior site. As opined by the respondents, the ML algorithms, which rely on feature extraction fail to detect the state differences in the installed, plastered and painted drywalls because the colour and surface differences of such indoor elements are not distinctive. On the other hand, moving of drywall sheets temporally while they are being installed causes clutter in the enclosed sites disrupting the data collection. All the respondents recommended to consider the size, shape, texture and colour as inherent properties of indoor materials related challenges. Providing an example, R1 stated how the detection algorithms mistakenly classify objects intrinsically slender in shape (i.e steel and timber studs) and the thin plates that may appear slender from certain viewing angles (i.e step ladders) as framing. Moreover, since the steel studs are usually grey in colour, its achromatic nature also makes the detection problematic.

3.2.2 Lighting-related challenges

The consensus of the respondents was that the artificial lights installed in the indoor sites cause noise on the cameras and laser scanners during data collection. This is especially applicable if the artificial lights create low lighting environments compared to the exterior of the site which uses natural lighting. The image capture resolution and point clouds accuracy tend to be higher in outdoor sites in natural lights. The respondents highlighted image pre-processing for enhancing the contrast of the images. They also recommended filtering out mixed pixels in point clouds before detecting the objects. According to R1 and R3, algorithms relying on extracting features such as edges, corners and texture to detect the objects are affected by the fluctuations in illumination created by indoor lights.

3.2.3 Data capturing devices related challenges

All the respondents endorsed the fact that unlike their effective use in outdoor sites, position data capturing devices like RFID and GPS fail due to blockage of satellite signals and radio waves transmission when the work moves indoors. However, R4 pointed out that the detection of the indoor objects by these devices in terms of location and presence can still be determined to a certain extent, without providing a clear picture on the physical progress changes. As pointed out by the respondents, the static nature of site surveillance cameras can constrain capturing the desired ROI both in the indoor and outdoor sites. It is more challenging indoors because the relocation of cameras and the use of drones can cause disturbance to site workers and create clutter in enclosed environments. The respondents agreed that despite the high cost of laser scanners, they provide accurate means of data capturing. However, they confirmed the literature findings on reflective materials and transparent materials creating incomplete point clouds. According to R4, when capturing a point cloud of an ROI, since the indoor sites are cluttered than outdoor sites, indoor materials blocking the field of view can create inaccurate point clouds for registration.

3.3 Discussion on the findings

As encapsulated from both the literature and interviews, the technical challenges for automated ICPM can be demonstrated in Figure 1. As discerned from the findings, the use of data capturing devices in the interior construction sites make up the major share of technical challenges for automated ICPM. Although every data capturing device category has their own benefits and limitations, digital cameras seem to be more convenient to handle and collect data with lesser cost and expertise compared to others.

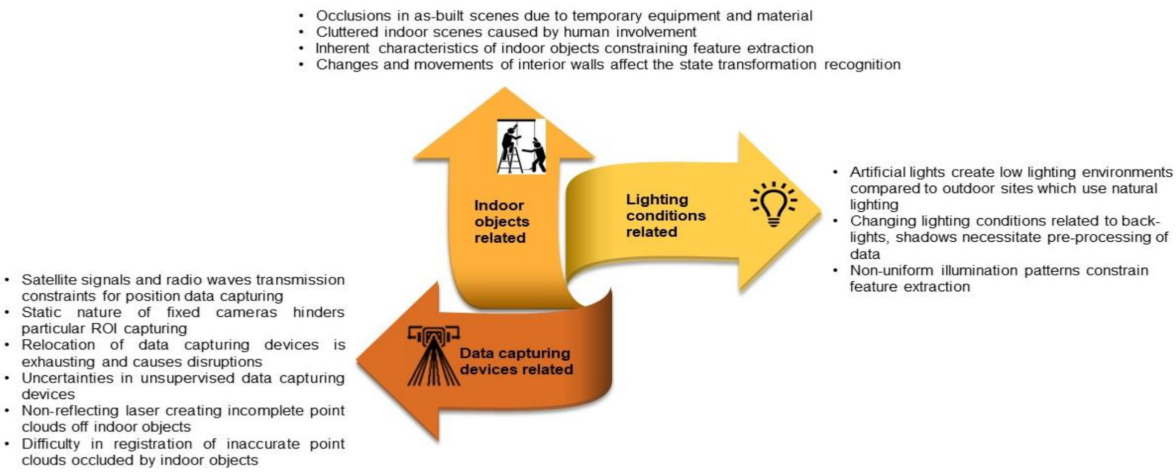

Figure 1. Technical challenges for automated indoor construction progress monitoring
Source: The Authors

All these challenges ultimately lead to difficulties in robust object detection using traditional ML algorithms, which is a core component of existing automated ICPM approaches built upon CV technology. Employing CV-based approaches entails using cameras for data capturing and ML algorithms for image processing and information extraction (Ekanayake et al., 2021). Figures 2, Figure 3 and Figure 4 illustrate how object detection is constrained by challenges related to indoor objects, lighting and data capturing devices respectively.

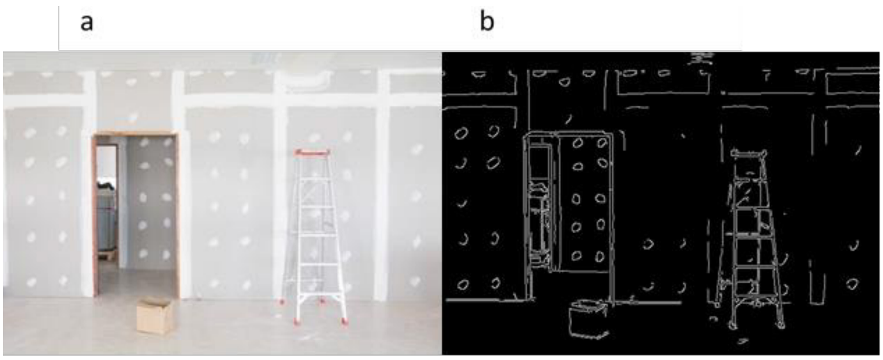

Figure 2. Detection of plastered drywalls by extracting edges is occluded by a step ladder;

a) Original image b) Edge detected image

Source: The Authors

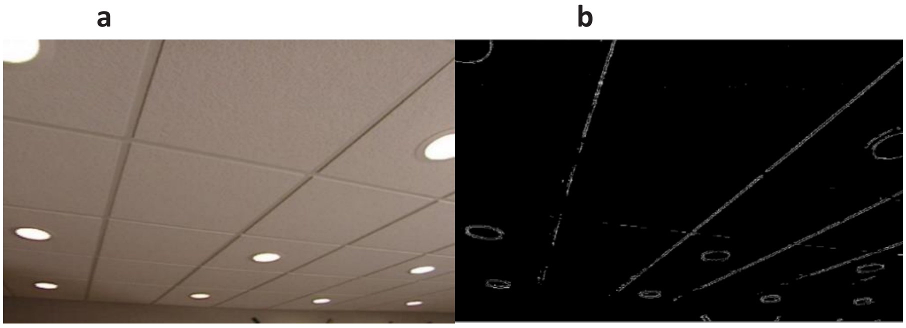

Figure 3. Detection of ceiling sheets is occluded by artificial lights

a) Original image b) Edge detected image

Source: The Authors

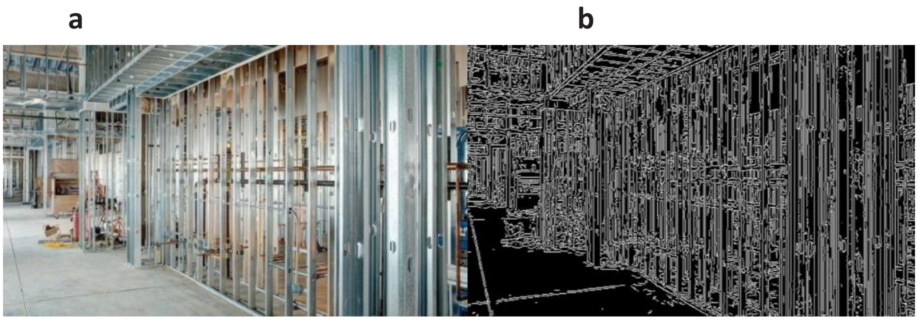

Figure 4. Site surveillance camera failing to capture the ROI causing inaccurate edge extraction; a) Original image b) Edge detected image

Source: The Authors

As illustrated in Figure 2 and Figure 3, it can be determined that compared to exterior sites, the inherant characterics of indoor objects and artificial lighting in the indoor sites constrain object detection through feature extraction by traditional handcrafted ML algorithms. Although digital cameras are an effective means of capturing data, strategic installation in the indoor sites is imperative for capturing the ROI. Since these challenges constrain robust object detection, indoor construction activity recognition which is required to analyse the as-built data of ICPM is heavily affected.

4 Conclusion and recommendations

It can be concluded from the findings that the inaccuracies of object detection triggered by the technical challenges is a reason for lack of studies on automated ICPM. The main limitation to the current study was finding the subject matter experts because automation application in ICPM is relatively new. Some recommendations can be presented to improve automation level in ICPM building upon the current technological advancements in the construction automation context. Instead of using handcrafted ML algorithms for feature extraction, the use of deep learning based neural networks for object detection is robust, because they automatically learn features by training data themselves. Since majority of the challenges are related to data capturing devices, integrating one technology with another using data fusion is recommended. Integration of several technologies alleviates limitations rather than them being employed individually. GPS can be integrated with laser scanning to track the position of indoor objects while capturing volumetric data on the physical progress changes. It is anticipated that the advances in CV will contribute to strengthening the research on automated ICPM, overcoming the technical challenges and automating the construction progress monitoring process as a whole. This will have a profound implication on reducing cost and schedule discrepancies of refurbishment and renovation projects in which most of the work is performed indoor.

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A Resilience Toolkit for Construction Management Graduates

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Abstract

The complex nature of contemporary construction work is associated with numerous stressors that not only affect the well-being of the workforce but also their productivity. Employers' expectations and work demands may exceed the capacity of fresh graduates who aim to progress their career upon graduation. When this reality is coupled with the lack of support and adverse conditions in the workplace, young individuals feel under pressure and unable to cope. Work-related stress has long been discussed in academic literature and resilience as an essential capacity is introduced as a solution. The future construction industry demands resilient graduates being equipped with the requisite skills to adapt themselves to the ever-increasing complexities. Researchers have attempted to conceptualize this concept in their field of interest. However, further research is still needed to outline its key determinants and introduce relevant strategies to promote them in the construction sector. In this study, factors affecting or being affected by resilience are discussed in this context based on the literature. Besides, suitable instruments for measuring resilience are introduced and academic interventions for building resilience are discussed based on the literature. Thus, the resilience toolkit in this study (1) explains the framework of antecedents, predictors, and consequences of resilience, (2) introduces resilience measures, and (3) argues academic interventions for improving the resilience of construction management graduates. This toolkit provides universities with insights on how to measure and plan for promoting the resilience of graduates during a construction management program. The findings add to the literature on the topic and open up a new outlook to the study of resilience in the construction management discipline.

Keywords

Resilience, construction education, construction management graduates.

1 Introduction

Junior practitioners should know how to cope with job difficulties in their early professional career. If difficulties exceed practitioners' capacity, they may face stress and anxiety which affects their productivity. Resilience as a solution to this situation is a well-established concept in literature (Holdsworth *et al.*, 2018). Resilience is defined as a combination of strengths interacting dynamically to allow an individual to perform above the norm despite

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existing barriers. There is a common thread in previous research leading to a broad statement introducing resilience as thriving in the face of adversity (Connor and Davidson, 2003).

The existence of this capacity in construction management graduates facilitates their adaptation process to overcome adverse conditions in an uncertain construction work environment (YS Chan *et al.*, 2014). Resilience improves the quality of work and helps graduates address major challenges in interacting with teammates, managers, representatives of third parties, and employers (Turner *et al.*, 2018). The main outcome of resilience is characterized by a pattern of stable personality and functional behaviour despite risks and adversity. The importance of adaptability to the workplace's ever-changing landscape in the construction industry has motivated researchers to examine different factors affecting this capability. Resilient practitioners can effectively communicate with their teammates to reach consensus and collaboratively make decisions on best practice solutions (Anjum, 2020). Fresh graduates that aim to progress their career successfully upon graduation should possess abilities such as problem-solving, conflict resolution and effective communications. Inadequate levels of social resilience may diminish their capability. Many other risk factors may hinder the success of fresh graduates in the workplace that can be properly addressed in the framework of resilience. Protective factors have been introduced in the literature to reduce these risk factors by promoting resilience (van Breda, 2018). This study provides a better understanding of protective and risk factors. Resilience skill is also essential for students to be prepared for successful completion of their studies and coping with challenges. Some studies found a declining retention rate in construction management programs. For example, Sperre (2010) calculated retention rate for a group of students and reported a declining rate with 82% in the first year, 66% in the second year, 56% in the third year, and 16% in the graduation year. Improving the resilience of students can help them to increase their awareness on how to manage adversities in their studies as well as their future professional career. Improved resilience capacity of students may be beneficial in increasing the retention rate during the construction management program.

2 Literature Review

Former research has examined the effect of resilience and coping mechanisms on the performance of construction professionals. For example, YS Chan *et al.* (2014) investigated the relationships between cultural values and coping behaviours of construction professionals in Hong Kong. It was found that interpersonal integration and disciplined work ethos alleviated emotional discharge and triggers coping skills. They found that work experience affects stress-coping attributes. However, graduates do not possess considerable work experience and need to practice authentic work scenarios to be prepared for future careers (Farquhar *et al.*, 2018).

According to Dray *et al.* (2017), protective factors include internal drivers that focus on someone's personality and external drivers linked to the wider surrounding environment. Personal resources emphasized the physical, intellectual, and psychological attributes of individuals. These can be considered as innate characteristics, or learned attributes during one's life; while, external or social factors are related to the external environment. These comprise the community, family, school, university, workplace, etc. Social resilience reflects the capability of professionals to interact with family, friends, colleagues and other parts of the community (Turner *et al.*, 2018). The associated qualities include support seeking, peer support, social relationships, etc. Internal and external mechanisms interact and influence each other to form resilience attributes. They determine practitioners' responses to an adverse work situation and adjust them to the environment (Holdsworth *et al.*, 2018).

Two kinds of approaches have been introduced by scholars to promote requisite aspects of resilience; first by taking control of risk factors (Herrero *et al.*, 2018) and second by enhancing the protective factors (Harms *et al.*, 2017). The main objective of controlling the risk factors is to prevent psychological disorders and side effects. Thus, the risk reduction approach emphasizes avoiding negative drivers or taking control of their impact. While the protective approach focuses on personal and social skills as enablers that a resilient professional utilizes to adjust to a new environment and take advantage of available resources for achieving successful outcomes in challenging situations. It has been shown that capacities that influence the resilience of students or graduands can be enhanced through educational experiences and engaging in social activities. Positive outcomes can be achieved by providing relevant protective conditions in a supportive learning environment (Zolkoski *et al.*, 2016). Thus, universities play a key role in promoting the abilities of graduates to effectively apply these two approaches. The mission of tertiary education is to develop the professional capabilities of students to prepare them for their future career.

3 Research Methodology

This study explains the literature review part of a research project on “developing a resilience toolkit for construction management graduates”. Literature reviews assess the current state of research on a topic by bringing together relevant ideas, theoretical discussions, and findings from separate studies (Tarhini *et al.*, 2015, Dikert *et al.*, 2016). The existing knowledge helps to achieve a better understanding of a phenomenon and its corresponding concepts. The main databases which were used for retrieving the studies include Scopus, Web of Science, EBSCOhost, ProQuest, and Google Scholar. Additional backward and forward reference searching method was applied to retrieve additional relevant articles (Okoli and Schabram, 2010). The results of the literature review on these three areas were discussed and the theoretical foundation for building a resilience toolkit was suggested. Three rounds of review were conducted to (1) identify antecedents, predictors, and consequences of resilience, (2) resilience measures for measuring resilience, and (3) academic interventions for promoting resilience. In the first round, all factors which may positively or negatively affect the resilience of students were elicited from the literature. They act as protective and risk factors towards shaping resilience. In the second round, the potential resilience measures which can be used for measuring resilience were identified and assessed in terms of their suitability to be applied in a construction management context. As a result of this process, the most suitable measures of resilience were introduced to be used. Finally, the academic interventions for improving resilience were extracted from the literature and suggested to be used by universities and academic institutes running construction management programs.

4 Findings and Discussion

The resilience toolkit in this study focuses on construction management graduates and comprises three elements (1) antecedents and consequences of resilience (Figure 1), (2) suitable measures of resilience for the target cohort of students, and (3) academic interventions to boost the level of resilience.

4.1. Antecedents of resilience

Antecedents of resilience refer to the events and pre-existing conditions which may shape the resilience of individuals. Such conditions can leave positive or negative impacts on people's attitudes and behaviour. Conditions that impact resilience may have biological, psychological, economic, and social causes (Windle, 2011). The antecedents of burnout for fresh graduates at the workplace would be time pressure, job uncertainties, interpersonal conflicts, job insecurity, and workload (Turner *et al.*, 2018). Such antecedents can easily lead to personal dilemmas if an individual lacks experience in confronting issues and has insufficient understanding of conflicts of interest situations (Mills *et al.*, 2018). Adverse situations, changes, and resources (personal and social) are among the antecedents which may affect the resilience capacities of people. Long-term stressors and strains accumulate over time and decrease the ability of individuals in dealing with different adversities and challenges in the workplace. Such conditions can exist as a result of a traumatic event of special circumstances associated with the environment (Caldeira and Timmins, 2016). Overall, a key to exploring aspects of resilience in construction management graduates is to capture prior events and circumstances contributing to their resilience capacities.

4.2. Predictors of resilience

There are both protective factors and risk factors that can predict the resilience skill of construction management graduates. Protective factors are described as operating to protect people who are at risk of burnout and stress while risk factors threaten them and limit their coping abilities (Tusaie and Dyer, 2004, Windle, 2011). Protective factors can be categorized into personal and social groups; personal attributes range from self-efficacy to empathy and target the inherent abilities that help individuals to make proper decisions and behave appropriately in response to stressors (Ershadi *et al.*, 2020). Different researchers have pointed to several personal skills that are important in tackling stressors and adversities. Among important personal factors, we can refer to optimism (MacLeod *et al.*, 2016, Ayala and Manzano, 2018, van Breda, 2018), sense of purpose (Knight, 2007, Rojas, 2015, MacLeod *et al.*, 2016, Mansfield *et al.*, 2016), Motivation (Martin, 2002, Windle, 2011, Rojas, 2015, Mansfield *et al.*, 2016), and Mindfulness (McGillivray and Pidgeon, 2015, Mansfield *et al.*, 2016). Besides, social factors reflect the attributes that link individuals to the surrounding environment and the important relevant factors comprise family support (Tusaie *et al.*, 2007, Rojas, 2015, Cheraghi *et al.*, 2017, Chen *et al.*, 2018), peer support (Earvolino-Ramirez, 2007, Tusaie *et al.*, 2007, Mansfield *et al.*, 2016, Chen *et al.*, 2018), teacher support (Alonso-Tapia *et al.*, 2013, van Breda, 2018), and social support (Liebenberg *et al.*, 2012, Pidgeon *et al.*, 2014, Rojas, 2015, Caldeira and Timmins, 2016, MacLeod *et al.*, 2016).

On the other hand, important risk factors that increase the likelihood of negative resilience outcomes are lack of support, family dysfunction, family conflicts (Rojas, 2015), racial discrimination, (Zolkoski *et al.*, 2016), depression, and isolation (MacLeod *et al.*, 2016). More specifically, examples of risk factors in the construction management graduates include lack of skills in negotiation, insufficient awareness of dispute resolution, inability to deal with highly charged people, lack of understanding of professional responsibilities, and insufficient knowledge of construction contracts (Mills *et al.*, 2018).

4.3. Consequences of resilience

Consequences refer to end-points occurring due to building the resilience skill, which includes physical/psychological integration, development of personal control, psychological adjustment, personal growth, normal behaviour, academic engagement, effective coping, sense of overcoming adverse situations (Gillespie *et al.*, 2007). From a construction management perspective, the consequences of promoting resilience in the academic environment include leadership to drive WHS outcomes, capability to defuse tension between parties, capability to protect actions by the codes of conduct and professional ethics, the ability to maintain clear contractual communications, understanding of the responsibilities and expectations of stakeholders (Mills *et al.*, 2018).

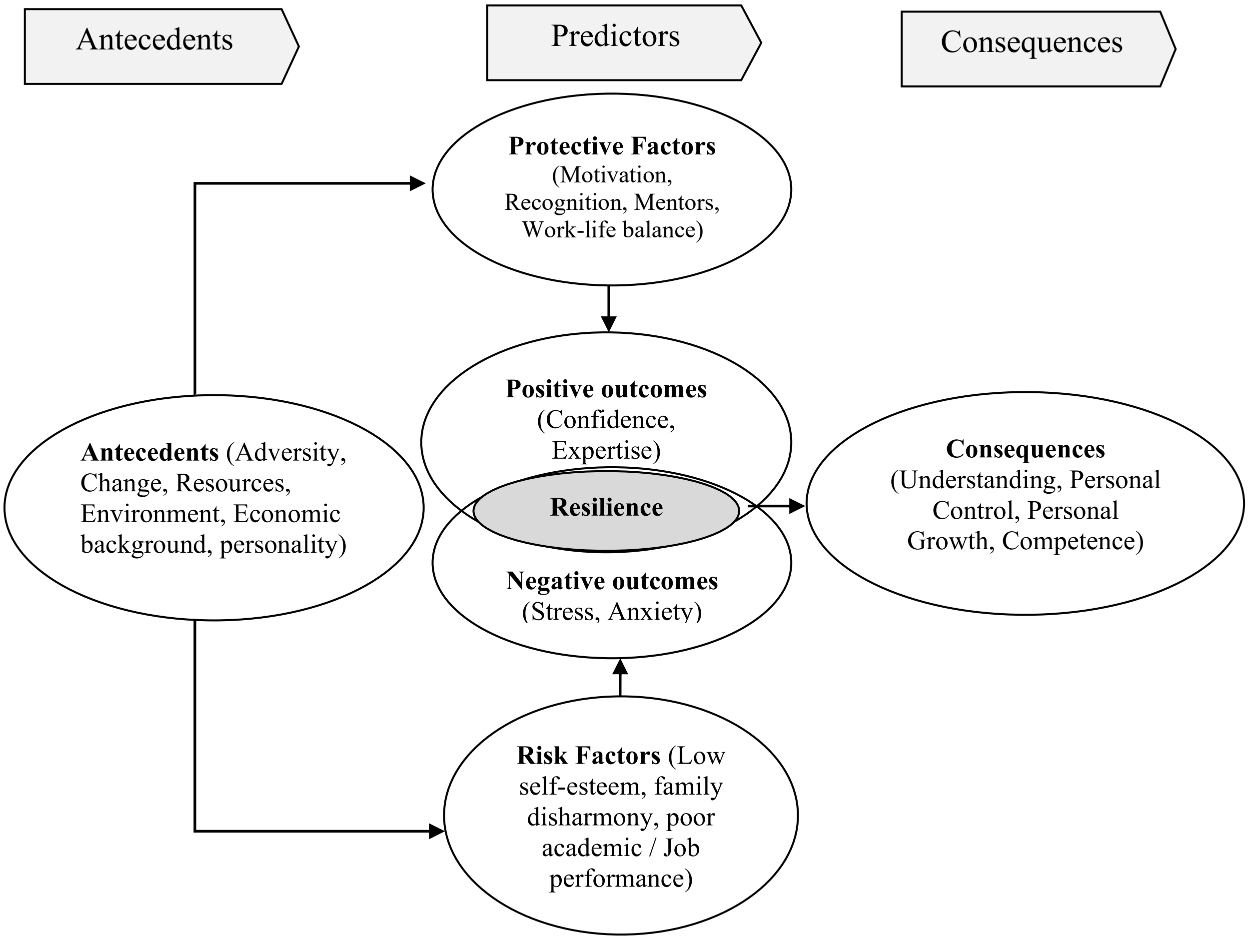

Figure 1. The framework for building resilience in construction management graduates (University of Newcastle, 2018)

4.4. Implications of the resilience framework for the construction practitioners

The framework which is presented in Figure 1 summarizes key factors and elements discussed in the literature. Further adjustments can be made using empirical evidence to adapt this framework for construction practitioners. Regarding the specification of the construction work environment, practitioners should be equipped with a high level of resourcefulness, self-control, tolerance (van Breda, 2018), and cognitive restructuring (Villasana *et al.*, 2017). The protective and risk factors also influence practitioners' level of resilience and, thus, need to be managed effectively. Key considerations to be taken into account for expanding the scope of this framework to practitioners include work-life balance (Kotera *et al.*, 2020) and peer support (van Breda, 2018). Another important concern that recently has affected the construction industry is the COVID pandemic and associated risks. COVID pandemic has imposed extra work stress on construction practitioners and students due to restrictions, exposure to the virus, and possible unemployment caused by lockdowns. Resilience capacities can help to improve the awareness of individuals and enable them to think about best solutions to control its impacts on accomplishing job activities. The introduced framework can be further validated and developed in future research to be adjusted for the construction practitioners. Measures of resilience and interventions are among major elements to be considered in future development of this framework. The following sections provide an overview of these elements and relevant findings from previous studies that should be incorporated in the development of such frameworks.

4.5. Measures of resilience

Several instruments have been introduced in the literature to measure the resilience skills of individuals. Each instrument focuses on specific aspects of resilience due to the point of research focus. Some researchers target school children, a group of them focuses on practitioners, and some researchers adopt a universal perspective and develop measures for adults. However, this study considers instruments that focus on university students to identify which of them are more applicable to the construction management discipline. For example, Limonero *et al.* (2014) developed Brief-Resilient Coping Scale (BRCS) for university students and focused on measuring personal attributes related to 1) creativity, 2) action control, 3) growth, and 4) replacing losses. McCabe and Hyatt (2017) introduced the concept of individual resilience (IR) to measure the resilience of construction workers based on a study in the Canadian construction industry. They considered six items related to 1) staying focused, 2) dealing with adversities, 3) calmness, 4) problem solving, 5) coping with stress, 6) think clearly. However, the limitation is insufficient attention to social side of resilience.

Another group of studies emphasized social and personal aspects of measuring resilience. Prince-Embury *et al.* (2017) targeted 290 undergraduates and took into account support, tolerance, trust, comfort, optimism, adaptability, self-efficacy, recovery, sensitivity, and impairment as important components to measure resilience. Harms *et al.* (2017) measured resilience protective factors in a group of Australian students by using the Protective Factors for Resilience Scale (PFRS) which is based on social resources, peers, social resources, family, and personal resources. In another study, Chisholm-Burns *et al.* (2018) developed Academic Pharmacy Resilience Scale (APRS-16) for 457 American pharmacy students using a 16-item questionnaire. Gras *et al.* (2019) adopted a revised version of the Connor-Davidson Resilience Scale (CD-RISC) and established it for Spanish undergraduate students using 22 questions based on criteria related to both personal and social aspects of resilience.

After examining all the established instruments at the university level, it was found that three are more suitable to be applied for construction management students due to considering a comprehensive set of resilience factors and covering both personal and social aspects. Resilience at University (RAU) is the most suitable measure which has been specifically developed for measuring resilience in construction management students. This instrument has been established in a sample of Australian undergraduate students (Turner *et al.*, 2017). Youth Ecological-Resilience Scale (YERS) is another suitable instrument that encompasses relevant criteria both in the social and personal aspects of resilience. It was developed for South African young adults and includes 117 items to undertake a thorough examination of the resilience level (Van Breda, 2017). The third suitable measure which has been established in a sample of 435 United Kingdom students is the Academic Resilience Scale (ARS30) that focuses on reflecting and adaptive help-seeking, perseverance, and negative affect and emotional response (Cassidy, 2015). Thus, RAU, YERS, and ARS30 are more suitable to be used for measuring resilience in construction management graduates.

4.6. Resilience interventions

Regarding the importance of resilience, several resilience-building programs such as Bounce Back, Mind Matters, and Seasons for Growth and Literature for Life have been introduced (Ershadi *et al.*, 2021). To design interventions, researchers seek more effective strategies that address important aspects of resilience. Intervention strategies that are commonly used by universities for promoting resilience in the construction management program can be categorized into two personal-oriented and group-oriented groups. The personal-oriented interventions target personal aspects of resilience through a variety of strategies.

As one of the basic interventions, academic institutions educate theoretical concepts of resilience to enhance the awareness of students (Herrero *et al.*, 2018). It is important to incorporate the code of conduct, workplace regulations, and ethics to improve their understanding (Mills *et al.*, 2018). Universities can play a prominent role by providing students with resilience self-assessment tools to help them plan for improvement (MacLeod *et al.*, 2016). Mentors can support this process by giving guidance to students and sharing life experiences (Farquhar *et al.*, 2018). Teachers should incorporate case studies to enhance the understanding of students on real-world scenarios in practice (Cheraghi *et al.*, 2017).

Group-oriented interventions focus on the interaction between students and their peers to encourage an interactive work environment in which students can share their experiences and support each other. For example, group discussions with peers help students to develop their social resilience capacities (Farquhar *et al.*, 2018). Promoting this aspect of intervention also requires close collaboration of academics and practitioners in the education of construction management students. Guest lectures by industry experts can improve the awareness of students to understand job challenges (Turner *et al.*, 2018). Industry experts can also act as role models for students (Beddoe *et al.*, 2013). Group site visits pose a source of information that students may not obtain as a result of theoretical education. This intervention provides an opportunity for students to discuss their concerns with practitioners and make a better sense of the construction work (Eiris Pereira and Gheisari, 2019). More importantly, internships in construction projects enable students to build their professional network and get early industry experience (Anjum, 2020).

5 Conclusion

Currently, there is little content contained within the construction management discipline that refer to graduate resilience skills. The present research shed light on resilience attributes, its measures, and the interventions to boost the resilience of the students who aim to commence their professional careers upon graduation from university. This study improved the understanding of the antecedents, predictors, and consequences of resilience from the perspective of the construction management discipline. Identifying these factors contributes to designing more effective curricula for construction management programs by incorporating all elements and practices that are necessary for boosting coping skills of students. It can be concluded that resilience skills enable students to promote protective factors and minimize the impact of risk factors. In the light of resilience, core competencies such as problem-solving, coping capacities, professional identity, resourcefulness, and adaptable leadership can be nurtured in construction management students. Such skills not only are essential for completion of the university studies, but also help them in their professional career in the physically and mentally demanding work environment of construction projects.

These three parts form elements of a resilience toolkit that improves the understanding of aspects of resilience and their development by leveraging academic interventions. Considering the complexity and multi-disciplinary nature of the construction industry, construction management students need to gain insight into risks and uncertainties in the workplace and also should develop technical knowledge of the relevant engineering principles. Universities are expected to equip such students with the essential skills to cope with job challenges and adversities. Notwithstanding the theoretical concepts which were discussed in this research, more studies still are required to design resilience-building curricula in the CM discipline.

Further research needs to be carried out to introduce effective interventions targeting both personal-oriented and group-oriented aspects of resilience. The application and effectiveness of advanced educational tools in promoting the coping skills of CM graduates needs more elaborations. The authors recommend that the following topics be considered for examining the aspects of resilience skills in the construction management discipline: (1) examining how resilience skills enable students to cope with COVID-related adversities, (2) exploring academic strategies that would help construction management students to improve their coping skills and be equipped with the essential skills for effective control of work stress in their future professional career, (3) introducing potential interventions to be used for promoting psychological resilience of students, and (4) developing a comprehensive cause-and-effect model of resilience skills.

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Creating the Emotionally Intelligent Home-Office

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Abstract

This paper builds from a literature review on environmental psychology and neuroscience and discusses initial observations through reflective practice methods on the impact of pandemics on workplaces, in the UK and Australia. Working from home is now legitimate and new challenges and opportunities emerge. In the face of smart office innovation, automation and artificial intelligence, the human skill of managing emotions is more important than ever. Emotional intelligence remains the key skill that companies demand. It is the skill that is most likely to get you your job and the one skill that is most likely to cause you to lose your job. The pandemic has made it clear just how important human qualities are in modern-day organisations. Whilst mobile technologies have got us up and running from home, we know all too well that there's something missing. As the days turn to weeks and months, a feeling of 'emotional drift' sets in – and with it a loss of motivation and staff engagement organisations are in need to emotionally protect their number one asset, their people and with that their ethos. The paper comprises of three sections: (1) instrumentality: the unsustainable home worker, (2) aesthetic: well-being and (3) symbolic: culture and identity.

Keywords: Interior Architecture, Emotional Intelligence, Motivation, Organisational Culture

1 Introduction

There's something missing in our home offices - and it's more than just the stapler. We've lost our 'emotional intelligence'. The technology was supposed to get us connected - but somehow, we've never felt more disconnected. This pandemic is crippling our emotional competence.

We've all become too aware that digital communication is left wanting when it comes to handling our own emotions and those of others. This paper aims to explain how even the emotionally compromised home environment does not have to set us completely adrift. And it's not technology that can fill the void (Finch and Aranda-Mena, 2019).

Of course, the whitewashing has already begun. The normalcy bias has kicked in. Forecasters of property markets are busy predicting future trends based on historic data or rather the non-existing historical data as the last pandemic of this magnitude was the Spanish flu a century ago (1919) and the world was a very different place then. Downside blip carried into 2021 with a similar upsurge since the start of the lockdown - live streamed through a comfortably remote virtual conference and initially discussed by Boucher (2020). Is this a forecast or just wishful thinking? History struggles to make sense of this pandemic. It's time to abandon the comfort zone and look at the structural changes that the pandemic has brought about. Now we are asking 'existential' questions about the future of the office?

This paper examines ‘emotionally intelligent home workspace’ pointing out how the recent Covid 19 pandemic defies traditional forecasting. The audience has changed. No longer is the message being conveyed to professionals such as architects, interior designers, facility managers or property professionals. *Instead, the message is for all of us that have become domestic workplace designers.*

The pre-pandemic message from Finch and Aranda-Mena (2019) is as relevant today as ever. In the face of automation and artificial intelligence, the human skill of managing emotions is more important than ever. Emotional intelligence remains the key skill that companies demand. It is the skill that is most likely to get you your job and the one skill that is most likely to cause you to lose your job (Yahoo, 2019). The pandemic has made it clear just how important human qualities are in modern-day organisations (Aranda-Mena, 2020). Whilst mobile technologies have got us up and running from home, a feeling of ‘emotional drift’ sets in - and with the challenge to motivate ourselves, to consciously or subconsciously self-actualise in our hierarchy of needs (Maslow, 1943).

In the following sections we discuss *how the workplace environment might do more to organisations other than providing square meters for daily staff occupation*. Workspaces are more than square meters of property space, they do become work environments that enable us to thrive at work and in life but if not well understood or managed, they can debilitate us, whether an office, a home office or a coworking space. Four selected scenarios are here described tapping into Schon’s (1992) method as reflective practice; how professionals think in action and qualitative-interpretativism as the approach:

- **The unsustainable home worker:** The home office is much more than just a tool, a place beyond the pragmatics of actioning work tasks and activities. How a focus on output and task creates an unsustainable working model has never been properly addressed but it is known that the work-life goes beyond work activities and the premise here is that home is not a substitute for the workplace in the wider sense. Questions organisations should be asking is on how to address the ‘emotional intelligence’ when staff work from home and domestic environments for an extended period of time?

- **Being in the present:** Another key emerging question relates to how the home workspace can enhance our capacity to be aware of, control, and express our own emotions and that includes the blurred line of home and workplace environments. Examining our sensory and aesthetic surroundings is not just about decoration. The aesthetics of our physical surroundings puts us in touch with ourselves i.e. our office creeping into our homes and our post-covid offices looking more like our home lounge?

- **Connecting with the past:** How the home workspace can enhance our capacity to handle interpersonal relationships judiciously and empathetically. Organisational belonging, relationships and meaning can be expressed as symbols. When our only contact with our organisation is in our domestic ‘goldfish bowl’. The use of symbols such as the wall with our trophies and awards, the wall with photos of colleagues celebrating completed projects or success histories that create a coherent narrative is invaluable in forming the organisational ethos, culture and identity. The pandemic presented a golden opportunity for organisations and Facilities Managers to get rid of such objects and spaces, at the risk of never recovering the actual organisational culture.

- **The unsustainable home worker:** This pandemic may have prompted professionals to hurriedly create home workspaces. There is an abundance of ‘Top 10 Tips’ about finding the right space, lighting, greenery, hardware and ergonomics. By the way, you might even look into ‘adding some little things’ or personal touches (Rattner, 2019). But far from being ‘little things’, these seemingly insignificant changes will dictate whether you will thrive in your home working environment. In the next section, we consider how our ‘emotional intelligence’ can be undermined by remote working. It also suggests that creating the right office can get us in touch with our own authentic selves.

2 Enfeebling your emotional intelligence

The casualty of remote working is emotional intelligence - that precious skill that appears top of employers’ recruitment profiles. It’s also the skill that will determine whether you keep your job or not (a better predictor than IQ). Technology may get your IQ connected - but not your emotional intelligence. A recent report by a prominent research institute (Ralph et al., 2020) suggested that:

“Emotional Intelligence (EI) – the essential skillset for the age of AI, EI will be a must-have skill in the future, with demand likely to rise six-fold within the next five years.”

So, what exactly is emotional intelligence? It’s an idea that was first formulated by the academics Salovey and Mayer from Yale university back in 1990 and was popularised by the journalist Goleman. It describes:

“The ability to engage in sophisticated information processing about one’s own and others’ emotions and the ability to use this information as a guide to thinking and behaviour” (Weick, 1979).

Latterly, the term has been hijacked by ‘positive thinkers’ (i.e. the positivist school of thought) who advocate a state of happiness by simply choosing to be happy. But emotional intelligence is entirely different, as Mayer pointed out:

“Emotional intelligence, however, is not agreeableness. It is not optimism. It is not happiness. It is not calmness. It is not motivation. Such qualities, although important, have little to do with intelligence, little to do with emotions, and nearly nothing to do with actual emotional intelligence.” (Mayer, 2009)

What effect does homeworking have on our emotional intelligence? Similarly, what effect does enforced home-schooling have on the emotional intelligence of a generation preparing for a workplace that craves these skills?

Working from home can affect our emotional intelligence. In this paper, we highlight the limitations of technology and the ‘instrumental’ home office. The frustrations of working from home invariably arise from simply thinking of our workspace as a *tool*.

“[tool] something that serves as a means to an end; an instrument by which something is effected or accomplished.” Merriam-Webster Dictionary (accessed 2020).

This *technological* view of our workspace undermines our efforts to understand our own emotions and those of others. Whilst our thoughts become preoccupied with productivity and efficiency, we leave little space for understanding our emotions and those of others and eventually with a high monetary/dollar cost to the business (Stokols, 1990; Brand, 1995).

Figure 1. The aesthetic home-office: as split vision metaphor (Source: Aranda-Mena)

2.1 Is homeworking the way ahead?

Perhaps homeworking is the way ahead? The coronavirus outbreak has caused some business commentators to suggest that homeworking will become the work style of choice: *"Remote work is here to stay. The coronavirus crisis is making companies and employees increasingly more comfortable about working from home or out of the office."* (Lazarow 2020).

But despite the prospect of reduced real estate costs and access to a wider flexible employment pool, many organisations have resisted homeworking as the default. It's surprising that it's the giant tech companies that have avoided homeworking. Back in 2013, the CEO of Yahoo banned employees from working remotely. A memo from the human resources chief indicated that *"to become the absolute best place to work, communication and collaboration will be important, so we need to be working side-by-side. That is why it is critical that we are all present in our offices."* The memo went on to argue *"Some of the best decisions and insights come from hallway and cafeteria discussions, meeting new people, and impromptu team meetings… speed and quality are often sacrificed when we work from home."* (Yahoo, 2019).

Yahoo's knee-jerk attempt to get people back to the office backfired. More than one-third of their staff left within a year. But many other tech companies such as Google and Apple continue to rely on an office-based culture. As recently as 2017 IBM sought to move 2,000 employees back to the office - despite the fact that 40% of their 40,000 employees did not have an office at the time. In a statement, it was said that "in many fields, such as software development and digital marketing, the nature of work is changing, which requires new ways of working" (IBM, 2017).

Emotional intelligence is a vital resource, yet homeworking technology often fails to capture this elusive quality. Companies have been haemorrhaging trust, loyalty and commitment. Despite the outward language of agility, process and efficiency- it's the inward language of emotional intelligence that is driving the corporate office.

3 Remote working - it's what we do

It seems that 'necessity is the mother of invention.' Living in a country that is almost the same landmass as the US, with a population that is less than 10% its size - has made Australians all-too-familiar with the challenge of remote working and remote education. While E.M. Forster (2011) was speculating about videoconferencing in 1909, the state of Victoria in Australia was busy developing its first distance learning correspondence program.

The unique challenge of an extensive landmass and a dispersed population made remote working and distance education part of their culture's DNA. By 1931, 1.5% of all Australian children were taught using a correspondence course.
'technology has been intertwined through Australia's history of distance education, impacting on today's developments in education and all educational sectors' (Stacey, 2005).

Figure 2 Australian early pioneers of distance education (Source: School of the Air, Broken Hill).

By 1951, teachers routinely conducted classes with students in rural Australia using two-way wireless equipment. Correspondence was reliant on the postal system and the teachers themselves depended on a correspondence qualification. Instead of Internet electronic packets, many distance educated students had grown up with physical packets at the doorstep. One of the reasons why audio communication proved so successful is the capacity of voice to communicate emotion as well as fact (illustrated in Figure 2). A recent study at Yale University (2017) found that it's easier for people to comprehend emotions from a voice alone than when watching a video. *"Listeners tend to be more accurate at gauging speakers' emotions during a voice-only interaction."* We often think of video communication as being rich in portraying body language and facial expressions. But it appears that it is precisely because we can be more deceptive about how we appear on screen; we have learnt to mislead our viewers. Doing the same with our voice is much more difficult because controlling vocals is much harder. So perhaps less is more in the instrumental homeworking office? Whilst emotional intelligence is often disregarded in the 'instrumental' office, it doesn't have to be that way. In the next heading, we look at the 'aesthetic' and 'symbolic' world of workplace environments.

4 Being in the present: the aesthetic home office

So, what are the features of the modern-day 'growlery'? The book 'Creating emotionally intelligent workspace' (Finch and Aranda-Mena, 2019) identifies three key facets of office space following a study by Rafaeli and Vilnai-Yavetz (2004): Instrumental + Aesthetic + Symbolic. The aesthetic qualities of any space are often seen as inessential – peripheral- nice to have but not important. But current scientific thinking shows that our environment has a significant influence on our emotional awareness, wellbeing and productivity.
Mood: Aesthetics and emotion influence our here and now. They impact our sensory system, without the intervention of cognitive processing. We feel things with our 'heart and not our mind'. One type of *affect* that is particularly important in our home office is *mood*. Unlike

emotion, mood is more generalised and is not tied to any trigger or event. Mood is that feeling that can last for minutes, hours or even days. Our environment can amplify or change our state of mind. As we walk around an art exhibition, we experience different emotions as we interact with exhibits. But when it comes to restaurants, we refer instead to the ambience or mood. The same could be said about home offices where mood is the most important effect, having lasting effects on our state of mind.

Mood and emotion are best understood from the point of view of evolutionary psychology. We like to think we can upgrade our printer, our computer or even our lighting system in the office. But when it comes to our own human ‘make up’ changes are not so easily made. In fact, we are hardwired in a way that reflects our human ancestry. Evolutionary psychologists argue that our modern-day behaviours, emotion and thinking reflect our ancestral environment where our forefathers survived. For a large part of human evolution, humans survived in the savannah grassland. As a result, humans acquired shorthand psychological adaptations to solve recurrent problems. These adaptations included the ability to infer others' emotions, discern kin from non-kin, and identify healthy mates. When designing our own home office, evolutionary psychology provides a key insight as to why some working environments are more attractive, more stimulating and less threatening than others.

The bespoke office: What are the design issues we should be thinking about in our home office? We have one thing working in our favour if we are freed from the constraints of the work office. We can arrange things so that they fit with our own temperament and mood. No more compromises with shared space. Everything from lighting, seating position, temperature and decoration are all under your own control. No interference from the workplace police. Below are listed 5 key areas that you might consider (all of which are now the subject of scientific research).

Naturalness: Often referred to as biophilia or ‘love of life or living systems’. The social psychologist Eric Fromm used it to describe a psychological orientation towards all that is alive and vital. Research in biophilia suggests that a level of visual complexity derived from naturalness can significantly improve our ability to concentrate and maintain attention Fitzgerald and Danner (2012).

Restoration: Art Restoration Theory (ART) (Kaplan et al. 1993) suggests that mental fatigue and concentration can be improved by time spent in or simply looking at nature. **ART** is intimately linked with biophilia. The ability to see clouds passing by, hear trees rustling in the garden or any other ‘soft fascination’ provides a restorative influence in the home office.

Colour: Choice of colour room colour is something that occupies the mind of most home office designers. It seems that different colours have different effects (Bucksteg, 2016).

Light: Traditionally, lighting designers have focused on the amount of light falling on the horizontal or vertical plane in order to accomplish tasks (task illuminance). Today, designers are showing a greater interest in the relationships between light-based emotions and behaviours, and the psychophysical responses to lit environments (Tomassoni 2016). Recent attempts to design dynamic lighting at work (van Bommel 2006) may provide some hope for those seeking to reproduce the natural activation and relaxation of natural light in the home office.

Artwork: Many organisations use artwork in the reception area and in meeting rooms. But rarely do they use it in the main office area. This is surprising because of its ability to reduce stress and increase morale. In a holistic UK study (Thomas, 2011) involving 350 workplaces, it was found that 70% of the workplaces had no artwork installed and 95% of people could not see a piece of artwork from their workstation. In the same study the colour of the walls, air temperature, air movement were changed as was the introduction of artwork. Artwork was found to be the most significant predictor of alertness and satisfaction. Having the ability to look at something other than their work was seen as important to overcoming their afternoon slump.

5 Connecting with the past: the symbolic home office

Perhaps we separate being and doing according to rooms in the house. Outside of the office, we are congenial, open and empathetic. In the office itself, *we just want to be left alone*. That is the maxim of the instrumental office. But a home office should provide space for *being* too. After all, isn't thinking and reflection just as important? We might call this daydreaming - but this is a little unfair. With the evolution of AI and automation, it's our unique human ability to cogitate that remains unchallenged. I hear you say *"I do most of my reflection when I'm walking the dog"* - but the home office can also provide a suitable environment.
Before the 20th-century, the home office was also a place where we could confront and understand our own emotional state. In Dickens' book 'Bleak House', Mr Jarndyce always retreated to the growlery whenever he felt the 'East wind'. It's defined as: *"A place of refuge or retreat when one is out of sorts or in ill humour"* (Collins Dictionary accessed 2020). Even the U.K.'s national newspaper The Times advocated the use of a growlery - during the Covid-19 lockdown period (Davies 2020). And of course, we don't just need the home office when we are 'out of sorts'. We also need the growlery to nurture positive emotions, perhaps we would call this self-actualisation or self-development if referring to Maslow's motivational theory represented in figure 3 (Maslow, 1943).

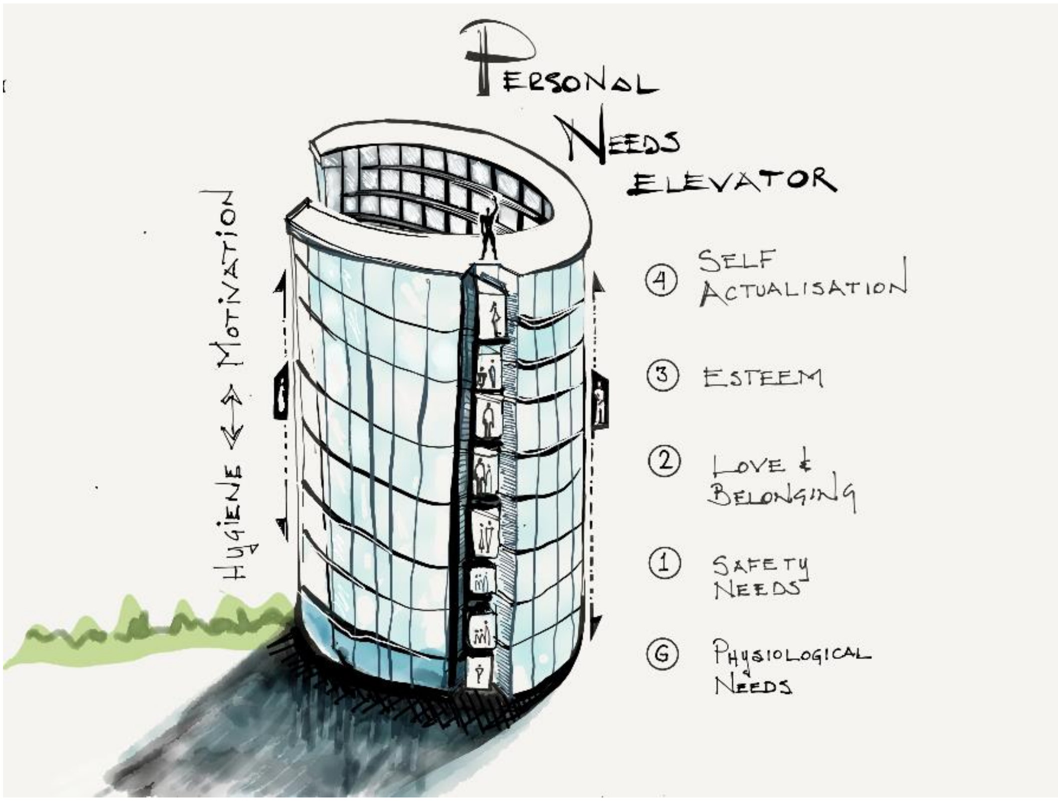

Figure 2. Adapted from Maslow's hierarchy of needs (1943) (Source: Aranda-Mena)

What is a symbol?

As well as providing the functional requirements, our home office also has the potential to speak to us; to speak to those seeing us through the aperture of a webcam; and speak to those that inhabit the blurred boundaries of our home. In normal circumstances, we can use gestures, non-verbal intonations and expressions to 'speak' to others. But we can also use our office environment to do exactly this through symbolic communication. The office itself and

the objects and spaces within can possess symbolic meaning. In Edmund Spenser's poem of 1590, a symbol is described as:
“something which stands for something else" from Edmund Spenser (1590)
That *something else* can be an object, idea or relationship. When we think of the office as an idea or relationship -rather than just an object or space - we start to understand the full potential of symbolic communication. We also unravel the conflicts that inevitably arise in a shared home environment. For many homeworkers, the home office is not dedicated, but instead is a multipurpose, transient space with fuzzy boundaries. Symbolism rather than Cartesian geometry is required to convey territory and space.
When we open up our home office to others through the use of web cams, a microphone or even an open door, people become more than observers. They become Interpreters of the physical environment rather than just participants in an exchange. The perceived office conveys many intended and unintended meanings. For example, when a home worker displays a well-stocked bookshelf as a background in a web conference, they might intend to convey the idea of being erudite, cultured or scholarly. For the remote observer, they may feel that the bookish display suggests insecurity, pretension or even deceit.

Sensemaking

Closely related to the idea of symbolism is the term sense-making. Its definition reminds us that any symbol relies on two things 1) memory and 2) some form of emotional attachment. *"the ongoing retrospective development of plausible images that rationalize what people are doing".* As we design our home office, as it evolves, as we create a history within it - these images together form a coherent set of images that enable us to make sense of our work and our organisation. The idea of sensemaking was originally conceived by Weick (1979) in the 1970s who sought a change in traditional organisational theory away from decision-making to ‘how meaning drives organising’. Despite its widespread adoption in management publications, scant research has been applied to the role of the physical environment in sensemaking. This stems from the common belief that sensemaking is a purely cognitive process. Contrary to this ‘purely cognitive’ approach, other authors have argued that ‘materiality’ and the physical environment are pivotal in creating a coherent narrative about ourselves, our work and our organisation. In other words, sensemaking should not marginalise environment-behaviour as a sense making mechanism. The office itself can change that way that we see things.
Bakke, Bean and Tamara refer to the “emergent trend in organisation studies that recognises and emphasises the materiality and corporeality of organisations and societies, which can be understood as thinking, working, and collaborating bodies within buildings, among technologies and art, together with a myriad of other artefacts, which all are interwoven in an equally complex material society.” (Bakke, et al. 2006).
It's been observed that “senses ‘make sense’. That is, they co-constitute and shape feelings, thinking, meaning and action as well as the culture of organisations.” Küpers (2013). Much the same could be said of artefacts as symbols in the workplace. It seems that our office tells a story - one that is deeply embedded and influential in our daily routines and our wider understanding.

Symbols in the home office

The impromptu nature of the home office during the Covid 19 pandemic illustrates how the office needs to be understood in symbolic terms:
“This is working from home, unexpectedly, during an unprecedented crisis. The normal benefits of working from home do not apply. Rather than working in a remote office or well-appointed home office, some people are working in impromptu in bedrooms, at kitchen tables and on sofas while partners, children, siblings, parents, roommates, and pets distract them. Others are spending all day alone in a studio or one-bedroom apartment.” (Ralph, 2020).

But how does my home office communicate meaning to myself and others? Symbols play a key part in creating and evolving a workspace at home. Sometimes the meanings are intended or unintended. Knowing the secrets of symbology can really make a difference. Issues to consider include:

How do we use space to define territory? How do we use space to enable transition?

How do we become attached to space and express ourselves? In the remaining parts, we explore practical issues surrounding 1) territory; 2) transitions and 3) place attachment.

Territoriality

Many people do not have the luxury of a discrete home office. Some form of distance is necessary to establish a separation between home and work. In a shared environment, work-family conflicts are inevitable. In order to be successful with teleworking, a remote worker needs to establish clear boundaries. Some observers (Golden, 2006) have recommended using barriers to establish a distance between family and work affairs. This process of appropriation (land grabbing!) is described by some as an orderly process:

"During the appropriation process, an individual adds his or her own ideas and symbols to a space. During the control process, worker behaviour with respect to the use of the space is laid out and defined by the teleworker. The other members of the household understand this and follow certain rules to respect the space." (Solís, 2016).

This process invariably involves conflict. If people fail to respect the elements that enable the representation of space (symbols), the remote worker will always experience difficulties. Establishing boundaries between work and family life is requisite for successful homeworking (Hill et al. 2003).

Liminal space

Goffman (1959) suggested that people manage their individual identity according to whether they are in a 'public' or 'private' space. In just the same way that actors perform 'front stage' or 'backstage' people in the home office do likewise. They manage how they present themselves according to the audience in front of them, whether it be their clients, work colleagues, children or spouses. In front-stage regions (front of house) people adhere to certain scripts - they are required to regulate their emotions during interactions with customers, co-workers and superiors. In a videoconferencing context, this emotional control may be difficult to adhere to - with viewers often seen as interlopers on a domestic scene. The term 'emotional labour' was used to describe this 'public face' by Hochschild (2012). In contrast, backstage regions (e.g. the kitchen) provide private arenas allowing individuals to step out of character.

Liminal spaces represent the in-between spaces that often have a strong symbolic meaning. "Our experiences and how we feel in these spaces are deeply connected to our memories, thoughts and imaginations" (Shortt 2015, p. 636). The term 'liminal space' comes from the Latin word meaning 'threshold' and refers to a period of time/space that is 'in-between': it is neither front of house or back office. It's often seen as an environment that is free from structural obligations and where 'anything may happen' (Turner, 2018, p. 13). In this transitory space, people can share secrets and speak frankly. Transition spaces are invaluable to home workers - even if they are only symbolised by a threshold, a piece of art or some mistletoe! In the Covid pandemic, the ceremony of going to the bathroom and washing hands provides a useful 'mental' transition from one role to another.

Place attachment

Unlike the traditional office, the home office enables us to incorporate something of ourselves. We like to feel that we have had some input, expressing our place in our own organisation (albeit remotely). Just how strong is that sense of attachment arising from our personal investment of emotion? A renowned study demonstrated the symbolic importance of 'self-made' products. The study entitled 'The IKEA Effect: When Labor Leads to Love'

(Norton et al. 2012) involved four exercises in which consumers assembled IKEA boxes, folded origami, and built sets of Lego. The researchers wanted to examine whether an increase in valuation of self-made products occurred - something they referred to as the IKEA effect. The suggestion is that when people imbue products with their own labour, their effort increases their valuation - giving as an example the 'Build-a-bear'™ phenomena illustrated in Figure 4:

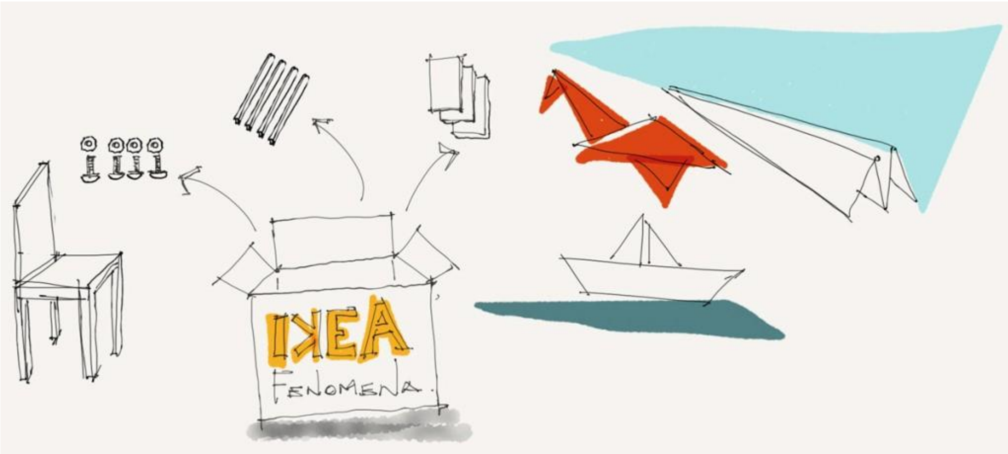

Figure 4. Illustrating the IKEA Effect (Source: Aranda-Mena)

Conclusion

The problems today are less to do with connection speed, latency or hooking up. The difficulties revolve around turn-taking, picking up on side discussions, eye contact and detecting the 'humphs'. And the casualty in all this is 'emotional intelligence'. We don't know when people are bored, frustrated, energised or indifferent. Actually, picking up on these emotions can be challenging in the virtual world - yet they are profoundly important to understanding the success or failure of a linkup. Working from home brings many benefits like saving commuting time but also many challenges, with not having the social work environment around us. This situation is also expected to bring staff disengagement and with it a loss of organisational knowledge, intellectual legacy and perhaps even more alarming, a diluted community of practice. Protecting office culture, a sense of purpose and a sense of belonging should be amongst organisations' top priorities beyond pandemics. As for your IKEA kit, don't despair as you put together your flatpack work unit. In the blood, sweat and tears (of which there will be many) you can say that you have put something of yourself into your home office. The office has become much more than a tool - it's become a symbol of yourself as in the post-pandemic world of 2021 over 90 percent of Australian office workers want to maintain a mix of remote and in-person working (PwC 2021) illustrated in Figure 5.

Figure 5. Connected but not connected; IQ versus EQ (Source: Aranda-Mena)

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Supporting Decision-making in the Construction and Property Sectors through Persuasive Virtual Reality: A Pilot Study

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Abstract
Persuasive technology is defined as technology that is designed to change users' mindsets or behaviours through persuasion. Previous studies have looked at the applications of persuasive technology in different domains. However, the use of Virtual Reality (VR) in persuasion is an emerging and novel area. In this project, VR is used as a tool with the aim of persuading potential clients to purchase low- or medium-density housing in New Zealand. We conducted a preliminary study during which we presented users with different models – 2D and 3D photos and a VR model. We aimed to investigate whether presenting a VR model of a target house would increase users' interest in potentially purchasing the house and whether it could also be used to educate users. We also wanted to know if allowing them to furnish the virtual house could enhance their user experience. The participants demonstrated high levels of interaction with the VR application, found it persuasive and educational, and believed it could be more effective in the decision-making process compared with existing 2D and 3D models. We present our design and implementation decisions, the findings of the study, and outline future work. We believe this contribution will pave the way for large-scale delivery of VR technology for sales of low- to medium-density houses in the near future.

Keywords
Buildings, Property sector, Persuasive technology, Virtual reality

1 Introduction

Virtual Reality (VR) is rapidly altering the world we live in. Technical limitations of VR hardware and a historically high price tag have prevented greater adoption by the public and wider industry (Falconer et al. 2016). However, VR has experienced a major resurgence, at least partially driven by the wider availability of consumer hardware and has attracted significant interest from industry and academia alike. Studies have demonstrated that visualisations experienced in immersive VR can be used effectively in various domains, from promoting residential earth buildings and changing attitudes regarding personal safety topics to improving mental health, physical health, and education (Baghaei et al. 2021a, Baghaei et al. 2021b, Samarasinghe et al. 2020, Berkovsky et al. 2010, Chittaro and Zangrando 2010, Smutny et al. 2019, Xu et al. 2021). VR has significant potential to save time and money, improve safety training, and enhance project collaboration (Samarasinghe et al. 2019). The application of VR in the building construction and property industries is flourishing and enables end-users to receive a quicker, more direct, and more detailed view of a target facility and building (Portman et al. 2015, Samarasinghe and Wood 2021, Samarasinghe et al. 2020, Lin 2020).

VR is an emerging and innovative field in persuasive technology (Burri 2020, Samarasinghe et al. 2020). The primary aim of persuasive technology is to use computers to interact with people and attempt to influence them to change their attitudes or behaviours (Fogg 2002). This technology is used in medical, educational, marketing and lifestyle applications, as well as in some recommendation system applications (Slamanig and Stingl 2008). According to the principle of attraction, engaging interactions in virtual environments can be more effective in persuading users (Fogg 2002). VR uses one or more senses to convey persuasive messages via multimodal communication, namely "via composite signals received through more than one sensory channel" (de la Hera Conde-Pumpido 2017). It simulates users' physical presence in a virtual world through sensory – especially visual – stimuli. Previous studies have also shown that decision-making habits can be influenced by virtualisation (Padilla et al. 2018).

The aim of our project was to design a persuasive VR model in a virtual construction and real estate environment and to examine whether the proposed model enhanced customer decision-making, education, and enjoyment compared with existing 2D-3D models. We targeted a medium-density house that is on the market. The house was not yet built, but the construction map was available. An interactive VR model of the house was designed and developed with Unity game engine (a popular 3D development platform and games engine with established VR support). The research question we investigated in this paper was whether our persuasive VR model could enhance client decision-making, knowledge, and user experience, as opposed to looking at 2D and 3D photos on an internet auction website popular in New Zealand.

2 VR Applications in Construction and Property Sectors

In the real estate industry, VR technology is often used as a marketing tool to assist potential customers and to create virtual properties, enabling customers to conduct virtual site visits (Hou and Wu 2020). The virtual properties are developed through digital realities and computer simulations (Ullah et al. 2019). The information provided using VR properties is the physical aspects of real estate, such as layout, structure, envelope, facilities, furniture, and the surroundings, to examine and facilitate customers' decision-making process (Cynthia and Wu 2020). Therefore, VR has greatly helped to fill the imagination gap in the real estate market, enabling customers to visualise the results of an on-plan project and to imagine how the space would look like after being built, refurbished, or emptied (Alaseeri et al. 2021). In the current COVID-19 pandemic, virtual site visits have become a resourceful way for potential home buyers to view properties. This contactless house viewing could be the future of the real estate industry across the world. Therefore, exploring the role of VR on decision-making in the context of buying behaviour in the construction and property sectors would be highly beneficial (Brenner 2017).

3 Our VR Model

We selected a house listed for sale on a popular internet auction website (www.TradeMe.co.nz) and developed a VR model to represent it. During the model development process, we followed three basic design principles to make our project more user-friendly, environmentally comfortable, ergonomic, and physiologically comfortable, as proposed by Alger (2015), LaValle (2019), and Hudelson (2017). Figure 1 shows the house selected from TradeMe for our VR model development.

Figure 1. The front view of the selected house

2.1.1 VR model implementation

The VR model implementation process consisted of the overall modelling process and the development direction of all functions. The dwelling and corresponding building plans were obtained through the listing on the TradeMe website, which provided all the necessary information to develop our VR model in alignment with the actual specifications. A demonstration of our VR model is presented in Figure 2, which shows how building services such as water pipes are accommodated within the building.

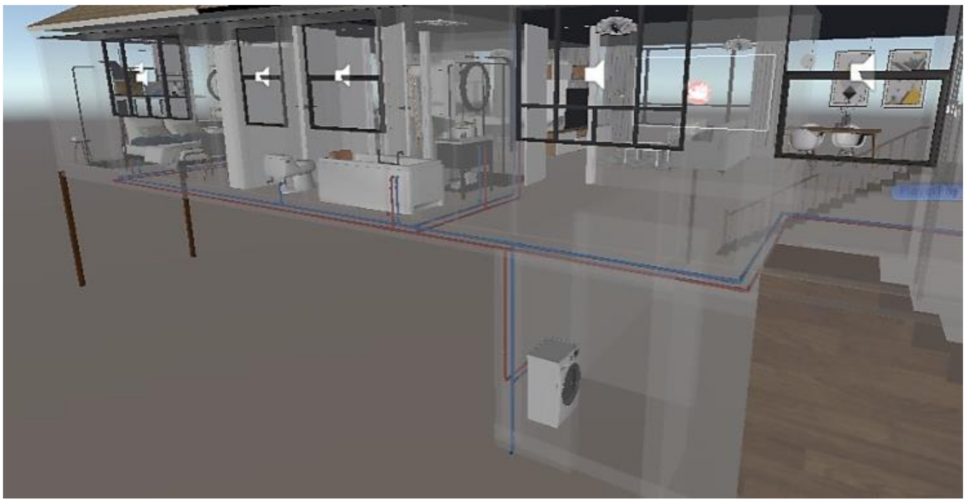

Figure 2. Overview of the water pipes

One of the key strengths of the developed VR model is the visibility of hidden building information, such as building services, that would not otherwise be visible easily to the potential buyers The water pipes in the VR model can be seen by making the walls transparent. Due to time constraints, only the plumbing was added to this model. All the lighting in the house – including area lights, point lights, and diffuse light sources – was configured to represent realistic lighting effects such as the shadows (see Figure 3). Reflective interior materials, such as glass or metal products, were implemented by defining environment maps for each of the rooms. These visual effects were all implemented to make the interior of the house look more authentic and help to immerse the user in the model.

Figure 3. House interior with lighting effects

2.1.2 Functional design decisions

Common problem users may experience in VR models is a sense of vertigo which may be caused by a range of factors, including - low framerate, stuttering, acceleration, particular drawing or illustration styles, texture complexity, lightness, and darkness, and more (Xu et al. 2021). One of the most influential factors contributing to this is the mechanism used to navigate the scene. Common options are joystick-controlled movement and teleportation. Using a joystick to control movement is easy for the user to understand, as is the case with traditional PC (personal computer) movement, but the dizziness associated with this type of action can be severe (Menin et al. 2018, Yeasmin and Albabtain 2020). As shown in Figure 4, the best way to allow the user to navigate the scene is to use hand-held controllers to teleport to specific locations in the scene.

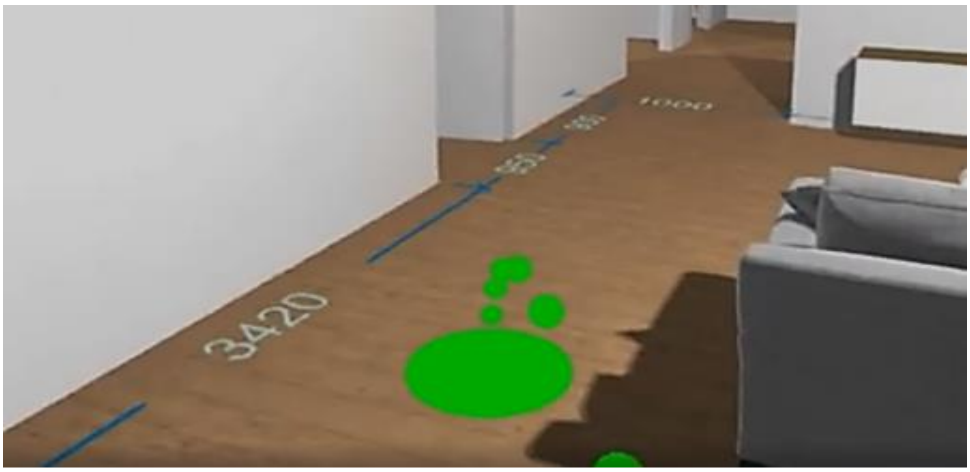

Figure 4. User moving function

At the beginning of this study, many features were considered to make the app more interactive for the user. This included following the user, integrating the menu into the joystick, and fixing the menu position. The fixed-position menu was used as the main interaction menu in this model (see Figure 5).

Figure 5. Main interactive menu

In order to encourage engagement and provide the user with a sense of accomplishment, we allow the user to add and arrange furniture within the virtual house. In the first iteration, we only set up the furniture moving and switching functionality on existing furniture. As the functionality increased, a one-page menu was no longer sufficient for all functions. In later iterations, we integrated all functions into a menu then attached these to an item (see Figure 6). We found it was inconvenient to interact by switching menus, with the rotations function especially hard to manipulate. As a result, in the final version, we only retained the item information and item switching operations in the item menu. The item rotation, delete, move, zoom in and zoom out functions were all integrated with two handles.

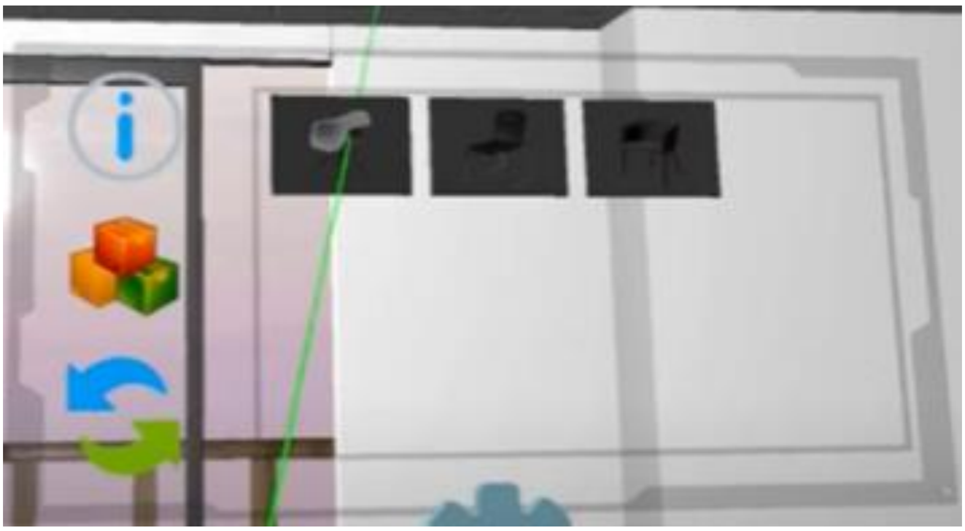

Figure 6. Furniture switching menu

4 Preliminary Evaluation

A total of 15 participants who were students and staff of the School of Built Environment at Massey University in New Zealand took part in this preliminary evaluation. The study was approved by Massey University human ethics committee. At the start of the evaluation, all participants were supplied with the research project details and were asked to provide their consent to participate.

Most participants were between 18 and 29 years old, accounting for 60% of the total number of participants. Amongst the six remaining participants, three were between 30 and 39 years old, two were between 40 and 49 years old, and one was over 50 years old. 85% of the participants self-identified as male. The demographic information showed that 80% of participants had attained educational qualifications at postgraduate level and above, and the remaining respondents were two undergraduate students and one high school graduate. In terms of experience using VR, most participants (75%) had done so previously. Six of them had extensive experience, and seven had less experience. Two had no experience and were new to VR. Based on the user evaluation results (see Table 1), 47% of participants found the VR model easy to use (this figure is comprised of those who selected 'agree' or 'completely agree' options). Additionally, 80% of participants found the VR model enjoyable to use. Almost all participants (93%) would recommend interactive VR houses to other potential property buyers.

Table 1. VR House User Questionnaire evaluation results

Evaluation criteria	**Evaluation results (%) (with 1 beings 'completely disagree' and 5 beings 'completely agree')**				
	1	**2**	**3**	**4**	**5**
I think the VR model is easy to use	0.00	13.33	40.00	33.33	13.33
I think the VR model is enjoyable to use	0.00	6.67	13.33	6.67	73.33
I think the VR model is fun to use	0.00	6.67	0.00	26.67	66.67
I think the VR model is educational to use	0.00	1.40	4.05	17.65	76.90
I would recommend it to other people	0.00	6.67	0.00	20.00	73.33
I think the VR house is effective in doing what it is trying to do	6.67	0.00	13.33	26.67	53.33
I think the VR house has the potential to be used out in the real world	0.00	0.00	13.33	33.33	53.33

The evaluation results showed that 80% of participants said the VR model would be effective in influencing their decision-making process, while 13% answered that it might be effective. The educational value of the model was appreciated by 94% of participants. Moreover, 87% thought the VR house had the potential to be used out in the real world. We believe that some of the lower percentages are due to the manoeuvrability of the handles, which will be discussed later in this paper. In addition to the quantitative data analysis results, we designed several open-ended questions to better understand the participants' perspectives on VR as a tool for persuading prospective property buyers. Overall, the participants were generally positive about the VR house. Almost all of them liked the appearance of the house. They appreciated the 3D experience and the ability to modify the rooms, which they thought would increase interest and enhance the immersive experience. However, some participants found the agency, or sense of control in the VR environment, could be improved. A majority suggested improving the control buttons, while some felt that adding more features to improve the landscape would make the VR model a better educational tool. All participants agreed the VR model was better than 3D images in terms of education and ease of making purchasing decisions and that it was a more compelling way to enhance the user experience.

We argue that our VR model is persuasive (see Table 2). The design was based on the systematic framework proposed by Kukkonen and Harjumaa (2008). It addressed three categories of design principles: 1) Primary Task Support (through Reduction, Tunnelling, Simulation, and Rehearsal); 2) Dialogue Support (through Similarity and Liking); and 3) System Credibility Support (through Trustworthiness, Expertise, Surface Credibility, Verifiability). We plan to add Social Support to the future version of the system.

Table 2. Why our model is persuasive

Category 1: Primary Task Support	**Reduction:** The system should reduce the effort that users spend in regard to performing their target behaviour. Our model shows examples of building services such as water supply pipes. **Tunnelling:** The system should guide users in the attitude change process by providing means of action that brings them closer to the target behaviour. Our model displays detailed information about the building structure, building envelope, and building services. **Simulation:** Systems should provide simulations for persuasion. Our model shows both the building and its surroundings to allow users to make an effective decision. **Rehearsal:** The system should provide means for rehearsing a target behaviour. Our model allows for the navigation of a building and its surroundings.
Category 2: Dialogue Support	**Similarity:** The system should imitate its users in some specific way. Our model imitates a typical house and usually shows unseen building services and how these are accommodated within the building. **Liking:** A system that is visually attractive for its users is likely to be more persuasive. Our VR model has a look and feels that appeals to users.
Category 3: System Credibility Support	**Trustworthiness:** A system that is viewed as trustworthy (truthful, fair, and unbiased) will have increased powers of persuasion. Our model provides an experience that is informative, truthful, and unbiased. **Expertise:** A system that is viewed as incorporating expertise (knowledge, experience, and competence) will have increased powers of persuasion. Our VR model provides information that indicates expertise. **Surface Credibility:** People make initial assessments of the system credibility based on a first-hand inspection. Our VR model has a competent look and feel. **Verifiability:** Credibility perceptions will be enhanced if a system makes it easy to verify the accuracy of site content via outside sources. Our VR model provides the means of verifying the accuracy of the content.

5 Limitations

Our study did not engage real or potential property buyers. Rather university students and staff who had knowledge of VR and building construction were engaged as research participants. We are planning to conduct the next phase of the study with a sample of potential property buyers in New Zealand.

It should be noted that when participants completed the transparency operation, we asked them to walk out of the house and look back at it from the garden to get a better view of the structure, the plumbing, and the outdoor environment. However, inexperienced VR users were unfamiliar with the controls and found that a little challenging. In contrast, some participants who were familiar with VR quickly learnt to use the controllers and easily moved around the house to complete their experience. In terms of menu operations, the furniture generation function was relatively important – the goal of the task was for the participant to select the right furniture menu with the controller and then select and generate the furniture. During this process, the user needed to press and hold both buttons of the left controller at the same time to manipulate the menu and select the furniture. The difficulty of these buttons needs to be reduced, as some users found that somewhat challenging.

Similarly, the amplify/shrink and rotate functions of the furniture used a combination of controller buttons to achieve the desired effect, and this could also be improved so less experienced users could easily interact with it.

The time required to complete the task varied depending on the degree of interaction by the participant. According to the survey data, this timing was also influenced by participants' different levels of familiarity with VR. Overall, most participants completed it in about 20 minutes, including filling out the questionnaire. A few participants took longer to complete the experience task. For the product satisfaction section, based on the table data and the answers to the open-ended questions, satisfaction was high for all participants. They felt that both the interior design of the house and the exterior scenes were very realistic and gave them a sense of immersion. The functionality of the furnished rooms was an especially appealing feature.

6 Future Work

The VR model can be improved going forward to enhance the user experience. According to a study conducted by Huis (2019), when functionality is simplified for user interaction, participants are more actively engaged.

A key feature of this study was allowing the user to organise the furniture as per their preferences. To this end, we added features that enabled the user to adjust the properties of the furniture and to rotate, move, toggle, and zoom in and out on them. According to Burri (2020), a persuasive VR experience should present simple concepts that the user can easily understand. Following that recommendation, we would undertake further work to simplify the interaction functions in our model. In subsequent versions, a possible solution would be to ensure the laser is always displayed and to let the left-hand joystick adjust the direction.

There are other features, such as scene switching and multiplayer enhancements, that could be incorporated into this model. Since there is currently only one scene, we do not have a scene switching feature in our model. However, with the addition of more target houses, having all houses in one scene would affect both the efficiency of the game and the user experience. We would want different houses to have their own scenes. Future work also includes a more streamlined process and/or tools for building VR models for further houses.

7 Recommendations and Conclusion

VR is a highly innovative and emerging field in the building construction and property sectors. It is increasingly being used as a persuasive tool to change people's attitudes and behaviours. This study was developed as an interactive model based on a real house for sale on TradeMe Website. Our aim was to investigate whether presenting a VR model of the target house would increase users' interest in potentially purchasing the house and to see if it could successfully be used to educate users. We also wanted to study whether allowing users to furnish the virtual house would enhance their user experience. The participants demonstrated high levels of interaction with the VR application and found it both persuasive and educational. They also believed it could be effective in the decision-making process compared with existing 2D and 3D models. While we acknowledge the need for further improvement and evaluation, we believe this interactive VR experience would enable buyers to learn more about properties they are potentially interested in purchasing and will pave the way for large-scale delivery of VR technology for sales of low-to-medium-density houses in the near future.

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Process Improvement Priorities for BIM related curricula in Australian Universities

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Abstract

Staff members at one New South Wales university collaborated with Transport for New South Wales (TfNSW) in the delivery of a specially designed unit that explored the process improvement priorities of Building Information Modeling (BIM) related curricula in Australian Universities. Current delivery mostly focusses on BIM as a software tool but not as a way of enabling the method of delivery. This paper showcases the need to alter perceptions when it comes to delivering BIM related units. A work-based project was put into use for a more practice-oriented contribution of knowing with, not about, people, that brings together action and reflection. To translate the learning from the specially designed unit, the authors propose BIMed 4.0, a transformational pedagogy for BIM related curricula. The critical levers in developing BIMed 4.0 is an attempt to replicate industry BIM standards and protocols according to PAS 1192-2:2013 in the method of delivery and the philosophy of systemic transformation for Construction 4.0. This paper discusses a change management plan for transitioning into BIMed 4.0. To the best of the authors' knowledge, this is the first paper illustrating how BIM can be used to enable a new method of delivery.

Keywords

Building Information Modeling (BIM), pedagogy, Common Data Environment (CDE), Australian universities, Construction 4.0

1 Introduction

The construction sector is experiencing a state of flux, with governments and business leaders trying to transform people, processes and technology into the ever-expanding and innovative digital era (Dowd and Marsh, 2020). Any transitional period creates the need for doing things in a fundamentally new way. Building Information Modeling (BIM), in fact, has helped to crystallise the current changes the sector is witnessing by bringing about new ways of working (Sacks et al., 2018). Transport for New South Wales (TfNSW) introduced a new way of collaborative working that connects emerging technologies with BIM at its core as a part of the Digital Engineering Framework (DEF) for project delivery and management (Transport for New South Wales, 2019). Also, the Victorian Digital Asset Strategy (VDAS) is a step change in the way Victorian Government departments and agencies plan, deliver, operate and maintain the assets they manage (Victoria State Government, 2020). The National BIM Report 2020 clearly finds that the industry sees real potential in new ways of working and digital transformation as a means of achieving better outcomes for the construction sector (NBS, 2020). This will require universities to review their courses and pedagogy for providing students the necessary capabilities to embrace the digital economy (Zou et al., 2019). Even though the National BIM Initiative highlighted the role of universities in delivering a multi-disciplinary BIM curriculum for professional development, a ready pipeline of BIM ready graduates remain elusive (Casasayas et al., 2021). In alignment, the Australian BIM Academic Forum (ABAF) was set up as an application to the Australasian BIM Advisory Board (ABAB), which acknowledged the need for an academic forum to support BIM education in Australia. The ABAF intends to explore the challenges of BIM education across Australia, create minimum standards for BIM-related curricula and standardise performance measurement for BIM education accreditation (Deakin University, 2018).

All previous efforts to this end have capitalised on the continued digitalisation of the built environment through a top-down approach by tackling the educational challenge holistically to uniquely identify the required standard for shaping BIM-related curricula. In contrast, to transform from traditional practice to a futuristic pedagogy, this research uses a bottom-up approach as an effective way to map the shortcomings of the traditional way of delivery and propose changes. This insights paper will establish process improvement priorities for Australian universities' BIM-related curricula by showcasing a specially designed unit. The paper responds to 'how BIM can be used as a new method of delivering units' instead of 'what the potentials of BIM are in a future graduates career trajectory' to put the process of transformation from traditional pedagogy in motion.

2 Future of BIM in Construction 4.0

BIM fundamentally changes business models from a scaled deliverable to a digital deliverable in Construction 4.0 (Succar and Poirier, 2020). Industry 4.0, rebranded as Construction 4.0, is characterised by profoundly systematic transformation and the way to move forward with BIM is by redefining business models and not just implementing technology (Dowd and Marsh, 2020, Das et al., 2019). There is consensus that BIM is an enabler of Construction 4.0 (Sawhney et al., 2020), but BIM talent development still is focused on technology-based learning outcomes more than a systemic transformation of the method of delivery (Ibrahim et al., 2020). Iordanova et al. (2020) developed a new graduate studies program in digital transformation in construction integrating BIM and Construction 4.0, a one-of-a-kind program to train students in digitalisation of the built environment through its whole lifecycle. However, even though there has been a significant addition to the curricula in terms of BIM and Construction 4.0, there is no fundamental change in the pedagogy.

Construction 4.0 has prompted the need to translate education and experience into internationally accepted skill profiles for the information age, requiring a fundamental shift in pedagogy in the current BIM-related curricula (Brown, 2020, Project Management Institute, 2019, Dowd and Marsh, 2020). As the industry responds to Construction 4.0, education and pedagogy should also significantly change to maintain their relevance (Ahmad et al., 2019). Velevska et al. (2020) raises a question regarding the current education in construction and built environment in the age of information and mentions the relevance of a fundamentally different form of delivery. Given this, the following section will review previous researches on BIM for education.

3 Previous Research in BIM for education

There is significant interest in academic literature on integrating BIM in education (Wang et al., 2020). Witt and Kähkönen (2019) conducted a systematic review of academic literature related to BIM-enabled education and identified 330 relevant articles. They conclude that BIM-enabled education has so far utilised 'BIM as a learning tool' and pointed out that 'BIM as a learning environment' appeared to represent a new transitional paradigm that can be usefully created and applied in education. Arashpour and Aranda-Mena (2017) argue that BIM has so far been utilised only as a visualisation and simulation tool without intending to offer solutions to real world management issues. Puolitaival and Forsythe (2016) also introduce BIM as a software tool and point out the major resource related challenges without mentioning how BIM could be utilised to fundamentally change student learning environment instead of just digitizing the learning outcome.

Pereiro-Barceló and Meléndez (2018) talks about how BIM could attract more students to built-environment courses by altering its image of being an old-fashioned sector but fails to elaborate on how BIM could effectively change the method of delivery to suit the future of work. Shelbourn et al. (2017) are of the opinion that many educators still consider BIM as just another CAD programme and hence introduce it as just an extended vocational training with no additional educational value threatening creativity. To move forward with BIM, the focus needs to be on collaborative working and not only on a technology tool, mirroring the industry; when BIM is adopted just as a software tool, the benefits are proven to be limited than when it is implemented as a process improvement priority (Abbasnejad et al., 2020). Despite this, many academic programs still do not consider integrated practice as a part of BIM-related curricula focussing on how to engage with and lead others, and how to collaborate with the professionals they are likely to work with later (Shelbourn et al., 2017). Consequently, graduates are exposed to working with multi-disciplinary team members only in a workplace as in most universities across the United States, Europe and Australia, students continue to be educated in silos, with very little integration or collaboration between the disciplines even with BIM on their curricula (Scott, 2016).

There is evidence of a collaboration stage in University of Sydney's illustration, manipulation, application and collaboration 'IMAC' BIM educational framework where students from different disciplines work together on joint projects; however, this framework fails to incorporate feedback which is the foremost objective of collaborative working (Badrinath et al., 2016). Feedback is a significant topic of discussion amongst practitioners within higher education for the enhancement of student learning and all effort is towards progressing the conventional one-way feedback system to a two-way interactive process which aims to create a dialogue and proactive participation from both the learner and teacher (Bevan, 2020, Biggs and Tang, 2011). PAS 1192-2 specifies that providing multi-directional feedback using BIM common data environments as a means of collaborative working would reap transformational benefits to the industry (BSI, 2013). However, most of the previous researches stress on availability of appropriate teaching and learning resources for BIM-related curricula and finding the balance between theory and practice as the main constraints for integrating BIM in education (Puolitaival and Forsythe, 2016, Badrinath et al., 2016, Casasayas et al., 2021). Still, none of them emphasises how BIM could reap benefits and transfer value to built environment pedagogy. To the best of the authors' knowledge, none of the previous researches have identified how BIM can be used as a new method of delivery.

4 Research Methodology

According to Yin (2017), a case study approach is best suited for this research as this insights paper attempts to answer 'how' and 'why' questions and focuses on a contemporary event in relevance to BIM pedagogy. The literature review has responded to 'why' this is required by building a rationale for the need of systemic changes in the method of delivering BIM related curricula as opposed to focusing on tool-based learning outcomes. To respond to 'how', a work-based project was put into use for a more practice-oriented contribution of knowing with, not on about, people, that brings together action and reflection in the pursuit of practical solutions to issues of pressing concern (Bradbury, 2015).

Staff members at one of the New South Wales universities collaborated with the Transport for New South Wales (TfNSW) in the delivery of a specially designed unit that explored a new pedagogy enabled by BIM common data environment, feedback loop, multi-disciplinary pathway stages and an Employer's Information Requirement (EIR) to ensure client's requirements are fulfilled. Fig. 1 illustrates the attributes of the specially designed unit. This unit is part of the bachelor's program in Building Design Management at the School of Design, Engineering and Built Environment. Each circle illustrates process improvement in the specially designed unit's pedagogy where the its size is representative of the extent of impact it has on the process. The design of the unit is based on attributes and the level of interaction with stakeholders as opposed to a work break-down structure of learning outcomes which illustrates a systemic shift from the existing pedagogy. The first attribute ATB1 is the EIR which according to TfNSW's Digital Engineering Framework based on PAS1192-2:2013 consists of the information to be delivered, and the standards and processes to be adopted. The second attribute ATB2 is a Common Data Environment (CDE) which according to TfNSW's Digital Engineering Framework based on PAS1192-2:2013 is a collective name given to the group of integrated IT systems that enables users to store, collaborate and exchange information and data. In this work-based project, Autodesk A360 was used. The third attribute ATB3 is the continuous feedback loop which is enabled by the CDE and has two distinct categories; between tutor and student and between students (peer to peer interaction). The fourth attribute ATB4 is the multi-disciplinary pathway stages where students go through two multi-disciplinary feedback workshops including external industry experts. The first pathway stage is to ensure client requirements are met, second one is to ensure functionality and finally the third pathway stage is to ensure a digital deliverable.

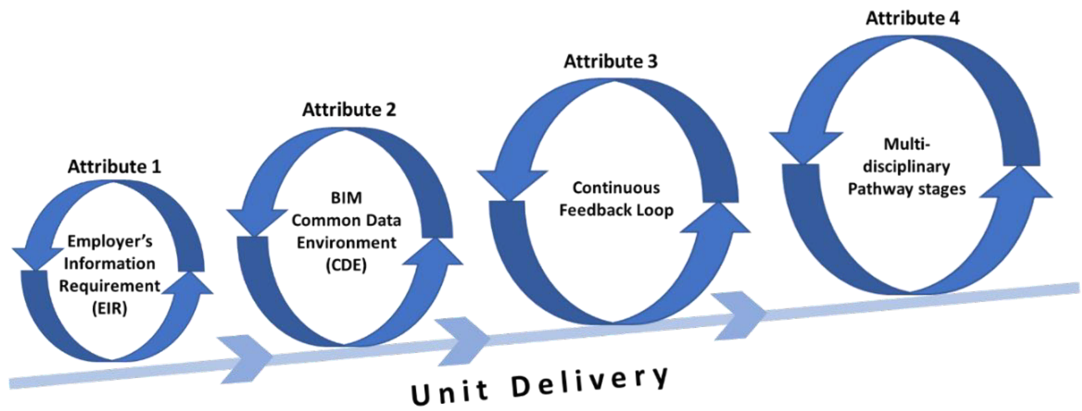

Figure 1. Attributes of the specially designed unit

To ensure a digital deliverable, the unit is interspersed by three software clinics. The students are given freedom to choose any BIM software including Autodesk Revit, Autodesk Infraworks and Archicad. The students are helped to choose their preferred software by understanding their concept according to the EIR in the first software clinic. They are then guided to prerecorded training material for their selected software from LinkedIn Learning as the university provides free access to such websites. The unit also provides two additional software clinics at the second and third pathway stages to cater to the student's requirements and to solve any software interoperability issues.

As this research discusses a work-based project, the attributes of the specially design unit as illustrated above were integrated with the unit delivery in a democratic and participative orientation towards knowledge creation. Figure 2 illustrates the process flow and timeline for conducting a fourteen week unit delivery incorporating the attributes. The unit was integrated with TfNSW's 'Sustainable Design Competition' offering students an opportunity to showcase sustainable design solutions in a real project context enabling students to address sustainable design integrated with place making and innovation.

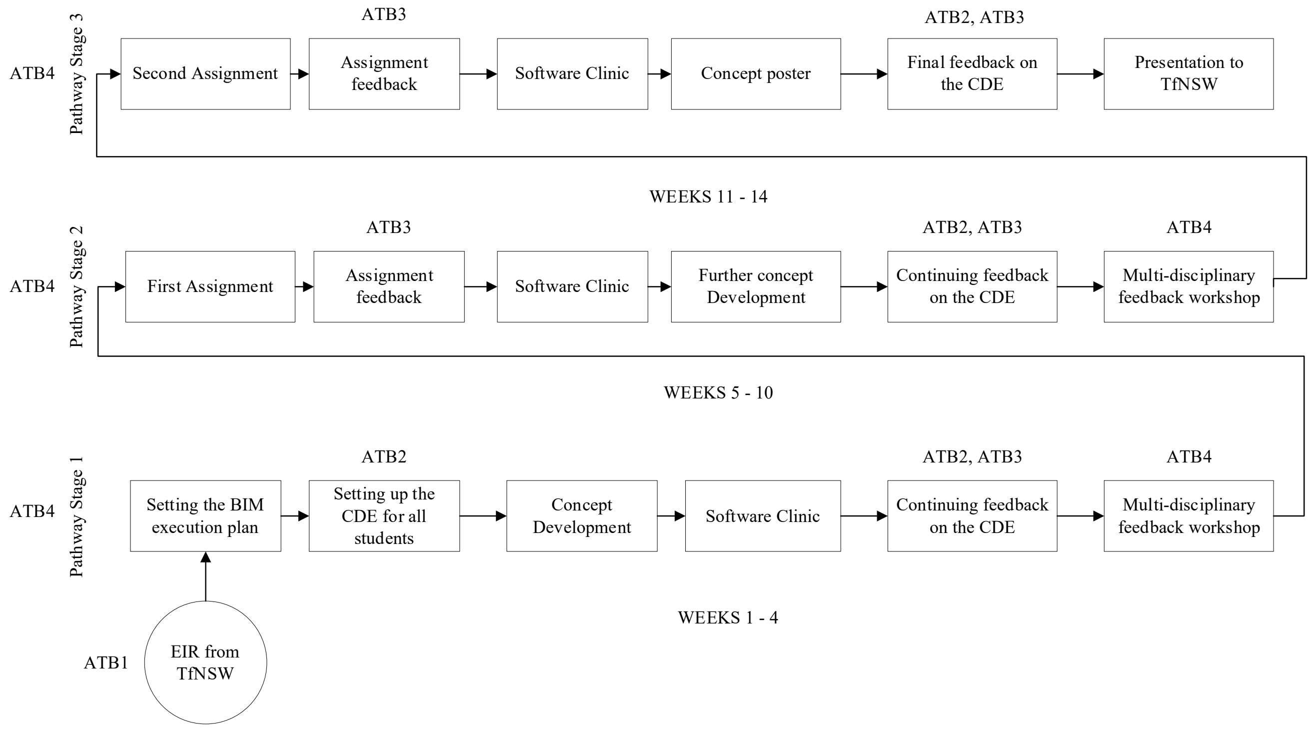

Figure 2. The process flow and timeline for conducting a fourteen week unit delivery

5 Findings and Discussion

To translate the learning from the specially designed unit, the authors propose BIMed 4.0, a transformational pedagogy for BIM related curricula for Australian Universities as a pilot case which will be discussed in detail in this section. The critical levers in developing BIMed 4.0 is an attempt to replicate industry BIM standards and protocols according to PAS 1192-2:2013 in the method of delivery and the philosophy of systemic transformation for Construction 4.0. Most internationally accepted BIM protocols prompt redefining roles and functions of key people as a means to pave the way for transformation to occur. According to the Pennsylvania State University's BIM Planning Guide, a BIM champion is a person who is technically skilled and motivated to guide an organisation to improve their processes by pushing adoption, managing resistance to change, and ensuring implementation of BIM enabled delivery (Messner et al., 2019). In the context of BIMed 4.0, a BIM champion is an academic equipped with managerial as well as technical BIM expertise besides having required domain knowledge specific to built environment. The BIM champion should be accompanied by a representative of the executive or leadership team to ensure desired vision by providing direction and removing obstacles (Construction Industry Council, 2013). In the context of BIMed 4.0, this role is played by the unit coordinator. It is critical for the unit coordinator to have innovative mindset to move out of their comfort zone in giving freedom and autonomy for the BIM champion to perform their function. To ensure the agility and change management of the transformation, a third role is necessary to be defined as the middle management's representative (Construction Industry Council, 2013) and in the context of BIMed 4.0, this role's main responsibility is to ensure continuous feedback on the delivery o and improve change readiness without waiting till the end of the semester for feedback. The third is

extremely essential as universities transform their BIM related pedagogy into BIMed 4.0 and look at standardising processes, however, once BIMed 4.0 matures and becomes business as usual, this role can be dissolved and can be taken up by the unit coordinator.
Another distinctive feature of BIMed 4.0 is the use of software clinics to guide the students in selecting the suitable set of softwares as opposed to the traditional pedagogy where the learning outcomes are set based on the software tools. In doing so, the unit considers the softwares as a means to achieve the deliverable just as the case in the industry. The freedom to choose any software that is deemed suitable gives autonomy and decision-making to the student which is an essential graduate employability skill. The students, in the context of BIMed 4.0, takes up the role of the BIM Implementer, however, while organisations can recruit based on an entry criteria, the unit cannot be selective about students which results in differential capabilities amongst them in their software learning uptake. The challenge is greater for earlier years of study than in the final years. Even if certain softwares might have been taught in earlier years of study, this still is a potential challenge as the range of softwares available are many. Universities are required to conduct a more outcome-oriented selection of softwares to teach in the earlier years of study based on industry surveys such as National Building Specifications (NBS) survey[1], to maintain continuity as students take up units such as the one being discussed, in more mature years of their study. Prompting students to the online courses on LinkedIn learning is another reflection on how this unit simulates a real workplace within the classroom and when a student completes a course, the completion certificate automatically links to their LinkedIn profiles which is a game-changer in making students job ready. Assessing effort is another critical challenge when software clinics are used as certain students, finding this pedagogy very motivating, put significant effort in learning the softwares much in depth to produce the required deliverables. A potential solution is a more integrated assessment, based not only on the formal submissions, but also on the communication on the CDE and the feedback obtained during the multi-disciplinary workshops.With the previous points in mind, the CDE proves to be an effective way of incorporate continuous improvement feedback into the unit delivery transforming the conventional on-way feedback to a two-way feedback mechanism creating a dialogue between the BIM champion and the student. This is an important step towards formalising the process of assessing effort. As mentioned previously Autodesk A360 has been used as the CDE in the delivery of this unit. It offers permission controlled settings where the BIM champion takes up the role of the 'project admin', the students are 'editers' and the unit coordinator along with the middle-management's representive are 'viewers'. Figure 3 illustrates the project access levels for CDE accordingly to Autodesk A360.

	Viewer	Editor	Project Admin
View Files(online), folders, comments(view and post) and people	✓	✓	✓
Edit, Upload, Download Copy, move, rename and delete files/folder		✓	✓
Manage Sharing Enable and set public sharing, invite others to project		✓	✓
Project Admin Project settings, approve people in project, set access levels			✓

Figure 3. The project access levels for CDE accordingly to Autodesk A360

The challenge in

[1] https://www.thenbs.com/

assessment through the CDE, is the fact that there exists no interoperability between CDE and the formalised university platforms used for assessment records. But there is no doubt that CDE enables interoperatibility for model collaboration as models can be shared and viewed simply by sharing a link without any hefty file transfer or software requirement for the viewer to add their feedback. Changes including additions, removal and modifications (See Figure 4) in student's models can be tracked fairly easily on the CDE which adds to the fact that CDE can help to assess effort. This specifically becomes effective in case of group work where each student's effort is clearly visible. However, for the academic who is acting as the BIM champion in the delivery, continuous feedback on the CDE is time-consuming which needs to be considered by the unit coordinator while evaluating their allocated workload. Assessing through the CDE is not standardised; while it helps in assessing effort, no formalised assessment criteria, could lead to potential bias in assessing. That is why BIMed 4.0 incorporates multi-disciplinary feedback workshops where a set of industry experts help to even out the bias and ensure the functionality of the solution replicating the industry. While the CDE drives coordination, the multi-disciplinary workshops drive the collaboration.

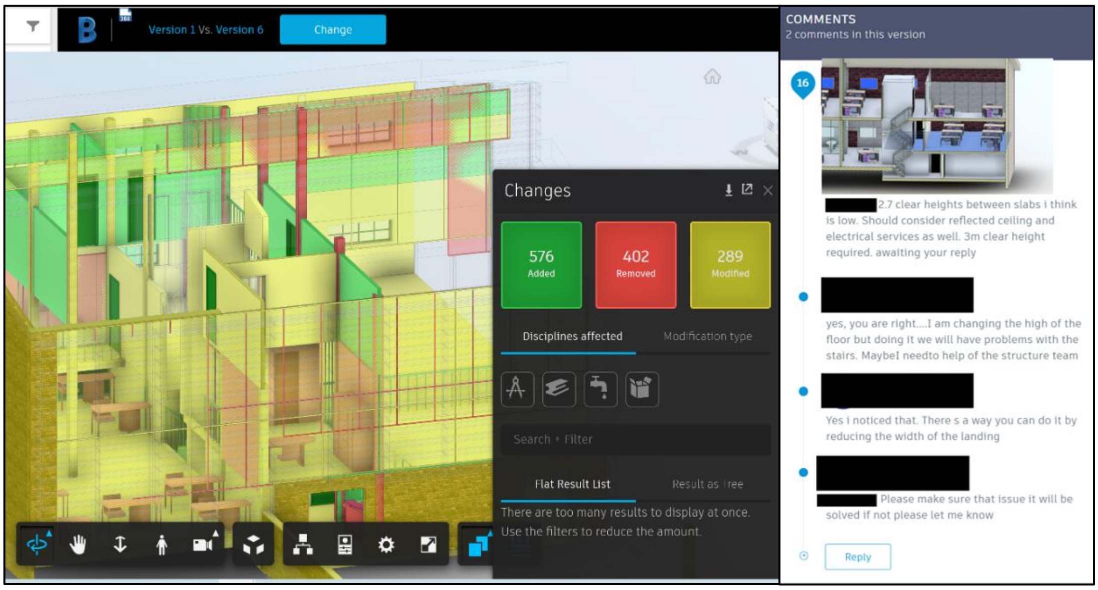

Figure 4. (a) Tracking changes on Autodesk A360 CDE (b) Continuous improvement feedback on on Autodesk A360 CDE

As in the case of BIM implementation in the industry, for transitioning into BIMed 4.0, the role of the BIM Champion is the most critical. During the pilot, the BIM Champion played a very hybrid role of ensuring unit delivery, setting up of the CDE, continuous improvement feedback on the CDE, conducting software clinics, liaising with industry experts and conducting multi-disciplinary workshops (MDW), marking and assessing students including assessing effort on the CDE. The authors recommend a role of a BIM Technician to set up the CDE and cater to student needs in the software clinics under the supervision of the BIM Champion. The BIM technician is not an exclusive requirement for a particular unit and is available for all units with software requirement. BIMed 4.0 simulates the industry within the classroom and helps students understand client requirements better, ensure functionality of their models and designs, get multi-disciplinary perspective along with learning BIM Software tools. BIMed 4.0 prepares graduates for BIM authoring roles and future BIM Lead roles as opposed to CAD or BIM technician roles. Figure 5 illustrates the change management plan for transitioning into BIMed 4.0.

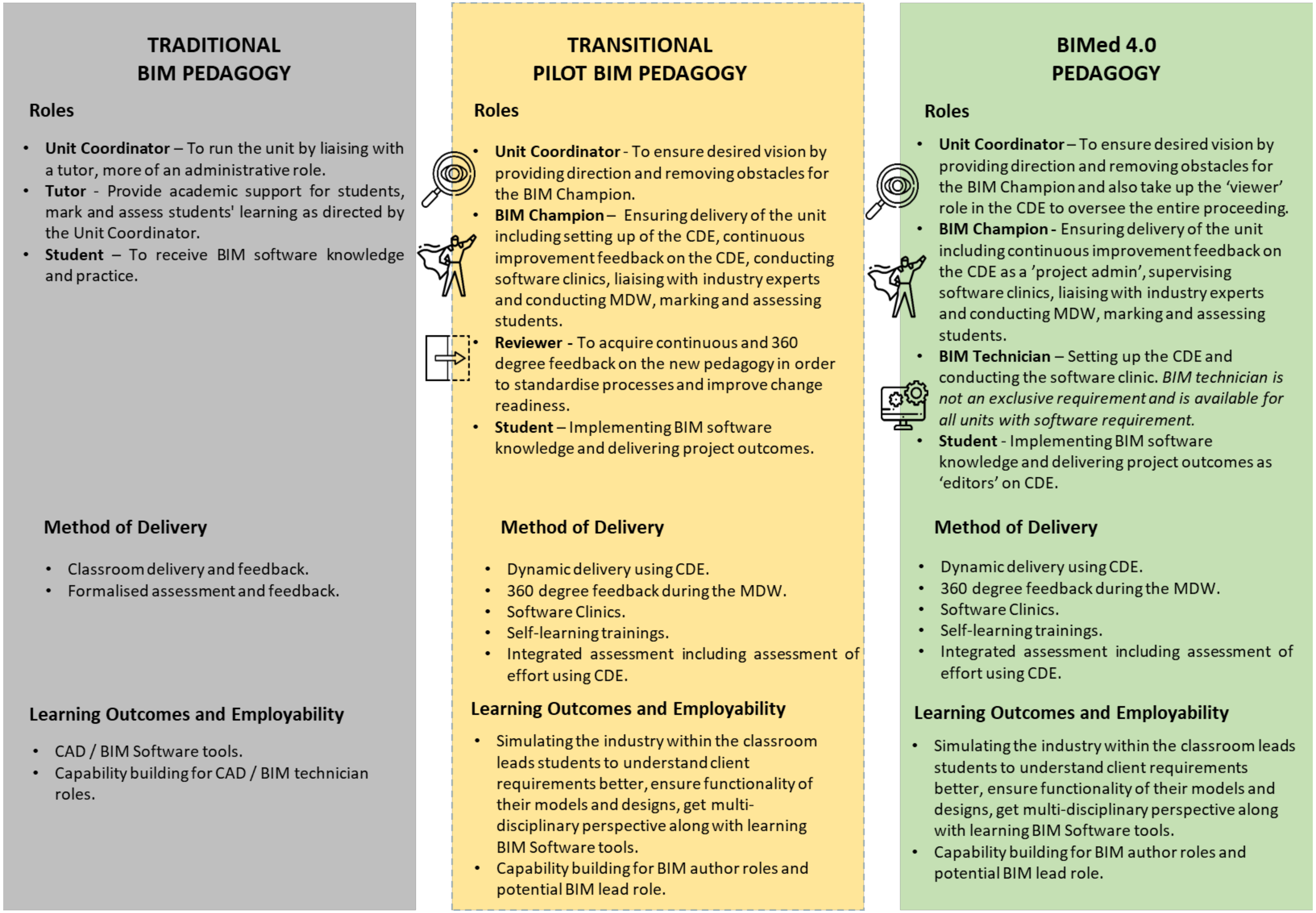

Figure 5. Change management plan for transitioning into BIMed 4.0

CDE – Common Data Environment
MDW – Multi-disciplinary Workshop

6 Conclusion

The paper presents the delivery of a specially designed unit in collaboration with Transport for New South Wales (TfNSW) that explored a new pedagogy enabled by BIM common data environment (CDE), feedback loop, multi-disciplinary pathway stages and an Employer's Information Requirement (EIR). To translate the learning from the specially designed unit, the authors propose BIMed 4.0, a transformational pedagogy for BIM related curricula for Australian Universities as a pilot case. To the best of the authors' knowledge, this is the first paper illustrating how BIM can be used to enable a new method of delivery. The critical levers in developing BIMed 4.0 is an attempt to replicate industry BIM standards and protocols according to PAS 1192-2:2013 in the method of delivery and the philosophy of systemic transformation for Construction 4.0. As in the case of BIM implementation in the industry, for transitioning into BIMed 4.0, the authors define the role of a BIM Champion as the most critical. The BIM Champion will ensure the delivery of the unit including continuous improvement feedback on the CDE as a 'project admin', supervise software clinics, liaise with industry experts and conduct MDW, mark and assess students. It is critical for the unit coordinator to have innovative mindset to move out of their comfort zone in giving freedom and autonomy for the BIM champion to perform their function. A distinctive feature of BIMed 4.0 is the use of software clinics to guide the students in selecting the suitable set of softwares as opposed to the traditional pedagogy where the learning outcomes are set based on the software tools. In doing so, the unit considers the softwares as a means to achieve the deliverable just as the case in the industry. The authors recommend a role of a BIM Technician to set up the CDE and cater to student needs in the software clinics under the supervision of the BIM Champion. The BIM technician is not an exclusive requirement for a particular unit and is available for all units with software requirement. BIMed 4.0 transforms the role of the students from just receivers to 'implementers' with dynamic engagement on the CDE that helps towards building their thought leadership redefining the classroom as a start-up and students as colleagues.

7 Acknowledgement

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Teaching maths not using new-fangled methods – who would have thunk it could work?

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Abstract
Students entering the university sector are often expected to have a base level of mathematics appropriate for their areas of study. It is being found that there is a growing diversification of mathematical skills with a growing diverse range of students entering universities. However, there are very few studies that investigate how to efficiently and successfully improve the mathematical abilities of the Construction Management (CM) students, particularly when facing the challenge of growing diversification. The Building Construction Management degree in the case of the School of Design and Built Environment, Faculty of Arts and Design, University of Canberra is studied. A numerical-based questionnaire was employed to collect analysis data. Through an initial investigation, a trial was undertaken whereby we utilised traditional-type hands-on approaches to positively and evidentially develop and improve the core mathematical skills for a CM cohort. The content-driven teaching method and flipped classroom instruction model are employed to implement the hands-on activities. This work showed that we should also use the best fit for purpose approaches and not necessarily rely on the trending approach to learning.

Keywords
Construction management; Content-driven teaching; Hands-on; Mathematics

1 Introduction

According to the report of *TIMSS 2015: A first look at Australia's results*, the Trends in International Mathematics and Science Study (TIMSS) of Australian students' mathematics and science achievement levels continued to decline from 1995 to 2015, and Australia performed below 12 other nations in the OECD countries (Australian Council for Educational Research (ACER) 2016). The declination would be a growing challenge for high education where students entering universities shall be with appropriate mathematical skills for their degree study. The Australian government has responded to this situation. For example, in 2020, the government has developed a policy for supporting the university students who study the cheaper degrees such as maths, which will favour for students to learn maths in Australia. However, with a growing diverse range of students entering universities, how to positively and effectively teach diverse students has been becoming a difficult task for university lectures, particularly in some degrees with the requirements of mathematical skills.

Building Construction Management tertiary education, by necessity, is required to ensure students develop a suitable knowledge and skills base that covers areas including legal, engineering, communication and accounting. Therefore students are taught a range of subjects and explore the best industry practices through a range of classes and activities throughout their study within the academic and professional environments. One skill set that underpins many of their activities is based around basic mathematics, which anecdotally has appeared to be an issue with many students in the past as a result of their fear of the topic. This paper reports on a successful practical approach that was used to help educate undergraduate students in this numerical area without resorting to modern technology-based methods.

2 Literature Review

The development of mathematic skills is an objective of many courses and curricula majoring in science, technology, engineering, and mathematics (STEM) (Galligan 2013). For example, mathematical analysis is considered a crucial lesson for engineering and information technology students (Peng *et al.* 2010). Ballard and Johnson (2004) pointed out mathematic skills are crucial for student success in introductory microeconomics and college economics courses. More importantly, mathematical skills have seriously influenced gender gaps in careers in the STEM areas around the world (Lyons *et al.* 2020). Besides, construction management (CM) has sometimes been considered as construction engineering, which is a STEM category, particularly when CM is in engineering or architecture schools. CM and construction engineering generally have similar course requirements and graduate careers (Glick *et al.* 2016). Therefore, mathematic skills could be considered as significant skills for the students studying in the CM area.

As quantitative thought and communication are essential in daily work in the construction industry, construction-related mathematics are expectedly required in most construction career pathways (Lee *et al.* 2016). This was previously stated in 2008, when the National Association of State Directors of Career Technical Education Consortium (NASDCTEc) pointed out that the mathematical knowledge and skills required to work in the construction industry. (Lee *et al.* 2016). Therefore, it up to the educators to ensure students graduate with the required mathematical skills skills and knowledge.

Graduated students in the construction context are expected to have mastered numeracy capabilities in areas including measuring, calculating, and predicting the issues related to construction material procurement, cost estimation and planning, quantity surveying, finance and economics, project planning and scheduling, structural analysis, and so on. If the students are poorly skilled in mathematical abilities, they would fail in the course units and career development. Therefore, construction-related tertiary graduates are expected to master fundamental mathematical skills for their career development.

In higher education systems, mathematics learning has been considered a difficult programme for many students, and mathematic teaching would have to overcome psychological obstacles for teachers and educators (Albeshree *et al.* 2020). For instance, it is surprising that a large number of CM students do not efficiently solve simple math questions which have been taught in elementary schools (Lee *et al.* 2016). Moreover, Davis (2011) had organised a diagnostic math quiz at Boise State University for CM students and found that a high percentage of the students performed poorly in an introductory-level course. Lee *et al.* (2016) even believed that over 70% of first-year university students studying CM must take remedial math courses to overcome found secondary school education deficiencies. Accordingly, mathematic learning shall be acknowledged as a difficult topic for CM students and it is necessary to study how to help them enhance their mathematical skills.

How to effectively improve the mathematic skills of students has become a challenge for teaching staff in universities. Albeshree *et al.* (2020) employed a systematic literature review to investigate mathematics teaching pedagogies. They categorized prominent teaching methods into four groups: assessment-based methods, technology-based methods, interdisciplinary methods, and instructional and content-driven methods. The content-driven instruction method, which is mainly used for a language teaching approach does not focus on the language itself, but rather on the content that is being taught through the language, where the language is the medium (Best of Bilash 2021). Therefore, the content-driven instruction method could not only benefit to achieve teaching objectives but also facilitate the learning of content. However, developing high-quality content-driven teaching material for mathematics is not efficiently studied at present (Albeshree *et al.* 2020). Besides, mathematic units are not part of the course framework for some CM degrees in some universities, such as the Bachelor of Building and Construction Management in the University of Canberra. For this situation, few teaching methods could be identified on how to improve the mathematical skills of CM students. Consequently, this study will employ the content-driven instruction method to develop high-quality content-driven teaching to enhance the mathematical skills for CM students without employing formal mathematics lectures or "newfangled" technologies.

3 Research Methodology

The combination methods of case study and questionnaire survey, which are encourageable and feasible methodology in research designs (Gable 1994), were employed in this study. The combination methodology has been utilised to study coastal zone management education using the ministerial brief (Lemckert *et al.* 2006). In this study, the case used focused on the degree of Bachelor of Building and Construction Management, offered by the School of Design and the Built Environment, Faculty of Arts and Design, University of Canberra. In some past years, it was observed that students who commenced the degree had varied mathematical abilities and they often struggled when they needed to complete units with a significant mathematical component. To help alleviate this observed deficiency in mathematical ability, the unit of Fundamentals for Building Construction Management (FBCM) was added to the program as an avenue to assist in the development of their mathematical skills. The FBCM unit is mainly for Year 1 students, and it introduces and develops the student's foundation academic and technical skills relevant to the building construction industry. One of the prescribed unit learning outcomes is to apply numerical processes to solve fundamental building construction management problems. Accordingly, the unit is not only aimed at providing the fundamental knowledge of building construction management, but also for improving the academic numeracy and mathematical skills of CM students.

To investigate the teaching-learning process of improving mathematical skills in the FBCM case, a questionnaire survey method was employed to collect analysis data. The survey project named "evaluation building construction mathematics training approaches" was approved by the University of Canberra's Research Ethics and Integrity Unit. The project aimed to examine if the mathematical ability of students entering the Bachelor of Building Construction Management can be enhanced through non-mathematical focused (to the students at least) teaching workshop activities. In the project, participants who agreed to participate in the research activity (which was all the students) were asked to complete an anonymous quiz asking them to answer a series of mathematical problem-related questions. The quiz consisted of 15 questions which are mainly related to calculating perimeter, area, volume, and data analysis. For reference, the quiz questions are attached as an appendix. At the end of FBCM, students were retested with similar questions – thus allowing for a direct before and after comparison to be made.

4 Findings and Discussion

4.1 Comparing the performance of students' mathematical skills before and after learning the FBCM unit

The quizzes were distributed to 40 students during their tutorial workshops. 27 students' answers were submitted in the first quiz at the beginning of the semester, and 21 students submitted their answers in the second quiz at the end of the semester. The final marking results are displayed in Table 1. In the first quiz, the students with High Distinction, Distinction, Credit, Pass and Fail are 6, 3, 5, 4, and 9 students, respectively. Most of the students marking with less than 50% failed in the first quiz, which indicates the fresh university students did not perform the expected mathematical skills of entering tertiary education. In the second quiz, the students with High Distinction, Distinction, Credit, Pass and Fail are 14, 1, 3, 1, and 2 students, respectively. Therefore, most of the students achieved more than 85% in the second quiz, demonstrating that students have significantly improved their mathematical skills during the FBCM unit. More importantly, students in the second quiz performed better results than them in the first quiz by comparing the indicators of maximum values, minimum values, average values, mode values, and median values among marking results. Particularly, the standard deviation of the second quiz is less than for the first quiz, which demonstrates the differences in mathematical skills among the students have been reduced after learning the FBCM unit.

Table 1. The statistic information of the marking results in the first and second survey quizzes

	Volunteer students	**High Distinction students (≥85%)**	**Distinction students (85%> ≥75%)**	**Credit students (75%> ≥65%)**	**Pass students (65%> ≥50%)**	**Fail students (50%>)**
Student numbers – first	27	6	3	5	4	9
Student numbers – second	21	14	1	3	1	2
	Maximum value	**Minimum value**	**Average value**	**Standard deviation**	**Mode value**	**Median value**
Quiz results – first	13	2	8.85	3.72	13	10
Quiz results - second	15	5	12.43	2.73	14	13

Figure 1 displays the average correct rates of each question in the first and second survey quizzes. In the first quiz, students demonstrated better outcomes in calculating perimeter (e.g. Q1 and Q2) and area (e.g. Q5, Q6 and Q7) than computing volume and data analysis. In the second quiz, except for the same situation, students also behaved very well in data analysis such as computing median and mode values. In both quizzes, students are not well in the calculation of volume, which may be because it could be more complex than other calculations. Particularly, students often make mistakes in labelling and the conversion of measurement units. For example, some students are difficult in the transformation between m and cm (e.g. Q3), m^2 and cm^2 (e.g. Q8), and m^3 and cm^3 (e.g. Q11). Moreover, by comparing the mean values between the first and second quizzes, it can be noted that the correct rates from 59% to 83% are significantly improved between pre-learning and after-learning the FBCM unit. For example, Q8 and Q12 have even been improved by the rates of 446% and 414%, respectively. Only Q3 is slightly decreased, which is because some students carelessly utilised a wrong measurement unit in the second survey.

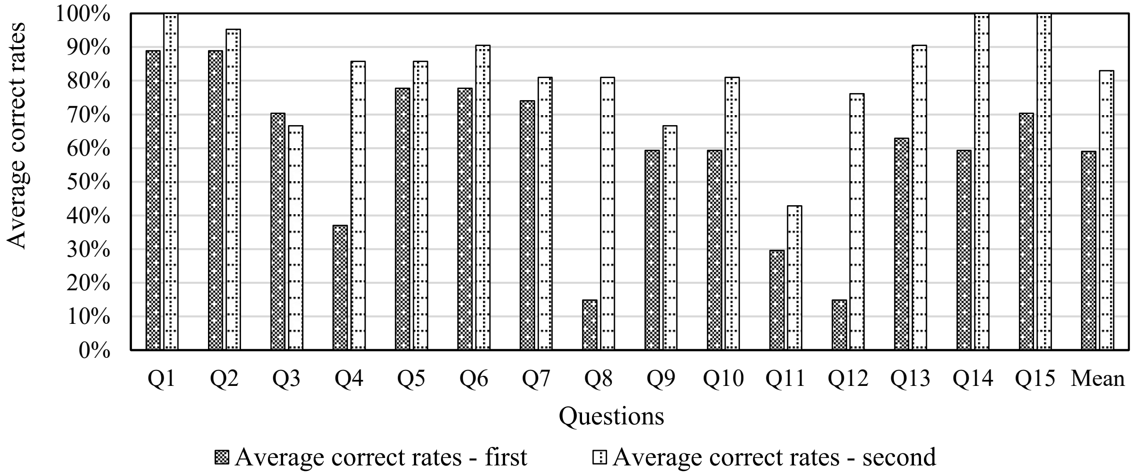

Figure 1. Average correct rates of each question between the first and second quizzes

According to the students' performance of the first quiz, the CM students in the case study are not well skilled in mathematical, which is similar to the US CM students studied in Davis (2011) and Lee et al. (2016). After completing the FBCM unit, students have improved their mathematical skills particularly in dealing with questions such as volume calculation and data analysis. Moreover, the improvements gained in FBMC were anecdotally noticed by staff teaching follow on units in building construction studies, quantity surveying, and construction economics. In summary, students have significantly developed their mathematical skills after completing the FBCM unit.

4.2 The content-driven teaching method for improving the mathematical skills of CM students

According to the above comparison, the content-driven teaching method used in FBCM positively and evidentially promoted students' progress in core mathematical skill development for a BCM cohort.

So, what was done? The teaching contents and workshop activities in FBCM were mainly designed for providing fundamental knowledge of learning building construction management. During the process, students undertook activities using traditional-type hands-on approaches, which required them to use mathematic skills to make calculations, compare results, analyse data and report on the findings. We did not actually teach them the mathematical steps behind this using lectures of 'newfangled' teaching approaches but instead let the students look up the methods themselves, ask questions and practice. As examples, some hands-on activities within the workshop environment are demonstrated in the following.

1) The hands-on activities of assessing sound, light, temperature and humidity levels

In the workshops, students first form a group and then learn how to use sound, light, temperature and humidity measurement devices. Next, students use the devices to record the sound, light, temperature and humidity values at 5-7 locations within a building. At each location, students would record 6-8 individual results. Based on the measurement results, students were asked to compute the mean, median and mode values for assessing sound, light, temperature and humidity levels at each location. Finally, the mean, median and mode values are further calculated to determine the human comfort levels for the whole building. Moreover, through these activities, students became familiar with the calculations related to data analysis, reporting statistical information and assessing the environment of working health and safety.

We did not tell them we were teaching them mathematics to avoid stress, but instead, we used positive supportive approaches to investigate and learn.

2) The hands-on activity of measuring material density

In the workshop, students first used meter sticks and rulers to measure the length, width, height and/or other dimensions of various objects made of different common construction materials with various shapes, such as cone, cube, cylinder, pyramid, rectangular prism, sphere, and triangular prism. Students then calculate the volumes of the objects. Second, the mass of the object was measured by using electronic scales. Third, the densities of different objects were estimated by measuring the ratio of the mass of the material to its volume. Finally, according to the density results, students could identify the specific material. Through the activity, students learned how to calculate the area, volume and density of different object shapes, and recognise how to deal with the complicated calculation processes.

The conception of measurement error is understood by students through comparing the actual value and the calculated value of material density for these common construction materials. Error is not “wrong” and is about accuracy, which describes how closely a measured value approximates its true value. Students examined ways to reduce measurement errors to enhance their estimations. Therefore, they learned how to investigate and examine the measurement process, analyse how to reduce measurement errors in practice, and report the results under considering measurement errors.

3) The hands-on activity of understanding design drawings

Students who master the required mathematical skills may still find it difficult in the construction context (Lee et al. 2016). This could result from that the students only superficially understanding mathematics without a true ability to apply math concepts (Worthington and Jones, 2007). Accordingly, this designed activity aimed to help solve this problem. Firstly, students were required to identify the building information such as the length, width and height of all independent rooms and the whole building for a particular case. Secondly, students needed to calculate the perimeters, areas and volumes of all independent rooms and the whole building. Finally, students needed to estimate the construction cost and duration of the whole building when the assumed information of different building parts was provided. Therefore, this activity facilitates students with the understanding of how to integrate mathematical skills into the construction context, which allowed the students to not be scared of mathematical calculation and data analysis in future practices as it was not a ‘mathematics’ lesson, but instead was focussed on CM, with the benefit of them actually doing the ‘maths’.

These hands-on activities in the FBCM unit could be also organised online in the workshop environment, as remote teaching is becoming a more popular and required teaching method in the Australian tertiary education system because of curriculum requirements and pandemic challenges. For example, students can download free APPs on their mobile phones to record the sound, light, temperature and humidity values around their buildings and then assess the human-comfort environment. Students can find any material objects at home and then compute their density values using their measurement tools. The building design drawings can send to the online students to let them calculate the perimeters, areas and volumes of all independent rooms and the whole building. Finally, the workshop instructors will share the results and discuss the calculation process with them.

The instruction model of the flipped classroom is mainly employed to organise these hands-on activities, such as through the methods of group work, case studies, simulation-based assessment, calculations, interactive discussion and assessments, group presentation, questions asked and real-time feedback by the peers and instructors. As an innovative pedagogical approach, the flipped classroom is to improve student understanding through differentiated instruction and hands-on practices (Cevikbas and Kaiser 2020). During the workshops, the flipped classroom model focuses on student-centred instruction, where students understand and put into hands-on activities what they learned from the lectures. The model process does not directly teach students mathematics through presentations, but instead implement simple mathematical orientated activities in the workshops. During the workshop time, students form groups, understand activity requirements, use devices and tools, record and measure values, compute and evaluate results, and report and present findings by themselves. The instructors question and guide students' procedures and methods, and provide real-time feedback and assessment based on their work performance and findings during the process and at the end of the workshops. Although the flipped classroom leads to some difficulties for teaching, the well-designed contents excellently provide an innovative pedagogical approach to efficiently transform the teaching and improve students thinking and understanding (Cevikbas and Kaiser 2020). Consequently, the content-driven teaching method and flipped classroom instruction model used in FBCM increase student participation and collaboration, improve their mathematical and communication skills, and enhance their self-learning and practical abilities in a sustainable way.

5 Conclusion

Mathematics is often a difficult subject, but mathematical skills are critical for CM students. Little research could be identified to study how to teach mathematics and improve mathematical skills in the construction context. This study investigated and compared the performance of mathematical skills of CM students between pre-learning and after-learning the FBCM unit in the case of School of Design and the Built Environment, Faculty of Arts and Design, University of Canberra. A numerical based questionnaire, repeated twice, was employed to collect analysis data on student performance. The findings indicated that the mathematical skills of the CM students were not well performed at the expected level that university students should have before entering tertiary education. After completing the FBCM unit, students had positively and efficiently improved their mathematical skills. The evident improvements could be embodied in changing measurement units, computing complex questions such as volume calculation and data statistical analysis, and reducing the differences in mathematical skills among students.

The content-driven teaching method and flipped classroom instruction model are implemented in FBCM. The method does not directly teach students mathematics through lectures, but instead execute simple mathematical orientated activities during the unit's workshops. In the flipped classroom model, students completed the activities by themselves by applying what they learned from the lectures or through self-study activities. The hands-on activities could be organised face-to-face and remotely in the workshops, such as assessing sound, light, temperature and humidity levels, measuring material density and understanding design drawings. The teaching contents and method provide pathways to promote student participation and collaboration, enhance their self-learning and practical abilities, and improve their professional and mathematical skills simultaneously. The teaching approach could be applied in the other CM programmes, and the teaching method could be applied to other programmes in other universities. Besides, the small sample size is the main limitation of the study. Future studies could collect more data and investigate the influencing factors and other teaching methods to improve the mathematical skills of CM students. For example, using two different cohorts (with and without intervention) could provide more credible results on the effectiveness of the intervention. The most effective method for improving the skills could be further identified. Future research would also be interesting to see how the third or final year students perform using the same test after studying different BCM units.

Who would have thunk that using traditional hands-on teaching approaches to enhance mathematics learning would have worked?

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8 Appendix

Fundamentals of Building Construction Management Quiz

This quiz is for the assessment of your cohorts understanding of mathematics

Question	Answer
1. What is the perimeter of a square with sides of 10 cm?	
2. What is the perimeter of a rectangle with sides of 10 cm and 20 cm?	
3. What is the perimeter of a rectangle with sides of 50 cm and 1 m?	
4. What is the perimeter of a circle with a radius of 10 m?	
5. What is the area of a circle with a radius of 10 m?	
6. What is the area of a square with sides of 5 m?	
7. What is the area of a rectangle with sides of 10 cm and 20 cm?	
8. What is the area of a rectangle with sides of 50cm and 1 m?	
9. What is the volume of a cube with sides of 10 cm?	
10. What is the volume of a rectangular prism (e.g. a building block) with sides of 10 cm, 20 cm and 30 cm?	
11. What is the volume of a rectangular prism with sides of 5 cm, 1 m and 10 mm?	
12. What is combined length of two pieces of timber with lengths of 5.0 m +/- 0.1 m and 3.0 m +/- 0.1 m	
13. What is the mean length of timber beams with individual lengths of 1.2 m, 1.3 m, 1.5 m, 1.3 m and 0.2 m	
14. What is the median length of timber beams with individual lengths of 1.2 m, 1.3 m, 1.5 m, 1.3 m and 0.2 m	
15. What is the mode length of timber beams with individual lengths of 1.2 m, 1.3 m, 1.5 m, 1.3 m and 0.2 m	

Causes of Accidents Confronted by Foreign Workers in the Malaysian Construction Industry

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Abstract
Recent statistics show that the number of Malaysian foreign workers who were killed from construction accidents was more than 2 times the number of local workers. This initiated a need to investigate in-depth of the accidents confronted by foreign workers to minimise the impact to the Malaysian construction industry. Thus, this paper presents major causes of accidents confronted by foreign workers in the Malaysian construction industry during 2013-2017. A comprehensive literature synthesis was adopted initially to identify the main accidents and related causes with respect to foreign workers and then an online questionnaire survey was used to rank the same to determine the major causes in Malaysian context. The findings revealed falls were low risk compared to being struck by an object, caught between objects, and slips that were all rated as medium risk. Unsafe acts (worker's attitude), lack of health and safety training and less awareness of hazardous activity as the major causes of accidents faced by foreign workers in Malaysia. Findings have the potential to serve as a reference to the relevant authorities and policymakers in taking necessary steps to improve the Health and Safety policy and practices among foreign workers.

Keywords
Accidents, Causes, Foreign Workers, Construction Industry, Malaysia

1 Introduction

Construction is an important industry which contributes significantly to the Malaysian economy. In 2016, the construction industry generated 4.5% of Malaysia's gross domestic product (GDP) and it is estimated that the construction sector is contributing 5.5% of GDP, in 2020 (Malaysia Productivity Corporation, 2017). Thus, the construction industry continues to play a significant role in transforming the Malaysian economy through its multiplier impact on different industries, thus stimulate domestic economic development and delivering comprehensive high-quality infrastructure in Malaysia (Malaysia Productivity Corporation, 2017).

The construction industry also helps countries to generate job opportunities, fight against poverty and accelerate economic and social development. Moreover, the construction industry is a labour-intensive sector as it depends intensely on the abilities of its workforce to carry out the work on sites (Agapiou et al., 1995; Hamid et al., 2011). Similarly, Adi and Niam (2012) pointed out that labour is one of the significant components in the sustainability and execution of construction projects, and the accessibility to skilled labourers is a critical aspect in constructing a quality product. However, the construction industry has faced severe labour shortages in both industrialized and developing countries, as it confronts an ageing workforce with less young people joining the construction sector (Gaylor, 1997; Yates, 1993).

To reduce labour shortages, some countries have hired foreign workers from nearby underdeveloped countries where salaries are comparatively low and labour supply is high (Goodrum, 2004; Kim et al., 2005). Additionally, Achim et al. (2017) agreed that the specific reasons for hiring these foreign workers are labour shortages and the intention of reducing the labour cost. This strategy, which has been adopted in many countries including Malaysia, is seen as a short-term and effective approach for overcoming the construction labour shortage. Furthermore, Othman and Rahim (2014) indicated that the local labour force in Malaysia is experiencing a shortage of workers, with companies having to rely heavily on foreign workers for their developing industry plans. Consequently, the number of foreign workers in Malaysia grew from approximately 0.5 million to 2.1 million between 1984 and 2009 (Abdul-Rahman et al., 2012).

However, Bank Negara Malaysia (BNM)'s Annual Report (2017) reported that the employment created was taken up by foreigners at the rate of 64.4% in 2015, with this showing an upward trend to 81.5% in 2016. Even though the percentage of the foreign worker workforce dropped from 18.8% to 12% from 2007 to 2017, foreign workers still occupied more than one-fifth of the jobs in construction, manufacturing and agriculture (Lim, 2018). Among Asian countries, the Malaysian construction sector has become the sector most significantly dependent on foreign workers, especially those from Indonesia, which has been a leading source of labour, followed by Nepal and Bangladesh (Kaur, 2017).

An increasing proportion of foreign workers recruited for the jobs created were low-skilled, from 8% in 2002–2010, then doubling to 16% during 2011–2017. At the same time, the number of high-skilled jobs dropped from 45% to 37%. In the meantime, accessibility to inexpensive foreign workers allowed employers to maintain low wages, with the result that Malaysia became trapped in a low-skilled low-wage conundrum (Lim, 2018).

Furthermore, Pungvongsanuraks et al. (2010) mentioned that diversity of construction products and materials, services, design and operation prevailing with different stakeholders contribute to the construction industry being among the most dangerous industries with low-skilled labourers a major cause of the high accident rate.

In the Malaysian context, as of June 2018, 1,809 accidents were recorded for all sectors. Of these accidents, 95 were in the construction sector, with 52 deaths recorded. The Malaysian construction industry therefore had the highest number of fatalities of all industries during this period (DOSH, 2018). Meanwhile in 2015, 140 Malaysian construction workers suffered fatal injuries, consisting of 47 locals and 93 foreigners, with these figures showing that foreign workers were killed at a rate double that of local workers (DOSH, 2016a). This evidence showed that foreign workers in construction in Malaysia encountered accidents at higher rates than local workers during the last few decades. Thus, this study identifies the major causes of accidents confronted by foreign workers in the Malaysian construction industry during 2013-2017. Eventually this will serve as a reference to the relevant authorities and policymakers in taking necessary steps to improve the Health and Safety policy and practices among foreign workers.

2 Literature Review

2.1 Foreign Workers in Malaysian Construction Industry

Both developed and developing nations have realised the value of the construction industry in their nation's socio-economic and sustainable development. Xu et al. (2019) indicated that the construction industry has made tremendous direct and indirect contributions to the economy through its multiplier outcomes. These encompass growing the amount of employment; supplying infrastructure and shelter; and boosting domestic consumption, particularly in fast industrializing and urbanizing countries.

Likewise, the Malaysian construction industry not only is a contributor to Malaysia's GDP growth, but it plays a vital role in the country's development. For instance, in 2017, the Malaysian construction industry grew by 8%, reflecting a total value of RM 170 billion (approx. US$43,943 billion), with this underpinned by several mega infrastructure projects (*The Star*, 2017). Furthermore, the Department of Statistics Malaysia (2016) reported that, in 2015 (fourth quarter), approximately 10,000 construction projects were registered, an increase from 2014 (third quarter) when only 9,883 projects were registered. Thus, over the years, a growing number of construction projects have been recorded in Malaysia

However, Najib et al. (2019) indicated that the Malaysian construction industry's growth has led to a dependence on foreign workers that has generated numerous problems. These problems include the dissatisfaction of contractors, local workers' unemployment, social illnesses, local currency outflows, the transfer of foreign workers' skills and knowledge to their home countries and foreign workers' levels of productivity (Hamid et al., 2011). Hanafi et al. (2015) revealed that the 3D syndrome (dirty, difficult and dangerous) as it applies to working in the construction industry has led to the constantly declining deterioration in the local workforce's level of interest, with this having an impact on foreign worker demand. In addition, Carpio et al. (2015) noted that the construction industry is recognised as having limited career development opportunities, offering work with a high level of difficulty and paying low wages.

Therefore, the Malaysian government has been challenged by labour scarcity and local recruitment in the construction sector. The Department of Statistics Malaysia (2016) stated that the Malaysian construction industry alone had hired 745,131 workers: in comparison, the ratio of employed workers to national income was unexpectedly high. With the high demand for workers and the requirement for satisfactory performance, foreign workers have been employed on 70–80% of development works (Yee et al., 2017). Similarly, Abdul-Rahman et al. (2012) reported that 800,000 workers, that is, 8% of the nation's workforce, had gained employment in the Malaysian construction industry: of these, 69% were foreign workers.

As shown in Table 1, the numbers of foreign workers in Malaysia from 2015–2019 by sector wise where manufacturing (3,443,586) hired the largest percentage of foreign workers followed by construction (2,067,532). Also, the decreasing number of foreign workers in the construction sector presents from 2015–2017 due to Malaysia's slow economic growth. Malaysian Industrial Development Finance (MIDF) announced that, in January 2015, the unemployment rate increased to 3.1%, reflected in the fourth quarter of 2014 by high deflation in the construction sector which influenced the labour market (MIDF, 2015). However, from 2018 through to June 2019, the construction sector employed an increasing number of foreign workers: this growing number of construction industry employees offered a strong indication of Malaysia's stable employment rate, with this possibly due to the many development projects implemented.

Table 1. Number of foreign workers in Malaysia by sector, 2015–2019

Sector	2015	2016	2017	2018	2019 (until June)	Total
Manufacturing	745,131	648,621	645,388	705,016	699,430	3,443,586
Construction	**450,364**	**387,934**	**355,968**	**435,002**	**438,264**	**2,067,532**
Agriculture	196,710	173,641	160,276	159,662	156,334	846,623
Plantations	300,770	268,478	260,429	282,494	273,079	1,385,250
Services	293,433	253,120	247,008	306,417	306,152	1,406,130
Total	1,986,408	1,731,794	1,669,069	1,888,591	1,873,259	9,149,121

Source: Ministry of Home Affairs (2019).

Wei et al. (2018) indicated that the supportive stance taken by Malaysia towards immigration and being among countries in the Asia Pacific with a high ratio of migrants to total population have long been of benefit to Malaysia's economy. Table 2 presents the distribution, by nationality, of approved immigrant construction workers from 2015–2019 in Malaysia.

Table 2. Distribution of approved immigrant construction workers by nationality

Nationalities	2015 (until 21 May)	2016 (until June)	2017	2018 (until October)	2019 (until June)
Indonesia	189,392	213,190	206, 858	162,844	153,470
Bangladesh	90,475	91,100	101,530	167,447	216,880
Thailand	675	623	597	1,152	689
Philippines	3,821	3,776	3,489	2,967	2,653
Pakistan	18,020	29,878	26,734	26,687	26,629
Myanmar	19,138	18,769	17,147	11,595	12,605
Nepal	16,137	13,420	11,609	8,333	6,919
Vietnam	4,798	3,949	3,775	3,022	1,850
India	5,434	9,121	9,214	11,329	9,852
China	3,679	5,707	6,624	10,900	6,322
Sri Lanka	157	134	186	243	279
Cambodia	227	214	170	134	116
Total	**351,953**	**389,881**	**387,933**	**406,653**	**438,264**

Sources: Immigration Department of Malaysia (2015b, 2019); Ministry of Human Resources Malaysia (2016); Department of Statistics Malaysia (2017, 2018).

The statistics in Table 2, in presenting the distribution of approved immigrant construction workers by nationality (2015–2019), recognized at least 12 countries as the major sources of foreign workers for Malaysia, with these identified as Indonesia, Bangladesh, Thailand, the Philippines, Pakistan, Myanmar, Nepal, Vietnam, India, China, Sri Lanka and Cambodia. Indonesia remains the largest supplier of human capital due to its similar background to Malaysia, such as language and culture, and is then followed by Bangladesh and Pakistan. However, the statistics in Table 2 also showed that the report was incomplete and does not include the full year, with 2017 the only exception.

2.2 Accidents that Involved Foreign Workers and Related Causes in the Malaysian Construction Industry

From January to June 2018, 1,809 accidents were recorded for all industries in Malaysia. Of these, 95 accidents had recorded in the construction industry. From the total number of accidents, the construction industry recorded 52 cases of fatalities, which is the largest total of fatal accidents in all industries. According to these statistics, the construction industry is a high-risk sector for fatal accidents (DOSH, 2018). The statistics showed that 1,116 work-related accidents occurred in the period 2011–2016 and that 37.85–51.50% of accidents at Malaysian construction sites resulted in non-permanent disability, permanent disability or death (DOSH, 2017). In addition, based on Social Security Organisation (SOCSO) report, Abas et al. (2013) revealed that 2,822 injuries occurred in casual occupations in Malaysia with an average annual incidence of 9.2 fatal job-related injuries per 100,000 workers. Table 3 illustrated that summary of health and safety (H&S) accidents and causes that involved foreign workers in Malaysian construction industry.

Table 3. Summary of Health and Safety (H&S) accidents and causes that involved foreign workers in Malaysian construction industry

Health and Safety (H&S) Accidents and Causes	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Health and Safety (H&S) Accidents							
Falls/ Falls from heights		X	X	X			X
Stepping on objects			X	X			
Striking or being struck by objects		X	X	X			
Causes							
Job-site conditions/ Nature/Location				X	X		X
Size and type					X		
Duration and diversity					X		
Unsafe acts						X	
Unsafe conditions/Work practice				X			X
Unsafe tools			X				X
Unsafe methods							X
Unsafe equipment	X	X	X				X
Hazardous machinery			X				
Unsafe materials/ Use of heavy materials		X	X				
Human elements/Players/Shortage of skilled labour	X				X		X
Environmental factors			X				X
Management element/ Lack of organizational commitment	X						X
Not wearing PPE/ Lack of PPE	X						X
Poor information system	X						
Structural failure/ Uncontrolled operation	X	X					X
Lack of training	X						
Lack of supervision/ Poor technical supervision	X						X
Lack of innovative technology	X						
Lack of first aid facilities	X						
Unwillingness to input resources for safety	X						
Incorrect or no work procedure/Lack of safety regulations/Poor safety awareness	X						X
Work at high elevation/Climb to high places			X				X
[1] Tam et al. (2004); [2] SOCSO (2009); [3] Chong and Low (2014); [4] DOSH (2016a); [5] Abdul-Rahman et al. (2015); [6] Shamsuddin et al. (2015); [7] Hamid et al. (2019)							

Accordingly, construction industry characteristics and the safety and health challenges they generate are well documented. Historically, the construction industry has been plagued by much higher and unreasonable injury rates compared to other industries, and, for this reason, construction is frequently regarded as a high-risk industry (Hamid et al., 2019). The next section presents the methodology implemented for this study.

3 Research Methodology

A comprehensive literature review and an online questionnaire survey were used as the main methods of data collection in this research. Focus of the online questionnaire survey was to identify the main accidents and key causes related to the construction industry. This involved with collecting large amount of data related to accidents and related causes during 2013–2017 from respective authorities involved with foreign workers. The contents of the online questionnaire include two sections. Section A are set to gain an overview of the background of the organisation. Section B was identifying the main accidents and key causes related to the construction industry during 2013-2017.

Random sampling was chosen in this research, based on the work of Gravetter and Forzano (2018) who indicated that simple random sampling is the purest and most straightforward probability sampling strategy. In simple random sampling, each member of the population is equally likely to be selected as part of the sample. It has been stated that “the logic behind simple random sampling is that it removes bias from the selection procedure and should result in representative samples.” The sample for the research comprised of 150 respondents, randomly chosen from a record of authorities involved with foreign workers prepared by CIDB Malaysia representing Government agencies (6), non-government agencies (6) and Contractors consist of G6 & G7 (largest grading). The main researcher contacted respondents by telephone and email to inform them about the plain language statement and consent form, which also contained the link to the online questionnaire survey. The 100 responses were received for the online questionnaire survey and respondents are project managers, project engineers, safety and health officers (SHO), site supervisors and others (architect, business development, director, EHS engineer, HSE assistant, HSE manager, HSE Manager, Corporate, inspector, operation manager, safety admin and site safety supervisor). Generally, online surveys have far less chance of reaching higher response rates than paper-administered surveys-although various practices have been used to increase these rates (Nulty, 2008). For most research, researchers have calculated sample size based on the rule of thumb, as suggested by Roscoe (1975), who noted that a sample size of more than 30 and less than 500 is most appropriate. Thus, the response rate of 67% achieved in this research is considered acceptable for conducting the analysis.

The SPSS (19.0) software was used to analyse the data collected from the survey. The SPSS software used is the statistical package preferred for comparison analysis over other statistical packages (e.g., STATA, MINITAB and RProgramming statistical software) as SPSS can easily perform parametric and non-parametric comparison analysis. It also allows the researcher to verify test assumptions (e.g., normality and outlier's tests). In addition, SPSS enables a frequency analysis to be conducted precisely (Ong and Puteh, 2017).

4 Findings and Discussion

Table 4 illustrates the distribution of 100 respondents who participated in this online survey.

Table 4. Professional Representativeness of Online Questionnaire Survey

Designation	Number of respondents (%)
Safety & Health Officers (SHO)	38
Site supervisors	22
Project managers	7
Project engineers	6
Others	27

As shown in the above table, all the respondents were directly involved in construction site activities and the majority of respondents were Safety and Health Officers.

4.1 Types of Accidents: Risk

Figure 1 shows the risk of the types of accidents which resulted in death of, or serious injuries to, foreign workers during the five years from 2013–2017. The questionnaire was based on three measurements introduced by Hazard Identification, Risk Assessment and Risk Control (HIRARC): "Low" (1–4 people per year), "Medium" (5–12 people per year) and "High" (15–25 people per year) and referring to accidents occurring per year (DOSH, 2008).

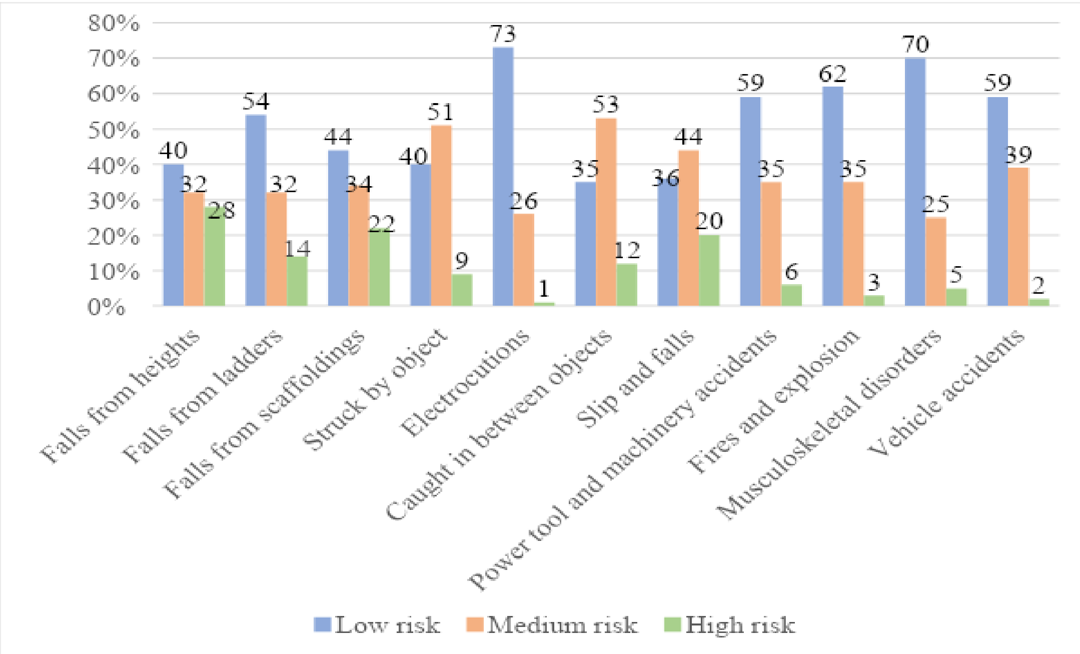

Figure 1. Types of accidents: level of risk

Results show that the types of accidents involving foreign workers in the Malaysian construction industry per year consisted of falls from heights; falls from ladders; falls from scaffoldings; struck by an object; electrocutions; caught in between objects; slips and falls; power tool and machinery accidents; fires and explosion; musculoskeletal disorders; and vehicle accidents. Meanwhile, being struck by an object, caught in between objects, and slips and falls were medium risk. In addition, one respondent stated that fatigue was a new cause of accidents that was becoming prevalent in Malaysia. This finding was contrary to findings in the previous literature that stated that the most common types of accident were falls and stepping on, striking against or being struck by objects, etc., which occur when workers are run over or struck by moving construction equipment (Chong and Low, 2014). Furthermore, Yilmaz (2015) stated that the accident risk on construction sites was possibly due to the following factors: falling from a height, falling objects, being hit by objects, machinery and crane accidents, electric shock and explosion. In addition, statistics published by DOSH

(2016a) indicated that the main fatal injuries involving foreign workers in Malaysia were falls from heights, followed by stepping on, striking or being struck by objects. However, survey findings for this study revealed that falls were low risk compared to being struck by an object, caught between objects, and slips and falls that were all rated as medium risk.

4.2 Major Causes of Accidents

Table 5 presents the questionnaire respondents' perceptions on the major causes of accidents based on accidents involving foreign workers in the Malaysian construction industry during the five years from 2013–2017. This question in the questionnaire was based on a general 5-point Likert scale measurement ranging from (1) "Least Significant" to (5) "Most Significant".

Table 5. Major causes of accidents

Major Causes of Accidents	Mean	Std. Deviation
Unsafe acts (worker's attitude)	4.18	0.796
Lack of H&S training and learning	4.15	1.149
Less awareness of hazardous activity	4.00	1.110
Unsafe conditions (poor housekeeping)	3.94	0.802
Unskilled workers	3.87	1.070
Poor site safety management	3.80	1.137
Cost saving	3.40	1.082

The results showed that "Unsafe acts (worker's attitude)" had the highest mean of 4.18, followed by "lack of H&S training and learning" (4.15) and "less awareness of hazardous activity" (4.00), with these three being the major causes of accidents involving foreign workers in the Malaysian construction industry. The other main causes of accidents were poor site safety management, unskilled workers and unsafe conditions (poor housekeeping), with mean values between 3.80 and 3.94. The accident cause with the lowest mean of 3.40 was "cost saving."

This finding is supported by the literature findings revealed in Table 3 (page 5) that unsafe acts by worker/s are regarded as the leading contributor to work-related accidents and injuries on Malaysian construction sites, due to workers having poor attitudes towards safety. One way to improve safety on construction sites is to conduct further safety training to educate workers on safety practices in construction. This is especially the case for foreign workers where special training is required to educate them well enough before they are posted to any respective sites. In addition, Lai et al. (2011) highlighted that safety training is the most effective method for reducing hazards as training can enhance workers' skills and abilities to recognize hazards. Moreover, Hinze et al. (2013) noted that intensive safety training would result in higher performance, after having interviewed 57 US project representatives.

5 Conclusion

In summary, findings revealed foreign workers in the Malaysian construction industry have often been exposed to numerous inherent risks associated with working conditions on construction sites during last five years. Further the workers unsafe acts are considered as a main contributor of work-related accidents and injuries on Malaysian construction sites by having poor attitude towards safety. Hence, H&S training and learning were identified as of utmost importance to improve safety on construction sites by educating workers on safety practices in construction.

The published research results cannot guarantee that they are representative of all foreign workers employed in the Malaysian construction industry, as only a small number of respondents participated in this research. The online questionnaire survey in this study were performed within the Malaysian context, thus focusing on Malaysian construction industry practitioners. Therefore, the culture of Malaysian people and their working environment have indirectly influenced the value of workers' traits.

Several areas identified in this research could usefully be further explored. In the future, more interviews could be organised with agencies that directly employ foreign workers and with the Immigration Department regarding requirements for working in the Malaysian construction industry. Additionally, it would be worthwhile to investigate how various industries and firm-specific characteristics drive the frequency and severity of accidents confronted by foreign workers in the Malaysian construction industry. Finally, researchers could explore an effective long-term approach to address the construction labour shortage in ways other than relying on short-term approaches, such as the employment of foreign workers.

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Lesson Learned To Mantain And Widespread Implementation Of Precast Concrete Building In Malaysian Construction Industry

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Abstract

Precast Concrete (PC) building implementation in Malaysia, though spanning over a decade, has been neither widespread nor optimal, prompting a need to identify lesson learned to achieving this. Data was collected through semi-structured interviewing of purposively selected constractors who have implemented PC within their organisations and on projects. Lesson learned to optimal and widespread implementation of PC in Malaysia include lack of standards and poor service delivery as well as defect repetition. These in turn contribute to varying patterns of implementation methodologies among collaborators along with conventional method and business processes. The conventional methods had significantly little emphasis on defect diagnosis tools. It had also increased the inadequate strategic decision making to analyse information in improving the maintenance project outcomes for PC building. Therefore, Building Information Modelling (BIM) tools is suggested as a good practice to reduce the repetition of defect on the design specification used and construction practiced.

Keywords

Conventional Method, Building Information Modelling, Malaysian PC Building.

1 Introduction

Structural repairing practice in managing PC building maintenance activities has been a hot issue in recent years due to lack of progress in the area of computer-aided maintenance management and difficulties with accessing information and data in maintenance support systems such as Computerised Maintenance Management System (CMMS) and Computerised Aided Facility Management (CAFM) (Duran, 2011). Clients and contractors should use the high-quality building information from an emerging application of computerbased technology during the maintenance activities of the Precast Concrete (PC) building's lifecycle. In response to the challenges of dynamic maintenance operations and the need for improving the quality of maintenance process in complex and high-rise structural building components, clients and contractors could change their method from conventional practices to more enabling technology to increase productivity and a new level of interoperability and collaboration. The conventional modus operandi (paper-based reports/unsystematic database), which is commonly being conducted in a sequential manner using CAFM and CMMS tools replaced to new business model which integrates various sources of data and knowledge such as CMMS with the Building Information Modelling (BIM) of the PC building in the maintenance activities (Motamedi et al., 2014; Nawi et al., 2014).

Maintenance staff generally introduces Information and Communication Technology (ICT) into PC building maintenance management for providing maintenance inspection records and results, including checklists, specification, and maintenance procedure by using software such as CMMS and CAFM. The CMMS and CAFM application provides various paper-based reports (such as inventory confirmation) related to maintenance and repair issues (Motamedi et al., 2014). Furthermore, the traditional 2D Computer-Aided Design (CAD) technology is widely used for maintenance information illustration and even integrating related data for PC building construction design history purposes (Amano et al., 2019). Despite the fact that the use of ICT solutions in assessing, planning or process execution takes place at a different scale and function, the emerging trend such as using sophisticated or innovative tools and techniques could improve productivity in PC building maintenance activities and have a great potential to redefine and re-engineer the conventional setting. The conventional method (paper-based reports/unsystematic database) is lack of knowledge support in coordination, maintenance monitoring, maintainability, automation and robot control systems. The PC building maintenance has different training or maintenance information to address the issue of defects for particular component compared to the conventional building maintenance. The connection of PC component such as by using corbel and PCB need the expert knowledge to improve the quality and reliability of PC scheme in order to avoid any defect repetition in the long-term of life cycle building services. Failure to capture the data acquisition and monitor the defects effectively will influence the assessment process including maintenance planning and execution. This can contribute poor quality, productivity and performance in PC building construction projects. There is also give problematic and inefficient in the handling of information and integration of data of maintenance components within a post-construction site activity (Kamaruddin et al., 2013; Chong et al., 2019).

Most PC building maintenance staff using basic ICT software such as CMMS and CAFM to record the information regarding with defects, diagnosis and maintenance planning as showed in Figure 1. Then, this information will be transformed into paper-based report to be distributed to other personnel that involved in the maintenance management. Besides, there are some maintenance organisation using MS Word and MS Excel completely to support their maintenance task for specific tasks (Malek et al., 2016). Nevertheless, there is no integration between these systems to improve the communication and collaboration between all parties in the maintenance management especially those involving with the transfer of knowledge in the defect diagnosis process for PC buildings (Mohamad et al., 2016). Thus, the intent of this research is to develop modern computerised systems using BIM to serve as a platform for decision making in defect diagnosis, as well as managing complicated data such as repair materials and methods of older methods of building structures and facilities.

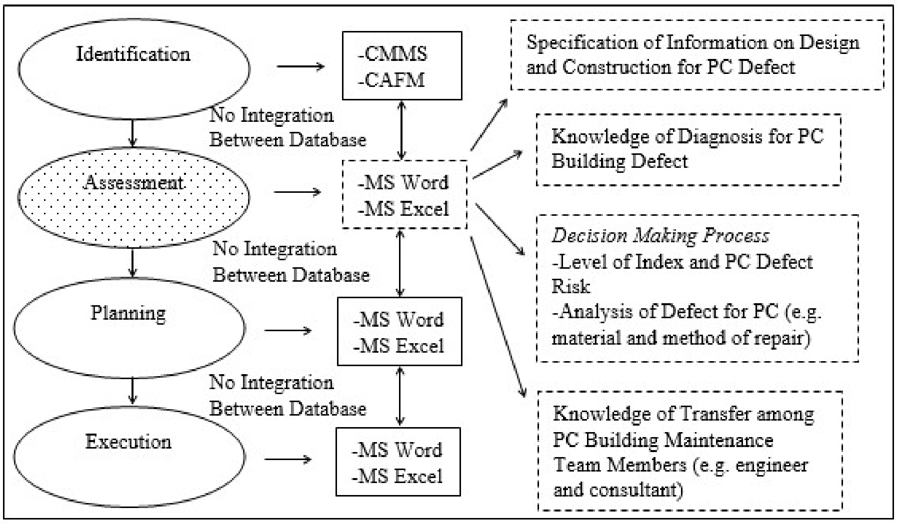

Figure 1: Key Problems for PC Building Maintenance Management Practices

2 Case Study

Case studies were undertaken in order to identify the maintenance management problems, the current approaches to addressing the problems and the latest technology practices for facilitating the maintenance management processes. The maintenance management practices was also studied to obtain information relating to the maintenance identification, assessment, planning and execution processes. Eight maintenance clients/contractors are selected based on major problems of using conventional method (paper-based reports/unsystematic database) in the comparison to investigate the maintenance management practices in each PC building. There are around 51 contractors of Industrialised Building System (IBS) building maintenance from a classification of PC system have the highest of IBS building maintenance projects in Malaysia according to Construction Industry Development Board (CIDB) and almost are using conventional method and inadequately use of modern ICT tools. The number is considered very big indicating that the use of modern ICT is still very limited for PC system classification in IBS building maintenance management in Malaysia. The adopted synthesis of good practices of maintenance operations is based on the findings of the interviews and case studies conducted with professional engineers working in PC building maintenance departments (Ismail et al., 2016). The interviews consisted of two types of PC building, namely, "Residential" and "Non-Residential". The case study was based on eight cases (Case A-Case H) of PC buildings in Malaysia. There were two case studies (Cases A and E) on "Residential" due to housing maintenance operation such as the Putrajaya Quarters. In addition, six more case studies (Cases B, C, D, F, G and H) were classified as "Non-Residential" which manages the maintenance operation with fully equipped office buildings. The interviews reached a saturated point after the eighth interview session.

The justifications for the selected case studies were according to the following main criteria: exposed to the conventional method used and major problems, attempted to implement computerised technology and the willingness of staff to share their experiences in improving the maintenance management processes at the PC building. The differences between the types of the PC building project provided an opportunity to explore variations in maintenance management issues for complex and high-rise PC building projects. The type of PC building under study for maintenance project were all varied from Quarters to Integration News Centre. The summary on the eight case studies is presented in Table 1.

Table 1: List of case studies

Case	A	B	C	D	E	F	G	H
Type of PC Building Project	Quarters	Malaysian Institute of Pharmaceutica ls and Nutraceuticals (IPHARM)	National Youth Skills Institute (IKBN)	Anti-Corruption Agency Office Complex and Housing	Double Storey Super link House	Inland Revenue Board of Malaysia Complex	National Audit Departmen t Office	Integration News Centre
Type of Building	Residential	Non-Residential	Non-Residential	Non-Residential	Residential	Non-Residential	Non-Residential	Non-Residential
Design of PC Building	High-rise	High-rise	Complex	Complex	Complex	High-rise	Complex	High-rise
Grade of IBS Contractor	G7	G7	G7	G7	G7	G7	G7	G7
IBS component used	Precast concrete, blockwork system, formwork system	Blockwork system, formwork system, steel framing system	Precast concrete system	Precast concrete system	Precast concrete system, formwork system	Blockwork system, formwork system, steel framing system	Precast concrete system, formwork system	Precast concrete, blockwork system, formwork system
Maintenance Management System	Conventio nal	Conventional	Conventio nal	Conventio nal	Conventio nal	Conventio nal	Conventio nal	Conventio nal
Person Interviewed	Engineer	Engineer	Engineer	Engineer	Engineer	Engineer	Engineer	Engineer
Years of Experience	10 years	20 years	10 years	4-5 years	24 years	21 years	4-5 years	10 years

*Grade of IBS Contractor is determined by the contractor's financial capability and their work capability. This enables the Public Sector, Private Sector and the CIDB in general to access a contractor's ability to undertake a respective project.

The semi-structured interviews were conducted with the engineers who were responsible for the maintenance management of the entire PC's building structure under the Facility Management and Development Unit (UPPF) and Maintenance and Development Unit (UPS) including maintenance contractor. The interview sessions took around five hours to accumulate the data on the maintenance processes including the demonstration of the current maintenance management system with the implementation of the ICT tools by the engineer. All the data from the interviews were recorded using video camera and transcribed verbatim.

3 Discussion

The problems identified from the eight case studies revealed that each case study experienced similar problems with defect repetition at the specific component part of PC building and are summarised and presented as below. The discussion involves a cross-case analysis and has been grouped into five main 'embedded units of analysis' identified which are (1) Maintenance Management Problems, (2) Approaches to Address Problems, (3) ICT Implementation, (4) Use of Emerging Technologies and (5) Maintenance Management System.

Table 2: Cross-Case Analysis

Case	Element of Analysis: Maintenance Management Problems
Case A	*Lack of commitment for handling defect* -Report delay and undelivered -Unsystematic database *Less competent contractor staff* -Less engineer competency -Technician's report is in general description -Technician's failure to identify defect problem *Defects repetition (surface cracking, leaking, scaling and jointing)* -Fault design *Poor quality work by contractor* -Less material quality *Poor buildability (M&E coordination)* -Lack coordination between design and maintenance team *Poor maintainability* -Unspecific accessibility to the defect location *Poor waterproofing* -Poor maintenance method
Case B	*Poor quality work by contractor* -Low repair requirements of the structure component *Lack of staff* -Lack of supervision *Limited Budgets* -Budget constraint *Defects repetition (surface cracking and aircond belting)* -Lack of technician -Less defect detection technologies *Less competent contractor staff* -Less engineer/technician competency
Case C	*Defects repetition (surface cracking, leaking and jointing)* -Low quality design control *Surface cracks due to improper jointing* -Less quality of joint material *Deep cracks due to settlement* -Less suitable soil *Less competent contractor staff* -Less engineer/technician competency
Case D	*Defects repetition (leaking and jointing)* -Design performance for concrete durability requirements -Structural installation method *Poor waterproofing* -Poor installation of the waterproof membrane *Poor quality work by contractor* -Lack of uniform standard -Poor material quality *Less competent contractor staff* -Less engineer/technician competency
Case E	*Defects repetition (surface cracking, leaking and jointing)* -Fault design -Poor material quality -Time gap of building repairs *Poor plumbing fitting* -Plumbing installation method
Case F	*Defects repetition (leaking and jointing)* -Design performance for concrete durability requirements *Less competent contractor staff* -Less engineer/technician competency
Case G	*Defects repetition (leaking, jointing and overload current trip)*

	-Fault design -Contractor ethics issues-Interested in making profits
Case H	*Defects repetition (heavy leaking)* -Poor quality of design -Less technician competency *Deep cracking on structure* -Limited experience by engineer -Poor maintenance method by contractor *Less competent contractor staff* -Less engineer/technician competency
Case	**Element of Analysis: Approaches to Address Problem**
Case A	-Improve the maintenance assessment for the building works did by contractor
Case B	-Provide more quality staff in managing the maintenance of critical defect -To replace the conventional defect detection method (e.g. visual inspection) with the sophisticated ICT application (e.g. CMMS)
Case C	-Improve the maintenance effectiveness for the building works did by contractor
Case D	-Proper supervision of work for the building works did by contractor
Case E	-Improve the building control for the building works did by main contractor
Case F	-Critical plan on maintenance repairs
Case G	-Conduct the maintenance assessment for evaluating the building works performance did by contractor
Case H	-Conduct the maintenance assessment for evaluating the building works performance did by contractor
Case	**Element of Analysis: ICT Implementation**
Case A	*mySPATA*-Data inventory for immobile facilities (e.g. building) *mySPA*-Data inventory for mobile facilities (e.g. furniture) *mySMS System*-for managing complaints
Case B	-Conventional (e.g. MS Word, MS Excel)
Case C	*mySPATA*-Data inventory for immobile facilities (e.g. building) *mySPA*-Data inventory for mobile facilities (e.g. furniture)
Case D	-Conventional (e.g. MS Word, MS Excel)
Case E	-Conventional (e.g. MS Word, MS Excel)
Case F	-Conventional (e.g. MS Word, MS Excel)
Case G	-Conventional (e.g. MS Word, MS Excel)
Case H	*Building Automation System (BAS)*-for detected building's heating, ventilation and air conditioning systems *Supervisory Control and Data Acquisition System (SCADA)*-to ensure that the building systems (e.g. fire alarm) were in good condition *E-Aduan*-for managing complaints
Case	**Element of Analysis: Use of Emerging Technologies**
Case A	-No
Case B	-No
Case C	-No
Case D	-No
Case E	-No
Case F	-No
Case G	-No
Case H	-No
Case	**Element of Analysis: Maintenance Management System**
Case A	-Conventional (e.g. paper-based reports/unsystematic database)
Case B	-Conventional (e.g. paper-based reports/unsystematic database)
Case C	-Conventional (e.g. paper-based reports/unsystematic database)
Case D	-Conventional (e.g. paper-based reports/unsystematic database)
Case E	-Conventional (e.g. paper-based reports/unsystematic database)
Case F	-Conventional (e.g. paper-based reports/unsystematic database)
Case G	-Conventional (e.g. paper-based reports/unsystematic database)
Case H	-Conventional (e.g. paper-based reports/unsystematic database)

A few clients at the PC building were not have specific knowledge for the structure defect that to be diagnosed. The deficiency of information was also due to the lack of the PC knowledge among the technician and staff about the technicality when addressing the defect problems at the PC site location. The maintenance management staff found that it was difficult to identify their building condition in order to manage the component defects and this affected the decision taken for maintenance defect diagnosis. Meanwhile, the 'mySMS' and 'E-Aduan' system were the technology used in managing the complaint at the PC building. However, both of these technologies were inadequate compared to the modern ICT tools to record the information related to the maintenance diagnosis management into the database system. The paper-based reports mostly used at the PC building provided not enough data and explanations such as structure and facility type, defect description, location and visual inspection such as condition categories in details that could help the maintenance management staff to conduct effective execution on the defect.

There was no dedicated system to improve the maintenance diagnosis for reducing the repetition of defect problems where the defect took more time to be investigated to identify the causal explanation. 'mySPATA' and 'mySPA' only supported the inventory management for the facilities while BAS and SCADA monitored the electrical and mechanical control systems as well as its conditions. The implementation of emerging technologies could solve defect problems for maintenance management processes. There was an inadequate use of modern ICT tools such as BIM to assist with a maintenance management, which could provide real-time information of PC building maintenance. The maintenance management processes at the PC building was also lack with ICT tools that can associate the design, construction and maintenance operation in one system with high level programming, defect diagnosis and decision making process.

3.1 Synthesis of Good Practices

Table 3 below represents the suggested solutions from the case studies to improve the current practices on the maintenance management by implementing three approaches at the PC building. Case A, B, C, D, F, G and H suggested improving the transfer of knowledge in the defect diagnosis by combining with the related software technology such as CMMS and CAD. In fact, the problem of knowledge transfer in the defect diagnosis delivery also does affect the other PC buildings to some extent and the significance of this factor is quite obvious. The maintenance contractors will use the inadequate knowledge to handle the defect problem and less detail of the defect source explanation to gather accuracy information record for inspection and planning works. The other suggestion from the client/contractor was to provide the transfer of knowledge to improve the maintenance quality of structure and facility at the PC building (Case A, B, D, F, G and H). All the related cases are facing the impact of problems for the quality knowledge management, which are associated to the defect repetition for handling the defect of structures and facilities with IBS score usage about 70% on its structure development of PC building.

Case C, D, E, F and G suggested on efficient controlling of building performance based design and monitoring the defect diagnostic operation in maintenance through implementation of emerging technology (BIM) on the PC building maintenance. These are also recommended by Case A, B and H to integrate the design/construction and maintenance's database in order to facilitate better decision support and coordination within and across multiple field (e.g. civil, mechanical and electrical) for effective management of the PC building maintenance. This suggested solution is ranked as the most important solution due to suggest from almost case studies in order to manage the large and critical maintenance services for the PC building structure and facility. The using of emerging technology is also the lowest in terms of existing practice for better managing PC building components including mechanical and electrical control systems. As the overall results indicated in Table 2, it was deemed necessary to analyse the use of emerging technology further. Therefore, the systematic system with the emerging technology, defect diagnosis and decision making process should be developed to improve the building structure and facility performance by conducting effective knowledge transfer on the structure component maintenance defects.

Table 3: Suggested Solutions from Case Studies

No.	Suggested Solutions	Case A	Case B	Case C	Case D	Case E	Case F	Case G	Case H
1	Provide more specific knowledge on defect diagnosis	/	/	/	/		/	/	/
2	Improve the maintenance quality in maintenance execution	/	/		/		/	/	/
3	Implementation of emerging technology (BIM) (efficient control of building performance based design/ monitor the defect component operation in maintenance)	/	/	/	/	/	/	/	/

3.2 Lesson and Enlightenment

- The PC building maintenance and the application of diagnosis techniques should be paid highly attention. Because of the defect repetition of structure components and limitation of understanding about the PC knowledge, the maintenance approach is very important. The application of modern ICT tools such as BIM integration can avoid or alleviate the defect of critical structure.
- The appropriate modern ICT tools should be selected in assessment areas (diagnosis and decision making process on the design specification used and construction practiced) for PC buildings. The high-rise or complex structure should be given the priority for these types of PC buildings.
- The maintenance quality of PC buildings should be strictly guaranteed.
- The deficiency of PC buildings knowledge affected the quality of competent maintenance staff in Malaysia. The future work should be strengthened to guarantee the quality and knowledge in case of defect repetition.

The repetition of defect was frequent at PC building. The maintenance inspection and assessment were not able to address the building structure defect problems at the particular location due to the less knowledge transfer between all members in maintenance management. Furthermore, the less competent contractor caused the maintenance faults to be increased to encourage the deterioration of the PC building structure and facility. In this research, the frontline approaches (new system development with BIM) is intended to counter the maintenance management problems on PC building which are:

a) Defect repetition information and knowledge due to failure to identify the actual reason of structure defect;
b) Defect repetition (leaking, jointing and cracking) information and knowledge due to design defect; and
c) Less competent contractor due to lack of knowledge regarding with materials, method and design of structure repair.

4 Conclusion

Presently, the implementation of ICT tools in the new system is the better improvement to lead the tremendous saving in budget, time planning and to receive the precise data in handling the defect diagnosis and control. The suggestion for good practices was through the implementation of BIM to reduce the repetition of defect on the design specification used and construction practiced for the building structure and facility. The implementation of operational BIM for PC building maintenance suggests that most of them are not sufficient to fulfill two key requirements: defect diagnosis and decision making process. Future of advanced BIMs are expected to use a combination of current CMMS data (for example, increasing the building component's ability to adapt to seasonal rhythms) and a performance information (e.g. defect distribution, PC connection and maintenance planning); however, this research will explore perception diagnosis-aided BIM for full autonomy and increasing productivity, particularly for facilitating the development of efficient, maintenance execution benefits are predicted and fully automated decision making applications on high-rise and complex PC building construction projects. Issues often arise during PC construction activity and pose a problem for the maintenance due to the poor and improper CMMS execution. Analysis of the issues and probable solutions has led to the development of extended components for BIM and CMMS integration. However, there are a few limitations to be taken into account in the execution of the both BIM and CMMS integration such as guidelines for intensive and systematic implementation, strategic knowledge of maintenance diagnosis benefits, competency of engineer and construction manager as well as technical models and support tools to help decision making actions. Therefore, the requirements of both BIM and CMMS integration should be taken into consideration from the construction initial stage of the maintenance management process to optimise design specification and quality practice throughout the total maintenance process.

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Curriculum enhancement through internships for construction, property and project management students: Australia-India experience

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Abstract
Several Australian graduates in the building and construction sector end up working in the Asia-Pacific region and beyond. Supporting cultural intelligence as part of their university experience allows students to get a better understanding of working beyond Australian borders and prepares them better for their working life. Such experiences also expose students to a range of socio-cultural, technical and other challenges and prepares them to work in a globalised world. This paper presents the experiences of Australian students undertaking internships in various Indian companies, supported by scholarship from DFAT's (Department of Foreign Affairs and Trade) New Colombo Plan (NCP). Ten students from the disciplines of construction management, project management, and property spent three months working in various companies across major metro centres in India over summer 2019-20. Students undertook internships in companies that were mainly focused on housing projects. The students were exposed to cultural, technical and scale challenges in India. Students reported that they found the experiences very valuable despite various challenges including managing expectations. All students recommended the experience to the next cohort of students involved in such internships. There were also lessons learned for the discipline programmes in engaging in such internships in the future.

Keywords
Australia, construction management, cultural intelligence, education, India, internship, NCP.

1 Introduction

There is no doubt that learning abroad experiences have an impact on student learning. Benefits for students, institutions and communities include enhanced learning, increased depth of academic engagement and success, improved career prospects, improved cultural understanding and individual development. Australian students have been enjoying study abroad experiences as part of their undergraduate study programs before the pandemic. According to ICEF Monitor (2021), such types of study abroad experiences increased from 13.9 per cent of students in 2015 to 18.5 per cent of students in 2018, across all areas of study. The increase has been particularly high for undergraduate students with almost a quarter of this cohort participating in study abroad acivities in 2018. Support by the Australian government through the New Colombo Plan (NCP) scholarships, grants and OS-HELP loans have supported the increased trends (ICEF Monitor 2021).

Almost 50 per cent of students to date went to the Indo-Pacific regions according to research by the Australian Universities International Directors' Forum (AUIDF) (cited in ICEF Monitor 2021). The most popular study abroad activities were faculty led study tours, followed by internships and other practicums comprising approximately a fifth of the total. Four per cent of students went to Japan, India and Indonesia while fourteen per cent of students went to China. While not suitable for all types of study abroad activities, India does offer some unique perspectives for students graduating in the built environment disciplines.

Before the pandemic, the construction and property sector in India was booming. After agriculture and manufacturing, real estate is the third largest employer in India employing about 50 million people in 2018. By 2022, it was expected that the employment numbers will increase 1.5 times the 2018 figures, although the pandemic has impacted the sector along with many other sectors in the country (KPMG 2018). While the pandemic put brakes on the boom, building and construction activity in India has continued at a less frenetic pace. In 2017, infrastructure spending in the country was 9 per cent of the country's GDP (Statista 2021). According to KPMG (2018), the real estate sector is estimated to grow to USD 650 billion by 2025 and increase by a further 200 billion by 2028. Additionally, the Indian real estate industry is expected to reach USD 1 trillion by 2030 to become the third largest real estate industry globally.

The author of this paper has taken students on short term (2 weeks) mobility sojourns to China, India and Indonesia, funded by NCP before considering the possibilities of internships. All other things being equal, the advantage with internships in India is that the primary language of operation is in English unlike Indonesia (Bahasa) and China (Mandarin). While the scale of building and construction activities in each of these countries is high, the uniqueness of the Indian context and shared colonial history provides interesting insights. Given the context of the importance of study abroad experiences for Australian students and the increased focus of India for the building and construction sector, it was logical for the author to seek support from the NCP for scholarships focusing on internships in India. The application for multi year-funding was sought in 2018, and the application was successful. Commencement was in 2019-20 for a three-year period ending in June 2023.

The aim of this paper is to understand the impact of student internship experiences in India and to enhance the experience for the remaining cohorts of students in the built environment. By sharing the key insights from the first cohort of students, the experience for other built environment students may also be improved, not just within the Australian and Indian contexts. The lessons learned may be used to improve experiences for other discipline students. Given the aims of the study, a course experience survey alone was not considered to be sufficient to understand the depth of student experiences. The research method followed was guided by action research and qualitative in approach to enable deeper insights to be obtained. The course on which the internships were based takes a case study approach as the literature does not have any documentation on internships for built environment students over the last decade. In total, ten students were awarded the NCP scholarship, and were based in Delhi, Mumbai and Jaipur during summer 2019-20. Students were provided pre-departure information, knowledge of the companies they were working with and support on accommodation arrangements. Students commenced discussions with the companies prior to travel. The author of this paper checked-in with the students in India during the internship and also discussed with the companies as to how the students were progressing. Students kept a reflective journal that they completed on a weekly basis. At the end of the internship, the students were interviewed.

The paper commences with a literature review focusing on four main areas associated with internship experiences. Under study abroad experiences, internships, study tours, cultural intelligence and resilience are explored. This is followed by the internship experiences of the students, analysed from the perspectives of the student and their hosts. Discussions follow with conclusions.

2 Study Abroad experiences

The literature on study abroad experiences is across a number of subjects; however, most of the study abroad experiences are in the discipline of business, particularly internships. There is very little reported in the built environment disciplines. Therefore, literature from other disciplines have been used to understand the implications of overseas internships for Australian students in the disciplines considered for this paper.

2.1 Internships

Generally, internships support students to experience the real world and put some of the formal training into an applied context. Internship may also be seen as a work-based learning experience. Developing reflective skills are part of the internship experience as students question ways of doing, values and in-built assumptions of their own and of others. By nature, internships transcend the boundary between academia and business. It engages students, soon to be graduates, into professional and organisational environments. It also enables students to reconcile different environments, particularly if supported by teachers who can make sense of these environments and the knowledge and logic students carry into these interactions. Proactive learning strategies at an individual level can assist in understanding and making sense of the experiences. Previous studies have shown the value of internships for students, employers and higher educational institutions (Vélez and Giner 2015, Helyer and Lee 2014, Green and Farazmand 2012, Weible 2010). For engineering programmes, Renganathan et al (2012) have shown that students viewed practical experiences gained through their internships favourably. The role of the host organisation was also considered to be important for overall positive experiences for the student.

Ripamonti et al (2018) term the internship experience as a 'crossing boundary' experience with important opportunities for critical reflexivity. Verney et al's (2009) research internship evaluation for business students presents evaluation instruments so as to better align with the learning goals of the internship. It also puts the onus on the institutions involved in preparing the interns to be a better fit with employers. Bhattacharya and Neelam (2018) examine how internship experiences are in turn, linked with employability. Interns' performance is dependent on the relationship between intern and the mentor, and potential value-add for the intern. Silva et al's (2016) study of Portugese students also demonstrated that such study programmes enhance employability. Student experiences of internships were found to be related to the nature of the internship experiences and the benefits received (Gupta et al 2010).

However, as the internships were undertaken away from their home countries, other related research on overseas study tours, cultural intelligence and resilience also need to be considered. Internships and study tours are activities, whereas cultural intelligence and resilience are attributes that students can learn to assist them in their personal and professional lives.

2.2 Study abroad/tours

A study focusing in the US spanning a decade's worth of information of study abroad programs has highlighted positive and negative experiences of such programs (Smith 2013). Opportunities to travel, learn new languages, experience different cultures, find one's strengths, develop work skills, form relationships with local populations, expand worldviews, and create future job prospects are some of the positives. Negatives include, unequal opportunities for certain ethnic groups, financial costs, culture shock, separation from family and friends, and language barriers. Experience of study abroad by authors such as Pipitone and Raghavan (2017) have shown how students' experiences of place and in place are shaped by experiential learning spaces. The findings indicate the importance of social interactions, engagement with local culture and intentional narratives as key components in engaging meaningfully with students.

The impact of motivational and metacognitive (tools to put knowledge into use) cultural intellingence on study abroad experiences was studied by Racicot and Ferry (2016). The context of the study was US, with students travelling to Australia, New Zealand, England and Singapore across the disciplines of business, criminal justice, kinesiology and applied physiology. Their study showed the value of pre-departure interventions for students including educational sessions about local culture so that students may be motivated to learn about the cultures they are being exposed to/being immersed in. Institutional support and guided reflection is very important to optimise outcomes.

2.3 Cultural intelligence

Cultural intelligence has a positive impact on individuals, teams and organisations (Dyne et al 2019). Fang et al's (2018) systematic literature review of research on cultural intelligence were categorised into direct effects, indirect effects and mediating effects. The authors found that psychological well-being, interpersonal effectiveness and performance impacted at the individual level. They suggest that further research in cultural intelligence should focus on culture-specific aspects, limitations and negative effects, and higher order indicators of cultural intelligence. A study by Nguyen and Benet-Martinez (2007) on bi-culturalism shows that bi-culturalism is related to better judgement, but only when that is measured bi-dimensionally. The authors posit that bi-culturalism leads to social and cognitive flexibility as opposed to individual or socio-cultural maladjustments. The process of adjusting to two cultures may not necessarily be stressful as has been commonly thought but it may be stressful only to those that are less oriented to the two cultures. They make a case that bi-cultural individuals have positive attributes such as bi-lingualism, cultural frame switching and inter-cultural sensitivity that are increasingly seen to be critical to engage in business in a globalized world.

Investigation by Watson et al. (2013) showed how language proficiency, cross-cultural competence and regional awareness are critical for formal assessments, pre- and post-experiences of students. Research by Cray et al (2017) focused on staff experiences from a business faculty teaching in an MBA programme in Iran. The Canadian staff's capacities to read, interpret and react to students in a different cultural setting brought new insights to supporting student learning outcomes. A study by Peng et al (2015), also with business students showed that there were links between cultural identity and cultural intelligence. Participants with strong cultural identity and low motivational cultural intelligence were viewed as least suitable for an overseas job. The initial levels of motivational cultural intelligence were positively associated with increases in cultural well-being reported by participants and peer perceptions for overseas work.

2.4 Resilience

The learning environment needs to cater not only to the academic needs of students but also the socio-emotional needs. Resilience refers to the ability of students to resist or manage adversity ('bounce back') without any physical or mental consequences. Rather than use of the terms such as *adaptation* and *acculturation*, *resilience* shines the spotlight on coping with challenging situations and gives agency to individual and diverse strategies. It may also be described as 'everday negotiation of concurrent and often conflicting spatio-temporal mobilities and flows' (Ploner 2017, 438). Walker et al (2006, p. 251) define resilience as the '… ability to recover rapidly from difficult situations' and 'capacity to endure ongoing hardship in every conceivable way'. Reivich and Shatte (2002, p. 59) define resilience as 'a basic strength underpinning positive characteristics within a person's emotional and psychological make-up' (cited in Ploner 2017).

Studies of resilience in higher education is not common, and the literature in relation to resilience of construction mangement students experiences, non-existent. In Australia, Pech (2017) explored the range of ways student's fostered their own resilience and the institutional support provided. She found that accessing social support rated highly as engaging in active personal care such as a healthy diet, prioritising sleep, regular breaks and relaxation, followed by psychological or cognitive approaches and engagement in personal interests. Insitutions can support these attributes by a range of interventions from student support services to facilities/spaces to support social interaction and individual self reflection.

Ploner's study (2017) on social science students in the UK calls for a critical re-evaluation of higher eduation student mobilites. The focus of Ploner's study was on international sudents in the social science disciplines. The students' account of their lived experiences and individual performances of resilience were documented and analysed. The findings show that resilience needs to be considered from day-to-day stressors' perspective and institutional support to combat resilience is important. In another study in the UK by McIntosh and Shaw (2017), factors involving resilience in students was found to be a combination of external and internal factors. External factors included social integration within a higher educational setting and support networks, both formal and informal, backed by existing social relationships and levels of satisfaction associated with these. Internal factors involved self management and emotional control. In a US study focusing on native Alaskan experience at university (Wexler and Burke 2011), it was found that a holistic, nuanced sense of cultural identity is critical to navigate native students' involvement in universities in the US. Rather than taking a dupolistic approach, a more rounded and holistic approach can support and increase student resilience throughout their university life.

The review of the literature shows no studies about overseas internships for construction, property and project management students. As students spent three months in an overseas location, they were exposed to settings where their cultural intelligence was stimulated and bi-cultural awareness increased. Further, their individual capacities for resilience to work in a new cultural setting was also brought to the fore. These are the areas through which the research is analysed in the next section.

3 Research approach

The research used a case study approach, as a novel case (Yin 2009) by focusing on the one course upon which the internships were based. The course was set up for the purposes of the internships upon receipt of successful funding by NCP. Students received a pass or fail for the course; there were no other assessments. Students kept a reflective journal in a simple excel, the template for which was provided to students prior to their travel. Students had to complete an information session after enrolling in the course where the course coordinator and author of this paper explained about the companies they were interning in, the sorts of projects the companies undertook and general living and working conditions in India. A pre-departure information session was also undertaken by the university, but this focused more on insurance, travel considerations, overseas assistance and other such risk-based considerations.

To answer the research question, a qualitative approach was most suitable with instruments focusing on in-depth probes of student experiences. In addition to the reflective journals, students were interviewed during their time in India (almost halfway through the internship) and again at the end of the programme upon return to Australia. The companies hosting the interviews were also interviewed. In most instances, the interviews were undertaken with the direct manager and the human resource (HR) person who assisted in facilitating the processes for student travel to India (such as letter for visa arrangements, accommodation suggestions). Interviews were recorded and notes/observations made by the researcher. Due to the numbers, excel was used to identify themes arising from the interviews and observations.

The students commenced the internships during summer 2019-20 period. The first year 10 students were awarded scholarships each of $8000.00, increasing to 25 students in the third year. Due to the pandemic, only the first year of the scholarship funding was used. The students had a travel ‘window’ for the internship but the start and end dates of the internship itself was flexible; it was left to the students and the companies they were interning with to determine the actual start date. The other reason for the flexibility was that students were not all from the same year of the programme, so their start date for the internship was determined by when their exams for the year was completed and if they had other courses during the summer period. Since the students were also from different disciplines (and years), they did not know each other prior to the internship and most of them met each other for the first time during the information and pre-departure sessions. In addition to the ‘formal’ interventions, a *WhatsApp* group was also formed so students stayed in touch with each other and the researcher, and were able to share their experiences on local observations whether this was about the work, food, and other cultural experiences.

In total, five students were allocated to work in New Delhi, three in Mumbai and two in Jaipur. Three students majoring in the disciplines of property, construction and project management worked for an international firm in New Delhi. Also, in New Delhi, two other students worked in a multimillion dollar Indian company focusing mainly on housing. Two students majoring in construction and project management worked for a major builder and developer in Mumbai. Of the two students who worked in Jaipur, one was a construction major and the other was a project management major. There was only one female project management student, working in Jaipur. The company in Jaipur focused on social housing. Most of the students arrived in India in late November 2019 and were back in Australia in early March 2020, just before Australia closed its international borders due to the pandemic. One student never made it to India as he was serving in the army reserve in remote Australia with little access to the internet. By the time he notified the author of this paper, it was too late to re-organise his internship with the company in Mumbai in light of the pandemic warnings. He was expected to travel later in the year but Australian borders closed for international travel.

4 Findings and Discussion

The findings and resulting analysis and discussions have been explored from three fronts: student’s reflections through their journals and interviews, discussion with the companies hosting the students and the authors’ own observations.

4.1 Students

The overall experience of the internship as reported by students may be classified as absolutely fantastic to very good and ordinary. Five students thought the experience was fantastic; all students said that they would recommend internships to others. Two students felt that the internships needed more structure and better understanding of expectations on both sides. Two students felt that the experience of not just the internship but also the experience of living in New Delhi was left wanting. All students felt that having someone else to talk to and share the internship experience with a mate was helpful. The internship drew the students outside their comfort zone and while this was challenging emotionally, they reported that the experience also made them stronger. The student experiences that made it fantastic were exposure to the types and scale of projects they would not have had an opportunity to work with in Australia, eye-opening experiences beyond the world of work, a sense of welcome by the companies, having an opportunity to experience living and working in a new culture and the ability to become more resilient by dealing with emotional issues.

The female student did not feel that as a female in India, she was subjected to a difficult work environment, but she did feel uncomfortable as a 'white woman' on the construction site. Students also reported the disconnect in the knowledge and expectations of the disciplines. In India, working in construction management generally requires an undergraduate degree in civil engineering and a post graduate degree in construction management. Project management was not really understood, it was considered to be a less technical 'version' of construction management. The expectations of a property discipline was similar to that in Australia.

4.2 Host

The four companies hosting the students had different approaches to the internship. Even before the start of the internship, it was quite frustrating to get formal documents to be organized so that students could apply for their travel documentation. Only one company seemed to have a 'professional' approach, with the one 'go-to' person who talked to the students before arrival in India, discussed travel arrangements and accommodation with them, and was supportive in every way possible to ease students into the internship. This company, based in Mumbai also provided not just HR support but also ensured that the managers looking after the interns were also well briefed so that the most value of the internship experience could be guaranteed for the students. Occupational health and safety (OHS) was taken very seriously in this company; one supervisor was fired for employing an under-age youth on the construction site.

The companies hosting interns in New Delhi had different approaches. The multinational company was able to better manage the interns and each of the interns had different managers supporting their discipline areas. The students did not see each other much during the day, as they worked in different departments. The other company hosting two interns (that found the experience wanting) seemed to have a disconnect between the HR and the technical departments. The main point of contact was HR who appeared to be very keen to host the students but the intern manager was never available to talk to interns or the researcher. The social housing company in Jaipur had a problem with their builder and architect resulting in construction work being placed on hold. This was unfortunate as it impacted the interns, particularly the construction management student. He learned more about sale and cash flow, which was unexpected. The project management student found it difficult, not just because of the stop in construction works but also because there seemed to be a general disconnect about understanding the role of a project manager. This was not expected as the company had student profiles and 'chose' the interns they wanted to host. All companies were keen to host students in future rounds and some were prepared to host more than they did in the first round. One company expressed interest in employing the students they hosted.

4.3 Researcher obervations

As course coordinator and having applied for the scholarship in the previous year for the students, the researcher was very keen for the first cohort of internships to be successful so that the remaining cohorts may also benefit from the experience. Unfortunately, the second and third cohorts were paused due to the border closures arising from the pandemic. With assistance from the companies, the researcher provided insights into language, culture, food, general exposure to the property and construction industry and assisted with accommodation where possible prior to travel to India. The researcher also undertook preparatory work seeking the companies to host the interns and kept close contact with the companies and interns during their time in India. Since this was a maiden experience, keeping a close tab ensured that should there be any problems, a quick response is guaranteed.

It was found that while preparation helped, the immersive experiences of the students varied depending on the ability of the students to ‘soak-in’ local exposure and the ‘to make most of their time’ in India. The two students in Mumbai had the best experience, not just because of the company they worked for (most professional), but also because of the students themselves. These students ate local (regardless of health warnings), travelled like the locals, made an effort to learn the language, and tried to interact with the labourers on the construction site. Each of these students ‘lived’ in the moment and supported each other to ensure a positive experience. The three students working for the multinational in New Delhi had similar experiences. They leaned on each other as they worked for different sections of the same company and used the evenings and weekends to explore their local area and where possible, beyond local areas. The other two students also working in New Delhi, who did not enjoy their internship experience found that they were bored, frustrated by lack of direction from the company; which in turn, made them want to quit the internship. These students returned earlier than planned. The company’s response to their complaint was that they should have notified the point of contact at HR of their concerns. The two students were also unlucky with the weather during their time in New Delhi. They also had a negative experience of a local transport driver wanting to swindle them. The students in Jaipur were somewhat frustrated by the pause in the construction on site. However, the female student made the most of her experience by finding an NGO in Jaipur and using her spare time to teach English to slum kids and other labourers on site.

The expectations of the internship on the part of the host and the students were not necessarily in sync. This disconnect between expectations of the discipline and the managers in the company was unexpected. When the researcher engaged with the companies, the nature of the undergraduate programme was explained, as also providing the companies student profiles so they could familiarise themselves with the students before selection. Students acknowledged that there was a general lack of punctuality, the work days were not always productive (a source of frustration), there were frequent interruptions with phone calls and the work place was quite lax with random converstions in Hindi with no accountability for deadlines. A student also reported that people slept at their desk whenever the manager was not around. Site labourers lived on site in poor conditions, a first time exposure for Australian students.

All students worked out of their comfort zone and preferred regular and more frequent check-ins during the week with their host managers/supervisors, wanted more responsibilities to be assigned to them by the host, and reported a general lack of structure compared to their experiences in Australia. From a cultural intelligence perspective as well as individual resilience, student’s capacities was tested, and the experience made some of them more resilient. The experience added to their skills. As noted in the literature on internships and study abroad, students came away with a value-add, both professionally and personally. The role of the host and the co-ordinator in building the relationship and nurturing the student is critical.

In terms of advise to future cohorts of students, getting immersed in the culture, embracing the experience, getting involved in understanding the work of the host company and enjoying the process as much as possible, and building on their soft skills of independence, adaptability, problem solving, communication across diverse stakeholders, finding things to do when bored (as demonstrated by the female student), having a peer to talk to and more interactions with the companies prior to travel to India were highlighted. Online meetings with all students and the coordinator was also suggested on a weekly basis. One student whose experience was ordinary said that in hindsight, it assisted him to better handle the situation with the pandemic in Australia.

5 Conclusion

The maiden internship experience of built environment students from an Australian university in India identified some clear positive experiences and some limitations. Due to the number of interns and hosts involved and the range of built environment disciplines, generalisations cannot be made. Yet, there are some lessons learned. Even with challenges, all students agreed that the experience was worth it and recommended the experience to other students. Interns had exposure to the country and culture, building their repertoire of resilience and cultural intelligence. It gave them a good insight into the building and construction industry, the challenges and limitations of working in the industry in India. It also provided a good understanding of the work culture. The negative experiences included; lack of transparency and clarity in the expectations of interns and host, poor planning and preparation by the host (bar one), mixed signals regarding points of contact when interns needed to talk to someone about their work/issues experienced, and lack of opportunities for understanding hosts and their culture prior to the commencement of the internship. Students also felt that they could have spent more time to get to know their mates before travel so they could support each other better.

There are some clear areas of improvement to consider for future internships to India. Clarity of expectations by host and interns and setting up a clear programme with periodic check-ins with the co-ordinator, host and interns would assist in managing expectations. Such regular sessions are helpful in raising any concerns between host and interns. Consideration on the part of the hosts to allow enough time for students to plan their travels would also assist. Even though a year was spent in planning the internships, many things such as letter of support arrived at the last minute making it difficult for students to avail off-peak fares. Online meetings between interns and hosts months before travel would also ease both parties into the internship and relationships will commence before travel. Having at least three (rather than two) students with one host was suggested as the optimal number by students for peer support (as 'someone is always around'). Giving students enough time at either end of the internship would also assist students to explore the country on their own and embed the bi-cultural understanding further. It was anticipated that longitudinal research with the second and third cohort of students supported by the NCP scholarship would provide a more rounded understanding of internship experiences of the built environment students. Unfortunately, the pandemic prevented subsequent cohorts of students to avail the scholarship and undertake internships in India. Nevertheless, it is anticipated that this research will contribute in nurturing not just built environment students but also other Australian students and their teachers in planning and implementing internships in India and other Asia-Pacific countries.

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Emerging Partnership Procurement Systems and Cost Management Strategies in a Cost-Reimbursement Environment – Lessons Learned from Megaprojects

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Abstract

There is a tendency to manage megaprojects using partnership contracts with cost-reimbursement payment methodology. There is a perception in the construction industry that cost reimbursement contracts underperform in terms of cost, there is no certainty of cost, and are very risky for the client. This is not fully true, and it entirely depends on the quality of the project and cost management strategies employed. An experienced Executive Cost Consultant with the support of the project team will be able to deploy effective management techniques to drive the cost down. This paper provides a best practice cost management framework and reports on the findings of 11 number of cost-plus contracts where certain cost management techniques were employed. It also reflects on the lessons learned by the practitioners through systematic means. There are certain cost performance evaluation systems suitable for megaprojects management. The systems include Earned Value Analysis and KPIs reporting of the Cost management consultant's performance. The outcomes of the systems can also be used to justify value for money in the partnership contracts. Measuring the level of collaboration between the joint cost managing team members will facilitate timely actions. The CM system used in partnership contracts can also be directly applied to traditional contracts. The knowledge shared in this paper will help fresh cost and project management graduates who are now increasingly working on Partnership contracts globally.

Keywords: Partnership, Case studies, Cost-reimbursement, Construction industry, key performance indicators (KPIs)

1 Introduction

The large and complex projects, with undefined scope of works and unidentifiable risks and uncertainties, highly benefit from the use of partnership contracts. This paper is written by practitioners with hands-on experience on the management of costs in several large partnership contracts.

Clear rationale for embracing new partnership contracting forms (both partnering and alliance types) is provided to assist the Employer in their decision-making process and support their business case and provide justifications to embark on this relatively new form of contract.

Based on case studies of 11 projects, it can be stated that by utilizing the partnership contracts the client could drive the construction cost down substantially (savings up to 10-15% of the construction budget is possible) and achieve other preferable outcomes/value additions if managed carefully and intelligently by an experienced Employer and his PM and CM teams.

The Employer and Contractor need to have right resources including human capital, systems, experience and organisational culture and commitment to embark on partnership contracts with cost plus arrangements. We have provided guidelines to effectively manage cost on Partnership Contracts with the objective of improving performance of the projects/programs or portfolio of projects via enhanced:

a) procurement system design and project/program or portfolio of projects delivery methodology, and
b) cost management system/framework, and techniques.

This paper captures the relevant practices and lessons learned from the cost plus contracts to share knowledge to continuously improve the cost management system. To enhance the performance of the system, the Employer needs to engage practitioners with prior experience in setting-up and managing similar contracts. The key role of the ECC on a cost-plus contract is explained in detail in this paper. The authors are certain that, an enhanced cost management system considering the lessons learned could be implemented on future projects.

The project cost management technique used in cost-plus contracts can also be readily applied on other projects procured through traditional contracting mechanisms with required amendments made to the selected suite of contracts and working out an effective relationship based operational model to put the partnership principles and cost management techniques to work.

The measurement of project cost management performance on large projects procured through partnership contract is recommended including KPIs to track Program/ Project performance as well as ECC's performance. It is also important to conduct regular Health/Pulse Check to detect prevalence of true 'collaboration' attributes among cost management team members. The collaboration is the key driver for pursuing partnership contracts and therefore, the level of collaboration needs to be measured at regular intervals. To measure this, an affective system developed by Walker, et al., (2015) is recommended.

1.1 Rationale for choosing Cost-reimbursement contract and Partneship approach

Based on the case studies, the key reasons for selection of partnership contracts are:

1) To avoid risk-pricing usually adopted by Contractors on large lump-sum contracts, 2) Due to lack of project scope definition and design as the projects are to be delivered in an uncertain environment, 3) Substantial risk exposures and unidentifiable/unquantifiable risks,4) To avoid disputes and claims 5) To accelerate the project delivery where early and certainty of delivery is of great value to the Employer, 6) Large pipeline of planned works and a delivery team with the required capabilities and capacity to deliver,7) The need to capitalise on the capcity and capabilities of a MC, 8) To achieve cost leadership and value generation, 9) The contractor's ability to use the financial ability of the Employer towards the project success, 10) Lack of available local resources/expertise to execute the proposed portfolio of megaprojects with major time-constraints, 11) To encourage the transfer of knowledge between international and local players, 12) To build capacity and capability of the developer's teams in Property Development, 13) To capitalise on the economies of scale resulting from repetitive projects and to drive the development cost down, 14) To enable the Employer to achieve down-stream integration of supply chains, and 15) The type of the procurement system and results match appropriately with Employer's and contractor's emerging business operating models while preseving their values.

1.2 Practical approaches to cost management in partnership cost-plus contracts

The best practice cost modelling (basis of the Development's financial appraisal), Cost Benchmarking studies, cost planning (A to D and PTE), cost checking and market testing of the rates (second CM layer), and cost control processes during the post-contract stage fit into overall cost management framework as shown in Table 1 below.

Table 1: A Cost Management Framework for a Cost plus contract (refer to **Appendix A**)

2. Literature review and Practice on Cost-plus contracts

Under cost-plus contracts the payment is not based on a predetermined contractual estimate of the fixed cost. The contractor is paid whatever the works costs him within the limits of the contractual arrangemets which will lay down the strict rules for the ascertainment of that cost via an open-book exercise between the client and the contractor (Davis Langdon LLP, 2007).

Walker (1969) who described target cost contracts as incentive contracts that provide a hybrid alternative to both the cost plus and fixed price contracts, because it offers greater negotiating flexibility concerning major design changes. A cooperative approach to the fixing of target costs was recommended, so as to reward a contractor for cost reductions while also eliminating the possibility of (contractor obtaining) excessive profit.

Under this arrangement the employer is at risk of the final cost increasing above their budget. However, the Employer needs a better control over costs and achieve certain level of 'cost' certainty for business purposes. An approach that balances the cost risk by splitting it between the employer and the contrator is the Target Cost Contract with pain/gain share arrangement which is a transition from the pure cost reimbursement contract and a further refinement to it. It creates incentives for the contractor to look for efficiency and reduces the costs. Thus, to set an appropriate target cost the Employers have introduced a market competion to select a construction partner based on an assessment of their submitted Target Cost Plans (TCP). This in turn drives the cost down while ensuring value for money. However, in some large projects, there is only a high-level budget at the time of the main agreement which sets out the commercial and operational rules. Then the parties will develop the design and prepare an appropriate TCP for each sub-project and follow the Gateway system to track the costs as design develops.
In some contracts, the initially ageed TCP will later be converted into a GMP and finally into a lump-sum contract over time based on a transparent open-book costing approach. In other cases the TCP will get revised based on the design development and risk mangement while the payment continues based on actual costs. In one case, based on the previous experience of working with a client on a target cost contract, the parties worked-out a GMP for a new similar project at the outset with further contractual and cost management enhancements such as ring-fenced preminiminaries and contractor's fees (to cover his over-head and profit margin). This explains a learning experience in the management of cost plus contracts and therefore, the idea for this research emerged to capture and disseminate the learnings for the benefit of the new practitioners.

3. Research Methodology

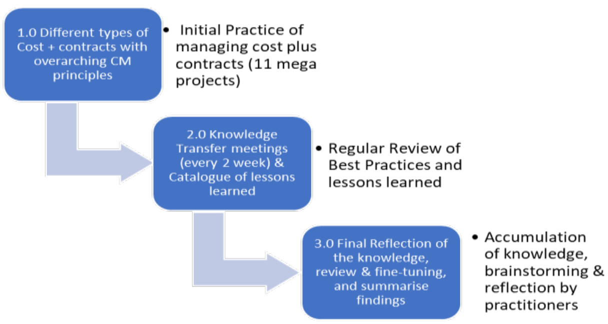

Figure 1: Research Method explanation

Due to lack of literature available on the cost management of cost-plus megaproject contracts, the technique of brainstorming among the practitioners is used. This is a reflective piece of research involving experienced practitioners who are systematically sharing their experience. As illustrated above, the idea is to systematically achieve a further optimisation of the cost management performance on cost-plus contracts based on the lessons learned by the practitioners.

4. Findings and Discussion

The ECC provides the Cost, Commercial & Contract Management services on a megaproject.

Members of the ECC teams will usually be embedded/positioned within the Contractor's pre and post contract teams on site and supported by Specialist Advisors/Cost Auditors (e.g., Central Procurement, Benchmarking, and FCA teams). The key responsibility of the ECC will be to manage costs and risks while ensuring the client's interests are protected.

4.1 ECC's Services on Megaprojects

ECC's services will be structured in the following ways:

- ✓ *Setting up Initial Development Budget (IDB) at Master planning stage.*
- ✓ Cost Benchmarking using their Cost Benchmarking Information (CBI) such as 'Should cost models'.
- ✓ Developing Target Cost Plan (TCP) with the contractor.
- ✓ Establishing target costs for trade packages (Sub-contracting and self-delivery) with the use of market tested cost information (e.g., using ECI/PCS) and elemental cost data.
- ✓ Implementing Value Management (VM) & Value Engineering (VE) initiatives.
- ✓ Assessing the contract Compensation Events (CEs) / Variations – The ECC will assess the variations based on CBI and validate the veracity of the CEs to enable the Employer to execute the CEs.
- ✓ Validation of Progress Payments (PP) – The ECC's team members who are integrated into the site project delivery team will review and approve PAs based on EVA and progress.
- ✓ Final Accounts (FA) – including review of sub-contractor's final account assessments, the expenditure of contingency funds, and pain/gain share (see below).
- ✓ Forensic Cost Assurance (FCA) Services – to ensure the actual costs incurred are justifiable and reflect the market prices based on their CBI. FCA team conducts reviews on the construction methodology adopted (such as Crane Strategy) and sign-off all the rates (e.g. hourly rates and unit rates).
- ✓ Management & expenditure of Contingency Funds - Figure 2 provides an example illustrating how the contingency fund mechanism is intended to work.

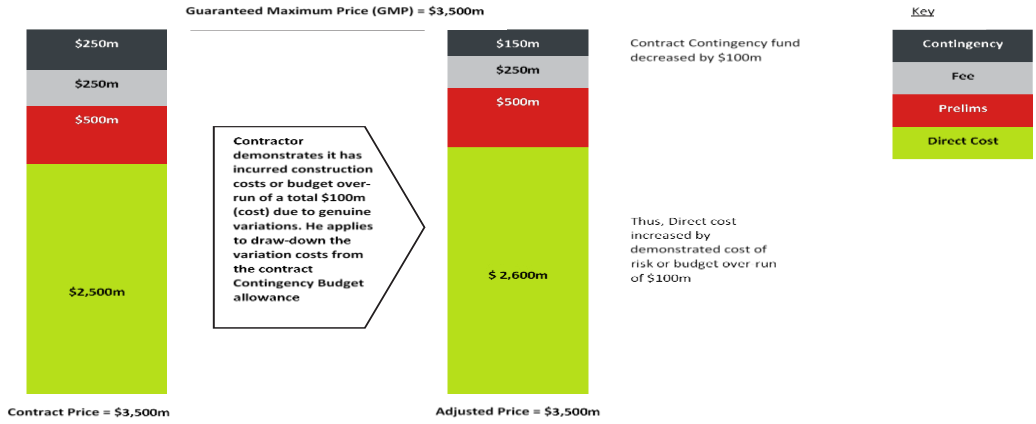

Figure 2: Management of contingency funds

✓ Sharing of project gains/pains under partnership contracts - Where the signed Final Statement shows that there have been Savings, the Contractor shall be entitled to be paid his share as per the contract clauses. The relevant mechanism is shown in Figure 3 below.

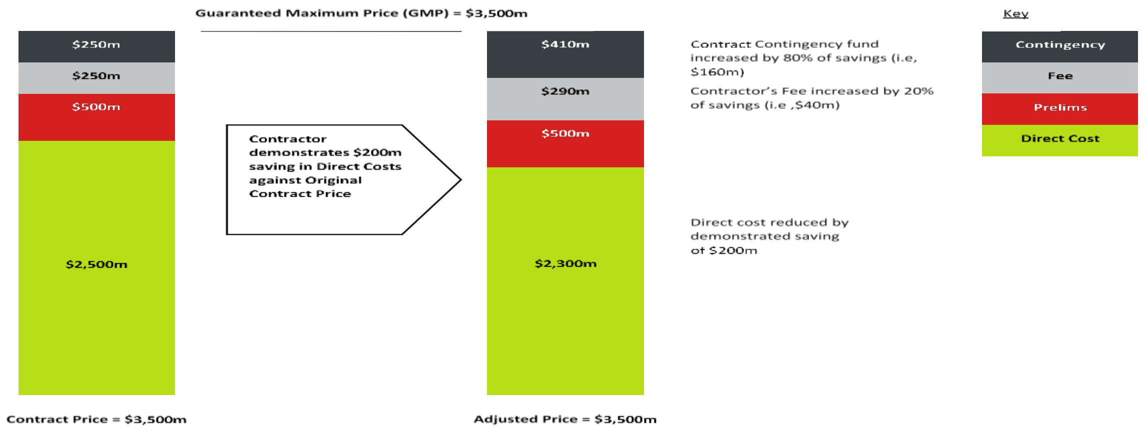

Figure 3: Contractor's share of demonstrated savings

✓ ECC's Performance & tracking Key Performance Indicators (KPIs) – Example, No of monthly commercial reviews carried out and associated savings.

4.2 Lessons Learned from Megaprojects procured through partnership contracts with cost-reimbursement payment mechanism

4.2.1 Types of Cost-Plus Megaprojects Contracts in use

There are three main types used in the case study projects are 1) Cost plus fixed contractor's fee (ring-fenced), 2) Fixed contractor's fee percentage (say, 5-7% of justifiable costs), and 3) Cost plus variable Contractor's fees percentage.

4.2.2 Creating cost certainty and incentive to save money with a GMP contract

Fixed price incentive contracts occur when the contractor is certain about the project scope, design solutions, its costs, and timelines. In a GMP contract, the project and costs are clearly outlined, and the contractor takes on the risk of completing the project on time and on budget. However, if the contractor can lower costs and generate savings, then the Employer may share with the contractor those savings as per the contract based on an agreed share (say, 50%/ 50% or 75%/25%). A competitive tendering mechanism can also be used to establish an appropriate GMP and VfM. Use Cost benchmarking to justify the cost and VfM.

4.2.3 Cost management techniques for a mega cost-reimbursement project

Based upon lessons learned from 11 case studies projects, the following best practices and techniques that have positive impact on the project cost performance are recommended for implementation.

a) *Tips for effective Administration of Contracts:*

- To establish a GMP for the contract to ensure that the cost does not exceed the limit and achieve certainty of outcomes.
- To ring-fence the preliminaries costs and contractor's fees, so that the contractor will not benefit from the increased package costs or project durations and will be compelled to control these costs and project schedule.
- To use competitive bidding to set-up the TCP and use IBI to verify the TCP and demonstrate VfM.
- To bring in a competitor into the picture to deliver a part of the project if required and increase performance (this is possible if you have a sole MC working on a megaproject and a part of it could be given to a large portion worth over $1bn).
- Employer's team to act consistently to maintain a competitive tension, suppliers' interests, and maximizing VfM.
- To incentivize the project outcomes (e.g. less the project costs and/or schedule better the incentives for the contractor) and share the gains as well as pains.
- To introduce a central procurement concept with the award of site wide procurement contracts based on competitive tendering for separate contracts (e.g. piling/excavation/formwork/post-tension/Lifts/Curtain walls/Doors and Windows/paint/tiles/marble/sanitary & kitchen appliances, etc).
- Both the Employer and the contractor shall be jointly taking procurement decisions and participate in tendering and negotiations with the help of cost benchmarking exercises.
- Market price testing of all rates shall continue throughout the contract period (using ECI/PCS), and agreed rates shall reflect the CBI.
- It is a good practice to produce a Project Contract Administration Manual (PCAM) document to guide the management of the costs and setting principles.
- It is recommended to set-out what costs are disallowable (thus, not to be reimbursed) and design the dispute escalation process.
- As a standard procedure for settling final payment, Financial and Forensic Audit Reports shall be prepared and adjustments made to the Contractor's Statement at Completion and release Draft Close-out report to the client and his financial team.
- The CA working jointly with the MC shall make interim awards on substantiated and verified cost and EoT claims to sub-contractors. Meaningful proactive efforts shall be made by the Project Team to avoid disputes and their effects on the project's good progress.

b) *Tips for achieving Economic Efficiency:*

- The project team and ECC shall carry out the design economics studies for vetting the design proposals that are not cost-effective using benchmarks and elemental costs breakdown.

- The contractor shall be encouraged to lock-in the prices of major commodities (e.g., rebar, cement, concrete, paint, tiles, sanitary wares, steel bridges etc) based on the forecast of market trends with the approval of the Employer's team (incl authorization of additional 'on-account' payments).
- Contracts shall include provisions that allow MC to place orders on long-lead items that are on the critical path to fast-track works on site and avoid delays.
- Contractor's operations on site shall be monitored such as off-hiring of the plant (such a cranes and formwork systems/scaffolds) and material usages and actions taken.

c) *Tips for effective use of BoQs and Unit Rates:*

- A back-up priced BOQ to be incorporated into the contract to support TCP and EV should be tracked monthly at the time of progress payment assessment.
- The BOQ shall include cost of preliminaries in detail and the preliminaries could be ring fenced (fixed element).
- The BOQ rates shall be agreed with the MC in the Labour, Materials, Plant and Sub-contractors format to effectively manage the TCP and costs.
- The sub-contract packages should also have a priced BOQ to support pricings.
- Contractor's or industry standard norms shall be used in pricing the BOQ (such as labour productivity, wastage allowances etc) and they shall be stated clearly in the contract document and agreed between ECC and MC. These productivity rates to be monitored.
- The BOQ shall provide staff details under preliminaries identifying staff positions, all-inclusive rates and setting out an overall staff budget.
- The all-inclusive labour rates should be part of the unit rates, but additional information setting out the total hours for each category of the labour and overall labour budget figure for review and monitoring.
- Contractor's fee shall be defined to indicate what shall it cover and it is deemed to cover entire contractor's over-head (site and head-office) and profit margin.

d) *Tips for Management of the Contingency Sums:*

e) A contingency sum with full break-down shall be allowed within the GMP (preferred option) or maximum price or TCPs.

Table 2: Breakdown of the Project Contingency allowances

	Items	**Allowance ($)**
1	Design risks and uncertainties (Services Diversions, latent ground conditions etc)	
2	Procurement risks and uncertainties (S/C poor performance and need to bring in additional S/C to share the works)	
3	Construction risks and uncertainties including pre-existing environmental conditions and site contamination	
4	Commissioning risks including temporary supply of power with generators and uncertainties	
5	Price Escalation on Major commodities and materials	
6	Possible need of Value Engineering	
7	Temporary chilled water supply and wild air supply to protect joinery works from humidity	
8	Prolongation costs (MC & S/Cs)	
9	Disruption and acceleration costs (MC & S/Cs)	
	Total $	

- Definition of the Contingency Sum shall be provided in the Contract.
- Conditions to access the Contingency Sum shall be stated in the Contract. Employer's approval shall be sought before accessing the contingency sum.

f) *Tips for Management of Design Costs:* Details and breakdown of the design fee shall be provided including budget fees and with the names of possible sub-consultants.

Table 3: Break-down of Design Fees

	Design Items	**Fee Allowance ($)**
1	Architectural design – AR Architects	
2	Engineering design (Structural, civil and MEP Services) - PKE	
3	Specialist design services (e.g, Landscaping, interior design, special lighting, smart homes, etc) - NMD	
4	Construction method design (CMD) – ABC Eng.	
5	Any other special services (TIS, Geo Tech, Site acoustic studies, Environmental studies, Pre-construction services, 3rd Party Design Checker, Special Tests & Studies etc) – Budget only	
6	Travel costs including factory visits – Budget only	
7	Any authority fees and disbursements – Budget only	
	Total Design Budget $	

- The cost reimbursement contract for consultants also should be drafted to limit the reimbursements of expenditures such as working from overseas, factory visits, hotel stays and travelling. The consultants should obtain expressed approvals from the Employer's representatives before embarking on any overseas visits.
- Consultants' contracts shall state the staff types and salary levels. and Employer's approvals shall be sought prior to deployment.
- The consultants' contracts shall define the normal hours of working per day, week and also include hourly/daily/monthly rates to be used during the post-contract period.

g) Tips for managing Procurement Strategy:

- A procurement strategy for sub-contracting should be agreed with the contractor including Tender Adjudication process and the selection criteria for every package.
- To limit the number of self-delivered work packages. If the MC's self-delivery of a package is approved, the MC must compete with other S/Cs and quote Lump-sum amounts. The resources allocated to this self-delivered package and costs will be tracked separately using an electronic recording system.
- The Contractor shall regularly update their Procurement Strategy document including the list of sub-contractors and their tender prices/tender awards & award values.
- The consultants should make sure that the contractor does not force a design solution with a sole supplier option for cost significant packages which limits their ability to obtain a competitive price and affects the negotiation process to reduce costs.
- Every sub-contractor should be approved by the ECC.

h) *Tips for managing Suspension of Works:* The contract or PCAM shall clearly establish the rules for the Administration of the suspension, contractor's entitlements, and payments.

i) Best Cost Management Practices (Getting the 'First Principles' of Cost Management right):

- Regular knowledge sharing meetings to be held between staff and management.
- The contract shall have a provision to enable conversion of the cost-reimbursement contract from TCP into a GMP, and GMP into a lump-sum contract as design develops.
- A procurement schedule should be monitored on a weekly basis to achieve anticipated schedule performance, manage claims, and assess culpability of sub-contractors for concurrent delays.

- All sub-contracting packages should be competitively tendered amongst at least minimum 3 sub-contractors unless there is a valid reason behind the sole source procurement and the associated RTA is to be approved by ECC and Employer.
- Risk assessment (such as MCS) shall form part of the Tender Evaluation process for every key Sub-contractors.
- Project-wide EWS to identify and assess risks.
- A smart use of WBS and coding and CBI. The WBS coding also helps compare development costs across various projects based on elemental rates and design efficiency.

5. Conclusion

The paper identifies project characteristics that warrant partnership contracts with cost plus mechanism for effective cost management and highlights the relevant best practices.
As a minimum, megaproject cost management process during the pre and post-contract periods shall include best practice initiatives such as:

- Setting-up Employer's Initial Development Budget (not-to-exceed budget).
- Establish a robust procurement strategy and policies.
- Develop a pre-purchase plan for long-lead materials and equipment and lock-in prices.
- Tender evaluation (especially the main construction contract) is to be supported by a comprehensive risk assessment (e.g., MCS) to make informed decision & selection.
- Implement a comprehensive Risk Management plan with an active EWS.
- Implement a robust Change Management process including an effective EA process.
- Maintain a live and real-time updated AFC.
- Implement a robust Claims and Dispute Management action plan to protect progress.
- Prepare Monthly cost reports based on Contract Reviews with EVA and comparison.
- Explore VE Options with project teams and sign-off the VE reports.
- Employ Central Procurement system across portfolio/program of projects to capitalise on economies of scale in mass purchase and lock-in prices early.
- Prepare Project Evaluation and Close-out Reports and develop CBI.
- Maintaining full cost audit trails from the initial MP stage up to the FA stage.
- Applying the special techniques and features of partnership to traditional lump-sum/D&B contracts.

The paper also recommends carrying out a regular health check on level of 'partnership' / 'collaboration' between cost management teams facilitated by experienced team building experts. This is critical and as seen in the case study projects, the ambition levels change over time affecting the CM performance which must be rectified as soon as possible. The outcome of such audit may lead to targeted actions such as training on how to effectively mount cost challenges while preserving the relationship and work as one-team which is critical.

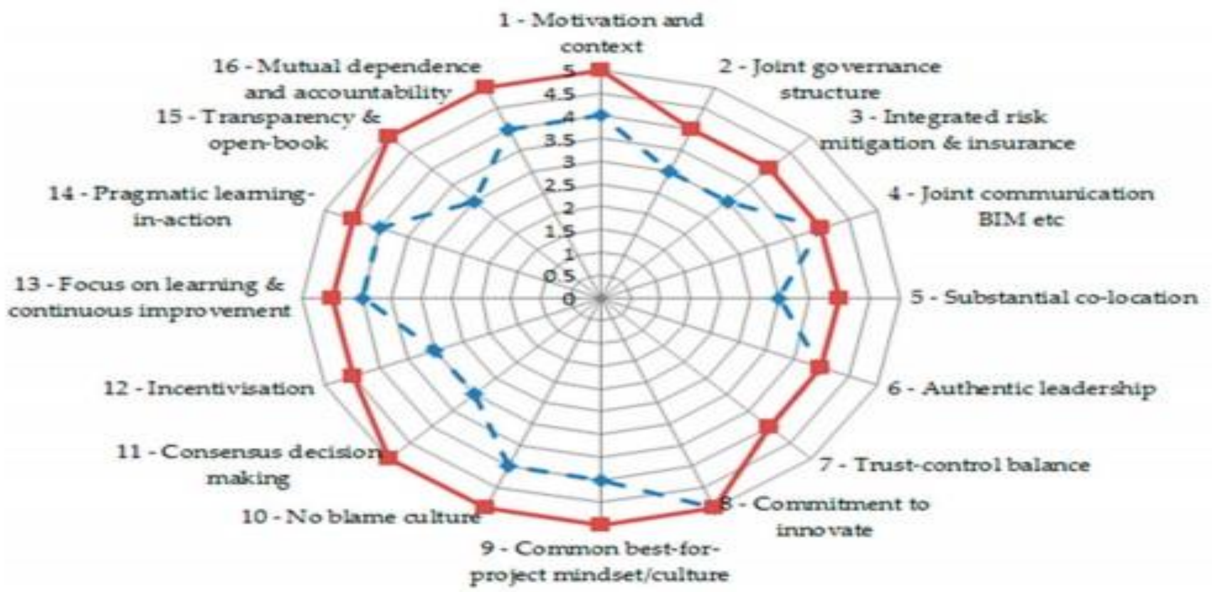

Figure 4 - Level of partnership and collaboration assessment tool (source: Walker et al., 2016)

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Acronyms and Abbreviations used in the paper

AFC	Anticipated Final Cost	ECI	Early contractor involvement	KPIs	Key Performance Indicators	PM	Project Management
BOQ	Bills of quantities	EVA	Earned Value Analysis	MC	Main contractor	RM	Risk Management
CA	Contract Administration	EW	Early works	Mgt	Management	SC	Supply Chain
CE	Compensation Events	EWS	Early warning stsyem	MP	Master Plan	SoW	Scope of Works
CBI	Cost Benchmarking Information	FA	Final account	MS	Master Schedule	SFA	Statement of Final Account
CM	Cost Management	FCA	Forensic Cost Assurance	MCS	Monte Carlo Simulation	S/Cs	Sub-contractors
CMD	Construction method design	FS	Feasibility Studies	PCAM	Project contract asministration manual	TCP	Target cost plan
DD	Detailed design	GWP	Gateway Process	PCS	Pre-construction services	VfM	Value for money
EA	Employer's Approval	GMP	Guaranteed Maximum Price	PP	Progress Payment	VE	Value engineering
EoT	Extension of time	IDB	Initial Development Budget	PTE	Pre-tender estimate	WBS	Work breakdown structure
ECC	Executive cost consultant	JV	Joint Venture	PMC	Project Management Consultant		

APPENDIX A, TABLE 1 (REFER NEXT PAGE)

Project Stage	Inception/ Concept	Schematic Design	Detailed Design	Tendering & Contract Award	Construction	DLP / Close-out
Project Objectives	• Establish & Verify the budget through benchmarking (Cost per m2 and Elemental CP) • Developing the 'should cost' model (tool for checking design economics) • Finalise the relevant gateway documents	• Development of Elemental cost plan against 'should cost' model • Cost checking & market testing rates – ECI/PCS • Maximise Return On Investment and Increase Value for Money (VFM) • Finalise the relevant gateway documents	• Drive out waste. Achieve optimal value • Refine and optimise the design including Design Economics • Finalise the relevant gateway documents	• Produce tender documents for each contract packages. • Tender evaluation, risk assessment, negotiation and award of contract by due date as per Master Schedule • Finalise the relevant gateway documents	• Undertake regular valuations, assess progress and cost workshops to identify and agree variations. • Manage changes & cashflow forecast • Establish project controls around cost and change management • Avoid disputes and smooth transition • Manage project cost and exercise cost control	• Assess and finalise variations, back-charges and final accounts • Negotiate disputed variations • Help Client negotiate final accounts by producing guidance / assessment options • Target final account agreement within 3 months • Record lessons learned and project background infor.
Executive Cost Consultant's Tasks	• Exploring alternative projects with preliminary outline concept design and Master Planning & DE) • Design Economic studies & parameters benchmarking • Contract Type Advice • Master Planning inputs & VE options suggestion • Advise on the optimum mix of assets (Early income streams / less risks / ready finance) • Procurement Strategy and Packaging of the works (E&EWs, Main Package of works, and NSCs etc) • Set up integrated Cost Model jointly with Finance • Appoint MPs, Designers & PMCs (Tender evaluations) • Set Initial Develop Budget (IDB – Not to exceed & risk adjusted). • Cash-flow forecast • Other preliminary estimates to verify the budget • Tendering of E&EWs and advance works packages to gain programme advantage • Develop cost mat policy and framework for JV contract • Develop TCP, Benchmarking & verification • Develop Risk management system with EWS and Mitigation Plan	• Procurement advice • Contract advice • Elemental cost plan • Capital cost advice • Cost studies of alternative design solutions / products • Life cycle cost advice • Contractor prequalification • Set Cost targets for Key Trades/elements for design guidance • Risks management advice and system • Assessment of finance alternatives and Financing plan advice • Advice on cost range of pre-fabricated products (DfMA) and suppliers • Continuous risks management • Updating contingency allowances in the TCP • Updating IDB (risk-adjusted) including development contingencies	• Contract advice • Procurement advice • Cost checks against the should cost model and optimum design / design to cost • VE studies of viable alternatives • Identify cost savings • Pre-tender estimates • Advice on procurement strategies • Preparation of BoQs • Reinforce cost targets of Key Trades with the designers • Continuous risks management and updating / contingency allowances in the TCP • Updating the cost plans and IDB (risk-adjusted) including development contingencies	• Contract advice • Procurement advice • Prepare tender documents (TDs) & review TDs • Assist in preparing the contract terms and negotiation of terms & conditions • Assist in preparing contract forms and schedule of unit rates / labour rates for Post-contract variations assessment • Finalise PTE for tender comparison & evaluation • Commercial tender evaluation report and risks pricing / excluded items pricing • Assist in negotiating lump sum prices & Priced BoQ • Assist in the assessment of risks attached to each tender & Tender Evaluation • Prepare contract documents • Continuous risks management and updating / contingency allowances in the TCP • Updating the Contingency	• Contract advice & Variation Order preparation • Value the work in progress and cost-to-complete and Certifying payments • Estimate changes and prepare contractual basis and EAs documents • Measuring and valuing variations & negotiation • Earned Value Analysis • Attend progress and co-ordination meetings • Contra charge procedure, Disallowable costs • Risk analysis support for assessment of the Tenders received • Monthly cost reports highlighting best case, worst case and most likely case in terms of AFC / Anticipate Final Account for packages / KPIs report • Red flag contractual matters • Settle disputes • Assist on claims assessment • Assessment of cost of defects • Risks assessment and management of contingency allowances • Prepare Draft-Final account and negotiation	• Updating the AFC • Contractual & claims Advice • Schedule for final A/C settlement • Negotiate final A/C • Present final account • Update cost models & Benchmarking reports • Finalise and submit Project Evaluation report in terms of lessons learned from costs management point of view • Cost reconciliation against the IDB, Financial appraisal, and performance of the Risk / Contingency Management • An assessment of Cost Variations to classify them into main root causes (e.g client changes, authority, design gaps, scope creeps, etc) • Assist in setting up O&M contracts (e.g., asset register, maintenance cashflow, etc) • Full development cycle cashflow forecast • Assist on tax and insurance matters

Emerging Risk Management Approaches on Mega Construction Development projects – International Case Studies

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Abstract
The main purpose of this research is to achieve optimum mega-project outcomes through adopting a smart risk management system. A case study approach was adopted. A review of 65 projects identified 10 Main Risk Categories for further analysis. Of these, 10 representative case studies were studied further to gain insights that can be applied in the future projects. Of the top 10 Construction Risks, the risks such as scope, design and quality management risks; construction & SC management risks; force majeure events & VUCA market risks; and procurement & contract design risks occurred more frequently than others. The remaining six risks are: schedule and cost overrun; authority approvals and environment; contractual claims and disputes; client's BM and PM expertise; client's leadership, project governance, and oversight; and project finance. Though those six risks did not occur across all 10 projects, but the management of these risks is also critical for the success of a hypothetical Megaproject. Of the risk mitigation strategies employed, the Front-end focused risk management involving BM, PM, and Procurement Management are the most impactful. It is imperative to devise strategies to manage risk at the critical tender evaluation and procurement stage to inform the key 'partner' selection decision. It is also found that not only the project level risk management strategies, but also program/portfolio level project management and risk management approaches are most effective and the client's PMs effectively utilise various best practices in this regard as documented in this paper. This research finding is important as a force-majeure event tend to happen on almost every Megaproject which needs to be understood and well prepared for by the PMs. Further research involving more Megaprojects and an in-depth study in any specific area (e.g. procurement, and post-contract risk management) could be undertaken.

Keywords: Business Management (BM), Construction, Case studies, Project Management (PM), Risk Management (RM).

1 Introduction

Mega Construction development projects are large size, complex, and volatile projects which are valued at US$1bn and over. They are often executed in a VUCA environment.

The Megaprojects are considered to be the most complex of all the various types of projects (Sanchez-Cazorla *et al.,* 2016). If you are able to manage risks on Megaprojects, that knowledge is special and can be effectively used to manage risks on any other complex or even medium size projects.

The mega and complex projects often exceed the established baselines with only one in thousand Megaprojects achieved all of their established cost, time and quality objectives (Flyvbjerg, *et al*., 2003). As the risk management is an integral part of Project Management (Burcar, *et al.,* 2013), the Project managers often use visualisation techniques to help understand the severity of the risks (e.g., colour light system as shown below) for providing schedule progess and cost status information. The well known saying 'a picture is worth a thousand words' is no less true than when communicating a project's risks, progress, and current status.

Table 1: Colour Light system to flag risks (A sample)

1. Development Budget (DB)		
1.1 Overall Budget	Based on the review of the DB submissions, it can be confirmed that the proposed budget is comparable with other 5-star hotels in the local region. Due to provisional sums in the agreed contract with the main contractor cost certainty on the development will only be achieved once these provisional sums have been firmed-up and relevant variations issued.	Medium
1.2 Risk of Loss and expense claim by the Main Contractor	It is understood that there is a potential risk for an extension of time and loss & expense claim from the Main Contractor as a result of client led changes/instructions. In the event that this issue is not resolved there is a potential risk of a dispute between the developer and the Main Contractor which might affect the progress of the works.	High
1.3 Developer's Contingency.	The current available contingency amounts to $ 300m which is 15.8% of the overall development cost to complete and 23% of construction cost to complete, which is considered sufficient to cater for any unforeseen variation costs during the period remaining.	Low

The best projects showcase the Project Management ability to manage risks more effectively, which in tern contrubutes toward positive outcomes (and benefits) and results in safer projects, lower costs, and projects being completed on time (Grieman, 2013).

Despite the industry's urgent need, the risk management research on Megaprojects is not sufficient and this area continues to be an area of Project management research that is still developing and expanding (Sanchez-Cazorla, *et al.,* 2016). Thus, we consider this research to be impactful.

Ten (10) detailed case studies have been conducted to achieve the results reported in this paper. While the seven case studies were in-depth studies based on practitioner's observations, the three case studies were based on published information including Government Auditors reports, business cases, project reports, and newspaper reports (investigative journalism). The costruction delivery of seven case study projects have already been completed and the remaining three are currently in progress.

A snapshot of the risks and their frequency has been analysed and mitigation measures adopted by the PMs have been highlighted.

It is perceived that due to the size of these Programs and multiple projects executed under each of the these programs, the Risk Management activities that were undertaken on those projects sufficiently provide a cross section of the similar approaches and practices deployed on simlar Mega Construction projects irrespective of their location. It is believed that there is no locational effect due to multi-national/international project managers involved in the oplanning and delivery of those Megaprojects with more or less the same level of Risk Management and Project Management knowledge, training and experience. The project environment and the calibre of the client and his supply chain (consultants, contractors, sub-contractors, etc.) also the same.

2 Theoretical and Practical approaches to Megaproject Risk Management

2.1 Definitions of risk and risk management

Risk is the effect of uncertainty on objectives (ISO 31000:2009). On the other hand, the Risk Management can be defined as 'the systematic process of identifying, analysing, and responding to project risk/risks'.

2.2 Identification of construction Megaproject risks

A research by Sanchez-Cazorla, *et al.,* (2014) identified nine main categories of Megaproject risks such as design, legal and political, contractual, construction, labour, clients/users/society, financial and economic, operation and maintenance, and force-majeure. Of which, the construction risks take prominence and are encountered most on Megaprojects. A research by CII (2016, cited Deloitte

2016) has identified 107 top construction risks while this research has identified and developed a comprehensive list of 200 Megaproject risks (which are grouped into 10 main categories). On Megaprojects, an Early Warning System (EWS) is effectively used to provide warning and initiate the risk management process. An EWS is effective when a joint mechanism for the management of risks is adopted by the project team members.

The Table in Appendix A identifies the sub-elements of the main 10 risks that are encountered on the Megaprojects based on the reflection and the review of the risks identified through the EWS adopted on such projects.

Refer to Appendix A: 10 Main risk categories and elements (Note: the list in not exhaustive).

2.3 Risk Management and Transfer stage

The transfer of risks to various stakeholders is an important action in the risk management process for which a 'risk matrix' tool can be used to analyse who would be best placed to manage a particular risk (Sanchez-Cazorla *et al*., 2014).

2.4 Risk analysis stage

The qualitative risk analysis method used in Megaprojects include use of risk check lists, giving a risk rating and impact expressed simply as low, medium, and high (see Table 2 below), and scenario planning.

Table 2: A Qualitative Risk Assessment (A sample)

Item	Identified Risks	Risk Rating	Impact	Risk Owner
1	Client's design changes	High	Medium	Developer
2	Late design deliverables	High	High	Developer
3	Design cost increasing	Low	Medium	Developer
4	Development Budget Increasing	Medium	Medium	Developer
5	Construction Budget increasing	Medium	Medium	Developer
6	Client's Procurement Changes	Low	Medium	Developer
7	Contractor's Procurement delays	High	Medium	Contractor / Developer
8	Authority approval risks	Medium	High	Contractor / Developer
9	Dispute between developer and Main Contractor	Low	High	Developer
10	Business Management & PM	Low	Medium	Developer
11	Project Governance	Medium	High	Developer
12	Finance	Low	Medium	Developer
13	Force-majeure events	Medium	High	Developer
14	Construction and supply chain	Low	High	Contractor / Developer

The popular quantitative risk analysis methods used are Severity Assessment (= Potential Impact $ equivalent x Likelihood (%) to arrive at a $ equivalent risk allowance value) and MCS.

The qualitative and simple quantitative assessments are usually carried out by project teams alone whereas the advanced MCS is usually carried out by the experienced Risk Management professionals. MCS is commonly used to develop and present the initial development budget and / or contingency allowance, master schedule/programme, and facilitate tender evaluation and selection of project partners. The information derived from MCS can be used to support decision-making and make an informed decision.

2.5 Risk Response Planning and Execution strategy

As per Webb (2003), there are six (6) popularly cited risk response strategies / principles available. They are: 1. Risk acceptance 2. Risk avoidance, 3. Risk reduction, 4. Risk mitigation, 5. Risk transference, and 6. Contingency provision.

Based on the risk response strategy or combined strategies, the action plans will be developed and implemented by the project team.

2.6 Monitoring and Control - the role of Visualisation Techniques

This process is supported by the continuous functioning of the EWS to flag any new risks (e.g., on a Megaproject over 500 number of such risks appear during the post-contract stage alone). The PMs use visualisation techniques to portray the project's current progress and status. Such example is shown in Graph 2 which will trigger management action to manage the schedule.

The monitoring is also carried out via tackers (e.g. AFC, Authority approvals, Design deliverables, Procurement schedule, EVA etc) and contract KPIs which plays an important role in the risk monitoring & control process. This information is also fed into functioning MIS for the attention of the top management.

Refer to Appendix B for Graph 1: Project Programme Status Visualisation (An Example).

2.7 Analyse, Evaluation and Feedback stage

Though this is an important step, this process is often neglected. The objectives of this best practice are to draw useful lessons and insights, collect information, and develop better tools and techniques to fine-tune and continuously improve the RM processes. This should be an activity carried out during and at the end of a project (close-out stage). It must be a continuous learning process that transfers knowledge across projects and organisations. It will trigger a timely and meaningful action which will benefit Megaprojects.

2.8 Previous research findings that support the Megaproject risk management research initiative

There seems to be consensus pertaining to the poor performance of Megaprojects (Flyvbjerg, *et al*., 2003). The Project Management community is still struggling to find consistent ways to improve the performance of Megaprojects (Soderlund, J *et al.*, 2018).

There is urgent need for research, not only revealing and documenting the many challenges associated with the management of Megaprojects but, equally, more knowledge about how to cope with them (and risks), how to build management capabilities, and how to improve the cooperation and coordination within (organisations and stakeholders that are involved in) Megaprojects (adapted Soderlund, J *et al.*, 2018).

Getting more into the actual occurrences and the nested processes of managing and organising in Megaprojects are critical concerns for management and organisation studies (Davies *et al*., 2017).

This research adopts an 'inside' perspective of the Megaproject risk management initiatives (with a more 'inwardly and outwardly focused' approach) rather than looking at those projects solely from an 'outside-in' perspective which is risky. The latter approach was similar to looking at a black-box of Megaprojects and making observations/judgement without really understanding and knowing the broader details/contexts/environments of the case studies and thus, the latter approach was criticised by Soderlund *et al*., (2018). Soderlund *et al*., (2018) recommended that the Megaproject researchers shall investigate and carryout longitudinal studies about Megaprojects.

Once the likely risk events are identified, and their impacts and probabilities are assessed, in order to reduce their likelihood of these risks causing the Megaprojects to fail, specific management actions have to be taken that involve the implementation of mitigation measures (Flyvbjerg, *et al*., 2003) and action plans.

3 Research Methodology

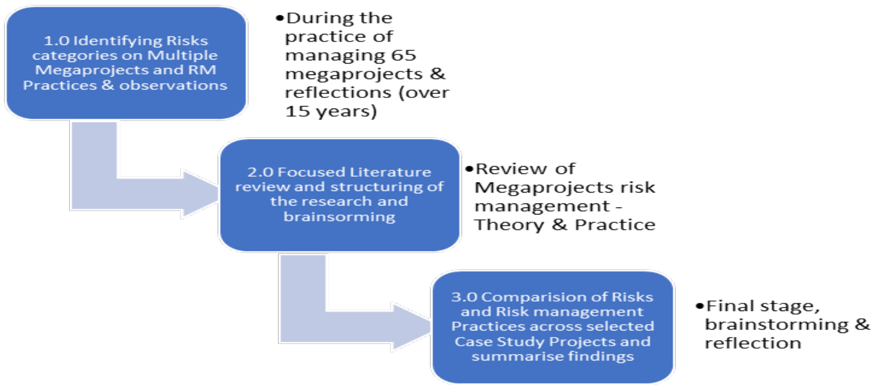

Figure1: Research Process mapping

3.1 Purposive Sampling Research Method

Purposive sampling (also known as judgment, selective or subjective sampling) is a sampling technique in which researcher relies on his or her own judgment when choosing members of population (in this research, the 'case studies') to participate in the study. Purposive sampling is a non-probability sampling method and it occurs when "elements selected for the sample are chosen by the judgment of the researcher. Researchers often believe that they can obtain a representative sample by using a sound judgment, which will result in saving time and money (Black, 2010) and improve efficiency and effectiveness of the research".

We have exercised due diligence to minimise the effect of the stated disadvantages and associated criticism made of the 'Purposive Sapling' research method, which are: **a) vulnerability to errors in judgment by researcher** (Research Team Response - Probability of this limitation has been minimised as the main researcher has 25 years of industry experience, he is a due diligence practitioner for over 15 years, and he is a RICS trained Chairman/Assessor of their APC Panel where professional judgement is critical), **b) low level of reliability and high levels of bias** (Research Team Response - In this research, the possibility of this issue is almost zero, because the researcher is personally involved in the Case Study Projects and can corroborate the data, and the researcher has used his professional, brainstorming, and reflective skills to increase the reliability and reduce potential bias), and **c) inability to generalize research findings** (Research Team response **-** in this research, the 10 selected cases were derived from 65 cases in the research pool after a risk mapping exercise and thus, this research addresses this criticism and the selected 10 cases provide a cross sectional analysis of the risks encountered and the risks management methods and initiatives implemented).

3.2 Case Study Research Methods and why this Case Studies research method was selected?

The decision was made based on the literature review and the professional judgement as to the effectiveness of the Case Studies methodology to capture and disseminate risk management knowledge. The Case Study method accurately captures the exact project context and environment in which the risks emerged, and the identified mitigation measures were implemented. There remains a dearth of detailed stories (and case studies) of major projects. We need to know what goes on in Megaprojects – how they are managed and organised, from within, by the managers who are tasked with bringing them to fruition. We rarely compare Megaprojects with each other (Soderlund, *et al.,* 2017).

3.3 Why 10 Case Studies (not more or less)?

Based on the review and analysis of 65 Megaprojects and a list of risks encountered on those projects, we could select 10 Megaprojects case studies that provide a fair representation as to the risks normally encountered on such projects (a risk mapping exercise carried out at the inception ensured we study the right projects in detail). Subsequently, we have captured the relevant risk management strategies employed on those 10 projects to effectively tackle those risks. The scale and size of the projects was an issue that impacted on the number of case studies selected. These are Megaprojects and as such, they are very large systems to study (e.g., one Case Study CS1 project was considerably large and worth over US$25bn). The time constraint was also an issue that led to the selection of 10 case study projects for further analysis. There have been studies in recent past on Megaprojects Risks involving both actual case studies (Alfaela-Luque, *et al.,* 2015) (but 'small scale' – the emphasis added) and focused literature reviews (Denicol, *et al*., 2020 & Sanchez-Cazorla, *et al.,* 2016) which this research study considers and benefits from to some extent.

The data collection was made based on the principal researcher's personal knowledge about the Case Study projects and professional reflection. The case study selection was made considering the potential lessons that they provide in respect of the identification, project context and complexities, and risk management methodologies to achieve this research objectives. In construction, though there could be a small number of risks that could be associated with different sectors (e.g., such as buildings and infrastructure sectors) and project location (such as Industrial Relations in Australia) the profile of the risks is more similar across the sectors. For an example, the environmental risks are more prone to occur on infrastructure projects (such as the CS8, CS9 & CS10 projects) than building projects (such as CS1 to CS7) due to the Mega infrastructure projects covering a large extent of land areas compared to the building projects. At the same time, the risks such as scope and design changes, procurement and contract design, contractual claims and disputes, etc are common for both sectors. Thus, it can be stated that, a research study on Megaprojects risks and management strategies could be undertaken across a spectrum of building and infrastructure projects. A such research could also provide new insights as to the specific risks associated with a particular sector that will be of interest to the construction research community. This is the rationale for selection of diverse case study projects across the sectors. The data analysis was carried out using the risk mapping technique, brainstorming and the use of checklists to identify risks and similarities in respect of Risk Management strategies among the case studies covered. The qualitative analysis was adopted, due to a small number of projects and case study research methodology selected. But the study and analysis are in-depth in respect of the risk management study and subject area to arrive at a full profile of the risks and the relevant risk management strategies. The finding of the top risks is based upon a simple quantitative method of counting which risks occurred on which projects and the objective of this research is to report on the risk management strategies more than the pure identification of the risks. There is a recognition amongst the Megaprojects practitioners that the risk management task is the main task for Project Managers on Megaprojects as their key responsibility is to ensure that the project is delivered as planned and meeting the accepted project baselines as per the approved Business Case. Despite the importance, the risk management strategies are not properly exposed in the past research studies as the case studies of Megaprojects tend to be shallow, mostly carried out external researchers with less understanding about the project ecosystem, and as a result, the research studies are not clearly exposing the useful knowledge about the various risks management strategies adopted by the team of multiple Project Managers engaged within the Megaproject environment. This study attempts to fulfil such critical requirement.

4 Findings and Discussion

Refer to **Appendix C** for a summary of case study details.

The above appendix provides a summary of the project details to understand the scale, complexity, and project environment. Through the above case studies, we have identified 10 tops risks that were more frequently encountered on those construction development projects at the time of PM's involvement. Table 3 below provides a snapshot of the identified risks across the case studies and their frequency among a small group of Megaprojects. The research identifies scope & design changes, construction & supply chain management, and force-majeure events and VUCA market as the three most factors encountered on Megaprojects and they presented considerable challenges to the PM teams. Thus, a key take away is that all Megaproject practitioners need to be aware of the force-majeure events that risk almost every Megaproject and develop an educated risk mitigation plan to manage the relevant risks proactively.

Table 3 – Frequency of the identified risks on Megaproject case studies (the score '1' against the Case Study project here represents the fact that 'yes' the particular risk materialised on the project and '0' represents the risk did not affect that project)

Risk Group No.	Top 10 Risk Categories identified and anticipated	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9	CS10	Total	Rank
1	Schedule and cost overrun	1	1	1	1	1	0	0	1	1	1	8	3
2	Authority approvals and environment	0	1	1	1	1	1	1	1	0	1	8	3
3	Contractual claims and disputes	0	1	1	1	0	1	1	1	0	1	7	4
4	Scope, design changes and QM	1	1	1	1	1	1	1	1	1	1	10	1
5	Procurement & contract design	1	1	1	1	1	1	1	1	1	0	9	2
6	Client's Business management and PM expertise (pre and post contract)	1	1	0	1	1	1	1	1	0	1	8	3
7	Client leadership, project governance and oversight (post-contract)	1	1	1	1	0	1	1	1	0	0	7	4
8	Project finance	1	1	0	1	0	1	1	0	0	1	6	5
9	Construction & SC management - CM, Resources, HSE, Operation and SC Mgt, and SC Bankruptcy	1	1	1	1	1	1	1	1	1	1	10	1
10	Force majeure events & VUCA market	1	1	1	1	1	1	1	1	1	1	10	1
											Total	**83**	
											AVG	**8.3**	

Except the Project Finance risk (Risk Group No. 8) which received total weighting of 6, all other nine risk categories received weighting of 7 and above which indicates that those risks are more likely to materialise on a hypothetical Megaproject.

The above total weighting of the cases where the risks materialised are the direct result of the risk drivers/triggers including the contextual and complexity factors within each project (which are listed in the Table 2 as sub-elements) that led to the risk occurrence and which subsequently informed the risk mitigation strategies adopted as detailed in the Table 6 below.

4.1 An analysis and findings of the Case Studies on the Risk Management Strategies adopted:

We have analysed the risk management strategies implemented on Megaprojects that were investigated. They are summarized and discussed below (not in any order of priority).

Table 4: Risk Management Strategies adopted on Megaprojects

The Risk Management Strategies as per the main risk categories
1) Risk: Schedule Overrun - The Possible Mitigation Strategies Are: • Develop a comprehensive Master Schedule based on the schedule information derived from Post-evaluation of any similar projects and make adjustments considering particular design schedule, procurement schedule, authority approvals schedule, productivity calculations, constructability issues, build-in buffer time for uncertainties & complexities, site logistic & specific issues, etc. (Precinct 3 of CS1 vs Precinct 2 of CS1 vs A Benchmark Project). • Use of the Master Planning with the benefit of using expert ECI and PCS service provides to clearly understand buildability issues at very early stage & at least resolve them by the Technical Evaluation stage using Contractor's responses (construction method design, 3D model, VR reviews). • Use Program/Portfolio PM Approaches and assess weekly progress %, VOWD and KPIs. Divide a Megaproject into constituent components/precincts/sub-projects to enable Micro Management and develop the MS accordingly and tie it up with the project WBS codes. • Build enough money into the budget to quickly handle unforeseen tasks/ delays. • Have a flexible consultant scope of work including Provisional Sums for possible additional scope of works (CS5) (to deal with additional services needed to be covered and extension of services due to schedule slippage – e.g., CS5 and provisional sums allowed for potential services).

The Risk Management Strategies as per the main risk categories

- Construction tender invitation might specify the requirement for two MCs to form a project-based JV to boost E-P-C and CM expertise, and increase resources pool available to serve the project (CS7) and achieve timely completion.
- Pre-purchase of long-lead items and essential materials (rebar, concrete, cement, paint, tiles, sanitary items etc)/MEP Equipment/Steel Bridges via a Special Advance Payment arrangement (CS1, CS5).
- Establish a realistic schedule and provide high visibility to tracking progress and share information (or high visualisation of the Project's progress via smart tools and techniques – e.g. Graph 2/Table 1.
- Carryout weekly progress review with the participation of all package managers and sub-contractors to understand any critical issues and to design suitable programme recovery measures / action plans on a timely fashion (CS1, CS5).
- Have options including cost allowances within the contract price/budget to mitigate the schedule delays by adopting DfMA (CS1) used this technique effectively) and off-site manufacturing methods (CS1&CS2) to fast-track the project and recover any delays occurred.
- Look at potential design and construction overlaps (i.e., Fast-tracked delivery as in the CS1). It is possible not only under partnership contracts, but also in traditional contracts if the PMs have the expertise to set-up and manage the process including contract design and site Contract Administration) (CS1 to CS5 & SC6).
- A joint Procurement Schedule monitoring between the Contractor and Client (/ PMCs) and schedule transparency (e.g., visible milestones and moving targets – CS2). This is an intelligent tool that also protects the client from un-substantiated contractor's claims by highlighting culpability for concurrent delays caused by the MC and S/Cs which can be recorded, notified, and further investigated.
- Client's Integrated working methodology with the contractors and sub-contractors and resolving critical issues that slow down the project (CS5)
- Clearly Establish and Maintain scope of works (possibly ring-fence the Concept Design or freeze it further at the DD stage) and try to keep outside/additional scope separate and deal with it as standalone (e.g. CS4 & landscape works). **Identify possible scope creeps arising from the infrastructure and utilities interfaces / diversion of services even located outside the current MP that might affect this project as this is the major cause of additional scope/cost/time on Megaprojects (CS1 to CS10).**
- Make early inquiries with the Authorities about their utilities capacity to serve the project and inform of them about the utilities requirements (e.g., Power / Chilled water supply demand and supply – CS3, VS4, CS5 & CS7)
- Make early inquiries with the Authorities with their clear requirements and appoint an experienced consultant (e.g. Architect of Records/Authority Liaison Officers/PROs with in-depth local knowledge about requirements as Megaproject have over 200 approvals/NOCs to secure from start to finish. Visit authority offices, and communicate time to time to make inquiries with Authorities proactively about potential changes in laws and requirements throughout the planning & delivery (e.g. use of PROs/Government Liaison Offices at CS3 and CS4) and also make sure to apply knowledge gained across other similar projects (e.g., CS5).

2) Risk: Cost Overrun - The Possible Mitigation Strategies Are:

- All development costs and design parameters to be benchmarked against their peers (preferably 5-10 reference projects) and use of an experienced ECC with extensive CBI/design economics studies data/information (CS1, CS2,CS5).
- In cost plus contracts, get cost certainty with a GMP and ring-fence preliminaries costs and contractor's margin (CS1).
- When establishing an Initial Development Budget (IDB – 'Not-to-exceed') (to be included in the Financial Appraisal & BC) use a cost range (P45 to P90/95) rather than point estimates and be transparent and provide full information/report to the decision makers based on the MCS or any other scenario analysis or a detailed qualitative analysis. If there is a requirement to give a point estimate, make it robust and comprehensive and have the 'Reference design' (MP & Concept Design possibly with a design freeze) attached to it.
- IDB shall be maintained throughout the development process with the careful adjustments made at each stage (e.g. on receipt of Construction Tenders and Contract Award) to reflect all necessary risks/contingency allowances & still benchmarked against a number of similar projects (CS5).
- Use a risk-based cost estimating method including itemised risk allowances and attach details including assumptions/calculations (CS5).
- Build cost cushion into estimates to deal with market demand/trend such as high-end finishes, HA, Swimming Pool, etc (Owner's requirements might change during construction for off-the-plan sales and tilt towards the market demands) and scope changes (gaps/authority/additions/shared cost increases).
- Make inquiries about potential changes in laws and requirements throughout the planning & delivery. Beef up the Sales Contract to include 'Force Majeure' events that might increase the cost such as Government Regulations on CCTV system upgrade (Facial Recognition capability) / Energy Efficiency Rating (increase from 5 to 7 stars) / Sustainability Principles (e.g., Rainwater Harvesting/Water efficient irrigation/Rain Garden) / 24/7 Fire Alarm connection to Civil Defence (C1 to CS7).
- Manage expectations of the stakeholders by carefully caveating the cost estimates and specifying inclusions, exclusions & assumptions (as in CS5).

3) Risk: Political Risk - The Mitigation Strategies Are (learning from all case studies CS1 to CS10):

- Brainstorm ways to de-politicize the project from very Early Stage and build a solid BC and foundations (e.g., Project options appraisal, financial appraisal, risk assessment, economic study, CBA, feasibility study, procurement analysis, etc) around it.
- Be professional and always practice professional ethics.
- Avoid optimism bias and benchmark the project's costs, quality, schedule, and scope to a recent and similar Megaproject and include sufficient risk allowances and provisional sums for possible scope creeps.
- Future-proof the project by engaging with all main political parties and getting their buy-in (make sure there is a solid business case and rationale behind the project which will survive any potential change in Government).
- Built-in project resiliency aspects to bounce back from any possible political impact (e.g. public, local & Environ. group supports, IRs, PR, etc).
- Achieve a higher ICN rating and maintain it by implementing LJF (using Local Supply Chains) and MPSG (employing Vic Trainees, Apprentices & Cadets) policies.

The Risk Management Strategies as per the main risk categories

4) Risk: Authority approvals including Environmental Agency and Public Support / Public Relations - Possible Mitigation Strategies are:

- Use a tracker with schedule linked to Master Schedule with real-time updates.
- Early, intensive stakeholder engagements to understand powerful stakeholders' needs, requirements, interests, influences, and views.
- Possible inclusion of design for open community spaces (such as pedestrian/cycle paths/playgrounds/parking areas/parks) and social & community buildings into the project objectives (and address community concerns / provide some additional benefits. E.g., LXRP - Sky rail and community parks/space/sporting venues).
- Early engagement of the worker unions (CS8 & CS10).
- Environment NGOs and engage with Govt Depts (and request for a joint-up approach as in CS3) and adapt the project processes to match with the client LEED and govt authorities' requirements (CS2, CS5, CS7). Possibly execute EES to confirm firm commitments (CS8, CS9, CS10).
- Handle environmental authorities with practical technical (D,C&OP) proposal with easy wins (such as LEED accreditations) and to ensure less environmental impacts, application of sustainability principles, and protection and conservation of the environment and its fauna & flora (habitats, sand-dunes, indigenous plants, etc) (CS2 & CS5)
- Provide solid technical solutions early before issues emerge at initial Planning Approvals stage itself, make commitments & keep promises made (follow this even if any environmental impacts concerns are raised by the authorities). Do this with demonstrated D, C & OP contribution to project sustainability, energy efficiency, and environmental protection and conservation (e.g Track relevant KPIs and report as was the case in CS2 & CS5).
- Strategic recruitment of authority liaison officers and consultants (e.g., Local Architects & AOR – CS1&CS5) and provide regular briefings & regular updates to all key authorities/public.

5) Risk: Poor Business Management, PM and CM Practices & Systems – Possible Mitigation Strategies are:

- ***Adopting educated approaches to Planning & Delivery. E.g., Front-end approaches (ECI, Strategies during Feasibility, Planning & Design, and Procurement stages):***

1) Focus on the Business case, value additions, PM Plan (PMF/PMP), and select a cost-effective contract/delivery model (CS8).
2) Pursue combined finance with equity & debt finance and syndicate finance (not sole finance by one financier) to increase the finance pool and reduce risks (CS1,CS2,CS3)
3) Risk management using the state-of-the art MCS (e.g., for setting development budget, for tender evaluation to workout less-riskier and cost-effective main contractor or specialist package sub-contractors, etc) (CS1).
4) Enhance the project scoping (incl Spec of business / Employer's requirements and SoW) and design management process, especially with respect to issues of constructability / methodology / environmental sustainability / community requirements / project interfaces (infra and utilities) (CS3&5).
5) After DD, develop early cost models for BM team with contingencies linked to project WBS system with details of the project packages/elements.
6) Design Management (CS1 to 10)– Develop plan for Mixed-use properties to balance risks (with short term and long-term revenue streams), Use of BIM model from outset; Design to cost, make use of DfMA, provisions to maintain functional flexibility and future proof design (e.g. Hotel rooms should be able to be converted into normal or service apartments, apply sustainability principles/accreditations, embed disaster risk resilience, etc).
7) Use of PCS and ECI to address and find the most suitable methodology from the early stage using 'options appraisal', CMD, logistics design, and brainstorming with full team members (to avoid situation like the expensive cost variation on the MMP at State Library station).
8) Due diligence of proposed Tender & Contract documentations for removing errors/ambiguities/conflicting information.
9) Use performance-based approach to partner selection (e.g., use selection criteria with weighting for Technical and Commercial tender evaluation with a robust Tender Adjudication process – this applies to Consortiums/Main Contractors/Consultants/Sub-contractors/Suppliers
10) The selected Main Contractor should be 'Programme' focused, preferably a project-based JV (to increase capacity, capabilities, resource access etc) and have proven past experience in programme recovery and fast-tracking delivery/similar project execution (e.g. CS2).
11) Develop, Monitor, and Manage a Benefits realisation plan.
12) Stakeholder Management and Comms Plans:
    (a) Meet with Government agency leaders and community affected to build awareness and support for the project (e.g., Accommodate site briefing, tours and site visits for adjacent neighbours and community – CS1, CS2, CS5, CS7).
    (b) Have a stakeholder's map showing adjacent property owners with full contact details and have regular communications (e.g., CS4&5).
13) Engage the Operator early in the Master Plan stage itself and make use of their tremendous and useful experience (e.g., Organise a joint T&C and Snagging process involving Operator and Lead Designer and Supervision consultants – CS3, CS4 & CS5).

- ***Leadership, Governance, Oversight, Project Monitoring & Control and Assurance System (During Post- Contract stage):***

1) Fast-track the project using experienced professionals and proven methodology with design & construction overlaps to de-risk the project.
2) Proactively managing a prioritised design deliverable schedule related to PSUM works and Variations in line with the updated MS and D-E-P-C schedules and vetted to ensure it matches the construction process/sequence at site and criticality and confirming any slippage accurately while monitoring the contractor's own concurrent delays (this is a main risk on all projects CS1 to CS7).
3) Sound Governance of Change and Variations management (with tools to assess variation costs – e.g., priced BoQs/CBI) and EA process.
4) Use of Portfolio or Program Management system
5) Performance Monitoring using metrics and KPIs to support MIS
6) A top class leadership – Role modelling, decision making autonomy (delegation of authority and at point of need), ownership of outcomes, work hard on relationships, retaining talented people & avoiding key staff turnover, etc.
7) Gateway development approval process & documentations to match the stakeholders' requirements and unique project profile (CS1,2,3,5,6 &7).
8) Robust Claims and Dispute Mgt incl DD&PA, protocol, processes & escalation map, MS and procurement schedule monitoring, being neutral, etc.

The Risk Management Strategies as per the main risk categories
6) Risk: Uncertainty About Mitigation Cost, and the Contingency Allowance Not Sufficient – Possible Mitigation Strategies are: • Identify likely mitigation measures early and allow cost provisions within the budget (but identify & itemise them separately from the other Cost Plan / Development Budget items and benchmark the allowances against similar projects). • Create partnerships with the Government Agencies such as DoT, DoI, Municipality and Environmental agencies so that agencies feel ownership of the project/performance. If possible, demand a co-ordinated approach between the authorities in giving planning, construction, and operational (BCC/BOC) approvals. • Engage with Construction and Other worker unions early to get a feel for the project engagement and potential additional cost that might put the approved budget and contraction contract price at huge risk (e.g., \$300k/yr Pay agreement for Tunnel workers on CS8 and CS10 projects).
7) Risk: Finance – Possible mitigation Strategies are: • Lenders not to finance 100% of the project cost. Better to use a combined debt-equity finance arrangement with preferably 50%/50% or 70%:30% (also applicable for additional costs) depending on the risks involved and market conditions. This is to control the cost and enhance the client led cost management performance on the project. • Learning was that that a syndicate financing approach (with a large pool of finance available to the project if needed) is effective on Megaprojects due to the greater possibility and requirement to finance additional costs (sometimes very large) (CS4 & CS7). • Use experienced DM to protect client's and financier's interests as they bring vast expertise into the project. Clearly design step-in rights in the LFA (CS4, CS7). • Develop mixed-use properties with both early and long-term revenue streams to balance the risk and reduce cost of finance (CS1 to CS7). • Use 'Side Agreements' (tri-partite) effectively and re-establish the baselines as soon as possible to gain commitment and avoid 'time at large' (CS7).

5 Conclusion

Managing and controlling the SoW, Design and MS, and ensuring the Megaproject is delivered on time without major design changes and using a fast-track approach (D&C overlaps/use of DfMA) is the only way to achieve the business success as demonstrated in CS5 (and all other projects had experienced shedule slippage and cost overrun). This requires BM and PM Maturity (see Figure 2), together with an experienced Main Contractor who is committed and on top of his CM, who has superb ability to achive a Programme focused delivery without compromising the cost and quality, and corporates with the client to recover progress when delay unavoidably occurs.

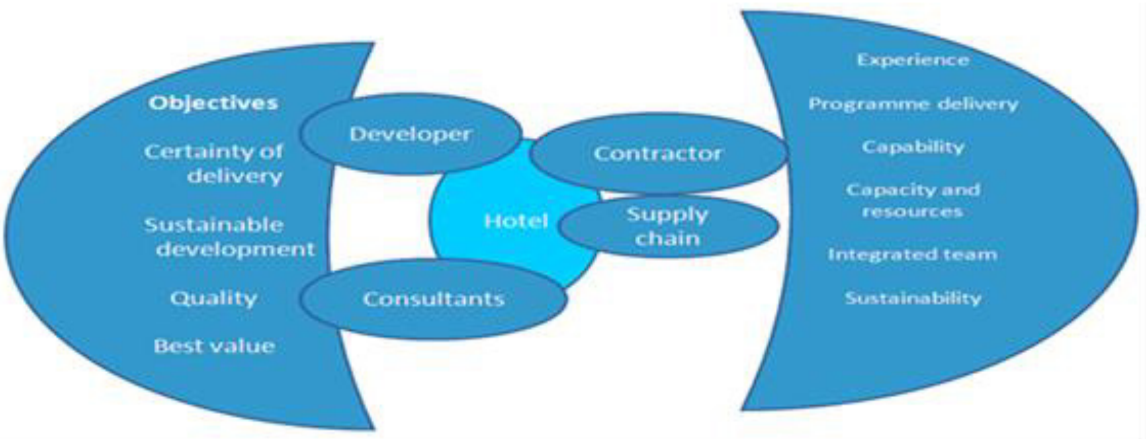

Figure 2: BM & PM Strategy for a mega hospitality project success

It has been revealed that the contractual claims & disputes, and environmental issues have the potential to critially affect all Megaprojects as we have seen across all case study projects (CS1 to CS10). Potential disputes shall be avoided through conducting comprehensive due diligence reviews throughout the D&C. However, they do occur on Megaprojects. Thus, effectively managing the disputes and claims (and variations in some cases) in a manner that they do not affect the programme is an art which requires contract and claim management expertise, contract manager/mediator taking a neutral position, looking at a bigger-picture, a mind-set that make the contractor succeed and ability to build a win-win relationship. This was achieved (on CS4, CS6

&CS7) by appointing contract management experts with exposure to Arbitration / Expert Witnessing who implemented an effective 'Dispute Protocol' which focuses on progressive resolution of the disputes/claims/variations without affecting the construction schedule or avoing the 'time at large' situation and working towards a re-baselined completion schedule to achieve successful completion. The Protocol is underpinned by a Side Agreement (usually takes the form of a tri-partite agreement inclding the financiers) which sets 'Conditions Precedent' that lock-in commitments from both parties and allows an on-account/ex-gratia financial assistance scheme to help the contractor/sub-contractors against a bank guarantee. The Side Agreement was used in three case study projects which faced severe financial constraints (CS4, CS6 & CS7). Due to the risk of being a show-stopper, the environment management of both the client (especially the Concept/Lead Designers) and the Main Contractor is key which should be considered at the time of decision-making for design and construction contract awards (e.g., LEED accriditation and experience, ability to provide practical environmental solutions, adopting integrated working mechanism with powerful authorities, etc).

The finance risk is also real as 6 projects studied had faced this risk (with two almost coming to a halt) and equity finance and syndicate finance helps to manage financial liquidity on Megaprojects. This also provides a mechanism for additional finance if needed.

Another key takeway from this research is to plan for managing force-majeure events as they tend to affect every Megaproject due to their large size and longer time horizon and are mostly unforseen.

Sometimes it is even stated as PM's roles and their majority (over 90%) of the monitoring, control, managing and reporting efforts on Megaprojects is all about managing the 'inherent risks' to the Megaproject baselines and wider performance outcomes, and relevant timely communications and mitigation actions. The Portfolio PM approach facilitates a good level of RM across large number of Megaprojects with proven benefits, mainly the rapid RM knowledge transfer between projects/staff and financial savings. The CS1,2&3 projects (and CS6 to some extent) benefited from Portfolio PM and Risk Management approaches. Therefore, the RM shall receive its due attention from the PM practitioners working at project/program/portfolio level of Megaprojects.

Eventhough the current research provides a cross sectional analysis of risks that are usually encountered on Megaprojects, a future research analysing a large number of Megaprojects is recommended to generate a large set of practical mitigation measures. Also an in-depth study in any specific area (e.g. procurement / post-contract risk management) could be undertaken.

6 Acknowledgement

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8 Acronyms and Abbreviations used in this paper

AFC	Anticipated Final Cost	DfMA	Design for Manufacture & Assumbly	IDB	Initial Development Budget	MS	Master Schedule
AOR	Architect of Records	EA	Employer's Approval	IR	Industrial Relations	MCS	Monte Carlo Simulation
CEMP	Contractor's Environmental Management Plan	ECC	Executive cost consultant	JV	Joint Venture	PR	Public Relation
CA	Contract Administration	ECI	Early contractor involvement	KPIs	Key Performance Indicators	PROs	Personal Relationship Officers
CD	Civil Defence	EES	Environmental Effects Statement	LFA	Loan Facility Agreement	PM	Project Management
CBA	Cost Benefit Analysis	EVA	Earned Value Analysis	LJF	Local Jobs First	RM	Risk Management
CBI	Cost Benchmarking Information	ERM	Enterprise Risk Management	LXRP	Level crossings removal project	SC	Supply Chain
CM	Construction Management	FS	Feasibility Studies	MPSG	Major Projects Skills Gurantee	SoW	Scope of Works
CMD	Construction method design	GMP	Guaranteed Maximum Price	Mgt	Management	S/Cs	Sub-contractors
D,C&OP	Design, Construction and Operation	GFC	Global Financial Crisis	MP	Master Plan	VUCA	Volatile, Uncertain, Complex, and Ambiguity
DD	Detailed design						

APPENDIX A - Table 2: 10 Main Risk categories and elements

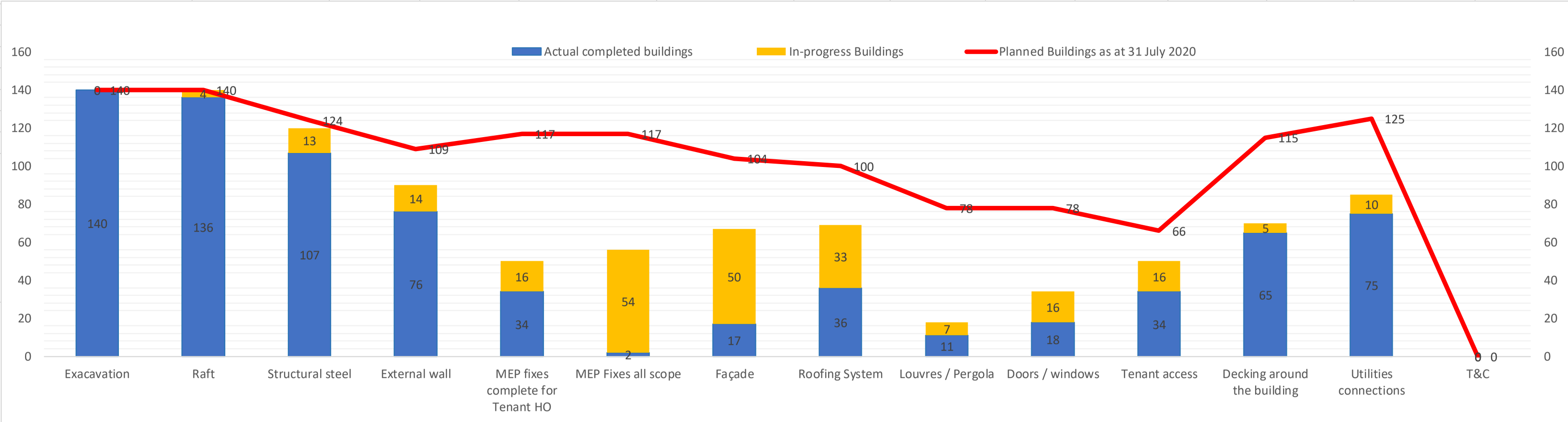
Group	Top 10 Risk Categories identified / anticipated
1	**1.1 Schedule overrun:**
	Very long E-P-C time horizon and more risk exposures, large scope and lack of scope definition at initial period
	Authority approval and land acquisition delays
	Evolving nature of the MP and lack of infrastructure designs/MS
	Lack of project monitoring & control
	Very large PSums & lack of detailed design at the time of contract award
	Unapproved variations, claims and bankruptcy of key S/Cs
	Building design issues and many subsequent changes
	Critical resources scarcity and main contractor's procurement delays
	Delayed payment to the main contractor and sub-contractors.
	1.2 Cost Overrun:
	The planned infrastructure assets sales became impossible
	Lack of detailed design and very large Psums in construction contract
	Unrealistic Estimates or substantial errors in the estimates
	Substantial scope changes
	Productivity lower than estimated
	Critical resources scarcity
	Poor execution management
	Increase in Labour/Plant/Staff/Sub-contracting costs
	Resistance from neighbours / public / labour unions
	Main contractor's procurement delays
	Delayed payment to the contractor by the client
	Procurement method causing cost increases
2	**Authority and environmental agency approvals:**
	Utilitites connections issues affecting cost & time
	Approval of Civil and landscaping works
	Green Building/Sustainability Regulations and Specifications (UPC and Municipality)
	Municipality engineers & structural design approvals
	Ministry of Interior (MoI)'s security approval requiring high-spec CCTV & monitoring systems
	Affection plan & private beach extent approval by UPC
	Municipality and Land Department with planning conditions
	DoT approval on carparking spaces
	Master Developer and Environmental Agency's approval on the sustainability
	Civil Defence approval on Fire and Life Safety works
	Master Developer (MD) delays on the delivery of the infrastrure works
3	**Contractual claims and disputes:**
	Claims from package contractors due to package co-ordination and Scope gaps
	Main Contractor's prolongation (EOT) and disruption claims
	Design Consultant's claims for scope changes
	PMC, Supervision and Executive Cost Consultants - Varied Service Agreements (VSAs)
	Claims and disputes with utilities and civil infrastructure providers
	Dispute with the financiers
4	**Scope, design changes and QM:**
	Design not developed and still preliminary
	Design Gaps and possible scope creep
	Substantial scope and design changes to be required (Luxury facilities, high-end finishes & new systems - e.g., HA & CCTV)
	Design changes introduced by the authorities & Master Developer

	Constructability issues existed
	Design changes to recover programme (DfMA); Late design deliverables
	Rework required due to QM issues (NCRs, inspections, T&C, snagging, DLP etc)
5	**Procurement & Contract Design:**
	New and unfamiliar cost plus contract procurement system with mainly cost exposures
	Ambiguities and uncertainty created by the errors and omissions within the contract document
	Designed contract mechanisms lacked the essential 'Programme and Cost Management' focus & controls
	Selection of the procurement system carries risk
6	**Client's Business Management and PM Expertise (pre and post contract):**
	Business Management expertise lacking
	Project set-up issues and not exploring alternatives
	Not following Value-based partner selections
	Design management and development risks
	Risks and opportunities management (ERM and project level)
	Setting realistic Project Baselines
	Contract & procurement management
	Design & Quality Management
	Schedule (EVM) & Risks Management (MCS)
	Value management
	Management of Health and Safety and Environment
7	**Client leadership, Project governance and Oversight (post-contract):**
	Top management support
	Development/Gateway approval process management
	Stakeholders & Communication management
	Change and Variations management
	Being an Intelligent client
8	**Project finance:**
	Political risks and funding issue
	Barrower's credit rating comes down and risk escalates
	Financiers / Owners unable to fund additional costs / variations (cash-flow issues)
	Requirement for finance exceeds the value of the security held by the financiers
	Loan repayment defaults by the borrower on other projects
9	**Construction & SC Management:**
	Lack of CM Capacity, Capabilities and systems
	Lack of Construction Master Schedule Management and focus
	Lack of Engineering design management
	Lack of procurement management
	Lack of Health and Safety, and Wellbeing
	Lack of Resources Management - Manpower, Plant, Equipment, Staff etc
	Lack of Procurement, Safety, Resources, Operation, and supply chain Mgt
	Supply chain bankruptcy and wrong selection
10	**Force majeure events & VUCA market:**
	Significant decline is potential revenues/benefits
	Financial crisis affecting funding and making buyers default
	Pandemic risks
	Terrorism risks
	Severe industrial relation issues
	Environmental Risks
	Global financial crisis (GFC)

Appendix B: Graph 1 – Megaprojects' progress monitoring visualisation tool

Revised Programme Rev 01 – Building Progress KPIs (No of Buildings)

Date	1/10/2021



Description	Exacavation	Raft	Structural steel	External wall	MEP fixes complete for Tenant HO	MEP Fixes all scope	Façade	Roofing System	Louvres / Pergola	Doors / windows	Tenant access	Decking around the building	Utilities connections	T&C
Planned Buildings as at 31 July 2020	140	140	124	109	117	117	104	100	78	78	66	115	125	0
Actual completed buildings	140	136	107	76	34	2	17	36	11	18	34	65	75	0
In-progress Buildings	0	4	13	14	16	54	50	33	7	16	16	5	10	0
Planned %	100%	100%	95%	88%	84%	84%	74%	71%	67%	56%	78%	82%	89%	0%
Actual %	100%	97%	82%	61%	24%	1%	12%	26%	9%	13%	40%	46%	54%	0%
Variance (Nos) - 31 July 2020	0	4	17	33	83	115	87	64	67	60	32	50	50	0
Variance (Nos) - 24 July 2020	0	-1	18	34	88	114	86	64	65	68	34	45	53	0
Variance (Nos) - 17 July 2020	0	3	18	34	86	112	82	62	63	70	31	40	45	0
Variance (Nos) - 10 July 2020	0	4	16	36	86	107	80	61	61	68	39	35	38	0
Variance (Nos) - 03 July 2020	0	3	18	33	86	107	78	60	61	66	36	30	32	0
Variance (Nos) - 26 June 2020	1	1	17	34	83	100	72	55	57	61	36	30	30	0
Total Buildings (Contract scope)	**140**	**140**	**131**	**124**	**140**	**140**	**140**	**140**	**117**	**140**	**85**	**140**	**140**	**140**

APPENDIX C - Table 4- Summary of Case Study Details

Case Study reference	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9	CS10
Project Type	A large size Mixed-use development including site infrastructure works	A medium size Mixed-use development including site infrastructure works	A large size Mixed-use development including site infrastructure works	A 5-star Resort, Hotel & Service Apartments with site infrastructure scope	A 5-star Resort, Hotel & Beach Villas with site infrastructure scope	A VVIP Specialist Hospital Project with infrastructure scope	A 5-star Resort, Hotel & Service Apartments with site infrastructure scope	A major city Metro Project with stations and tunnel	Railway project involving Rail Crossing Removals	A city major transport project with tunnel and road works
Contract Type	A JV contract cost-plus contracts with site-wide infrastructure works	A series of Lump-sum package contracts & Remeasured utilities works	A series of lump-sum large contracts (approx. 20) and one cost plus contract	A lump-sum contract with 40% Provisional Sums	A lump-sum contract with 34% Provisional Sums	Fixed lump sum 'Construct only contract with design portions'	Two stage Construction Management contract	Partnering & Alliance contracts	Alliance contract with over 50 sub-projects	D&C Contractor
Design Schedule	3 yrs	3 yrs	3 yrs	3 yrs	6.5 yrs	2 yrs	2 yrs	2 yrs	2 yrs	1 yr
Construction Schedule	10 yrs	5 yrs	7 yrs	2 yrs	2.7 yrs	3 yrs	3 yrs	7 yrs	8 yrs	5 yrs
Schedule overrun (yrs)	No	1 yr	1 yr	4 yrs	No	2 yrs	2 yrs	2 yr	1 yr	2 yr
Original Budget Value (US$)	$ 25,000,000,000.00	$ 1,200,000,000.00	$ 6,000,000,000.00	$ 1,250,000,000.00	$ 1,202,300,000.00	$ 1,010,000,000.00	$ 2,020,400,000.00	$ 8,250,000,000.00	$ 5,700,000,000.00	$ 5,025,000,000.00
Revised Budget Value (US$)	$ 25,500,000,000.00	$ 1,250,000,000.00	$ 6,500,000,000.00	$ 1,436,000,000.00	$ 1,252,300,000.00	$ 1,110,000,000.00	$ 2,381,167,075.00	$ 8,437,500,000.00	$ 11,100,000,000.00	$ 6,018,750,000.00
Cost Overrun %	2%	4%	8%	15%	4%	10%	18%	2%	95%	20%

Notes: CS9 – 1) The original budget is based on removing 50 Level crossings (LXRs) whereas the revised budget is based on 75 LXRs. 2) However, the original program suffered a cost over-run of 9.2% based on an approved BC budget of A$7.6bn and revised budget (2017/18) of A$8.3bn.

Determining the Best Intervention Times of Whole Building Assets for Renewals During the Planned Period

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Abstract
The objective of service life analysis is to establish and explain the performance-over-time functions, which describes how the measured values of chosen performance characteristics are expected to vary with time. Applicable to buildings, the most viable method of capturing the performance is according to their condition; furthermore, referring to the minimum acceptable condition of the given building or component. Below this level, performance is considered not to be acceptable for the intended function, although the building or component can still be functional or operational. A deterioration curve represents the condition degradation over time, which can be regarded as a performance indicator over time. Referring to the deterioration curve produced regardless of deterministic or probabilistic way, the current study conducts a theoretical investigation of best intervention periods for renewals of whole building assets. Theoretical investigation is mainly underpinned by the relevant variables of the prediction curve such as useful life, remaining useful life, planned duration, minimum acceptable condition for performance, current year and last year of the planned duration and the first and last time that the intervention can be done effectively. Given that three interventions are the maximum number of interventions expected to occur during the planned period, eight scenarios of interventions come into effect. Hence, theoretical investigation has been applied to each scenario. The study has also used actual case study data hypothetically applied them to each scenario for further clarification of theoretical findings. The outcomes essentially guide building/ facility owners and managers for better informed decision-making of their building renewals.

Keywords
Whole building assets, Best intervention periods for renewals, Minimum acceptable condition, Deterioration curve, Theoretical investigation

1 Introduction

Most asset managers are curious as to how to best answer the following question:

What are the best times to intervene for renewals of whole building assets during a planned period?

By answering the question, asset owners can ensure the future condition of assets associated with service levels and budget allocation. With reference to the above, the best intervention can be planned subjectively by responding to the reactive maintenance inquiries, which is the common practice in the absence of an objective method. However, Mohseni (2012) emphasises that a reliable approach to the prediction of the condition states of assets is essential for a strategic asset management plan enabling a proactive maintenance and rehabilitation regime. Accordingly, ddeterioration is the main factor which causes maintenance actions for building components. Furthermore, a deterioration curve represents the condition degradation over time, which can be regarded as a performance indicator over time. Linear variation is assumed for the deterioration in some financial analysis, but it is not the actual shape. Deterministic and probabilistic approaches used in deterioration prediction give reasonably close shapes for deterioration, even though they are not the absolute correct shapes. For examples of both methods, IPWEA (2009) shows a deterministic curve because it is the most common approach used by the industry, whereas McDulling (2006) and Mohseni et al. (2012) applied a probabilistic approach and generated probabilistic deterioration curves. Deterioration curves generated in both situations are the combined effect of natural depreciation and depreciation occurring due to other external factors.

According to the deterioration curve, whichever way it was produced, service life is the time taken for the complete change from condition 1 to condition 5 (Common practice is condition 1 to 5 but there are other ways as well defining the condition from 1 to 10- the current study will adopt the common practice). Given that different mechanisms are applied in deterioration prediction models (Morcous, Rivard & Hanna 2002a), production of the deterioration curve of a given building is possible. However, it is questionable about the extent of research conducted to investigate the possibility of using the deterioration curve for the purpose of best intervention of renewals. This knowledge gap has led this research to undertake adopting theoretical investigation approach as the research methodology. Limited to maximum three interventions, the study considered possible eight scenarios to determine the best intervention periods of renewals. Using diagram illustrations followed by clear descriptions derived the best time periods for renewal interventions of whole building assets based on the eight available scenarios. The findings has addressed the knowledge and practice gap of a method for determining the optimum intervention time for the renewal of whole building assets.

2 Theoretical Background

According to Jernberg et al. (2004), the objective of service life analysis is to establish and explain the performance-over-time functions, which describe how the measured values of chosen performance characteristics are expected to vary with time. Related to buildings, the most viable method of capturing the performance is according to their condition (IPWEA 2009). Jernberg et al (2004) further explain the performance with a performance criterion which suggests a minimum acceptable performance. Below this level, performance is considered not to be acceptable for the intended function, although the building or component can still be functional or operational. When the performance is captured by the condition, it becomes the minimum acceptable condition for the given building or component.

According to (Hovde & Moser 2004):

> Service life prediction of buildings or building elements, components or products can be both complex and time-consuming process. To date, the methods have not been developed into an exact science given the many different factors that must be considered that thereby make a thorough service life prediction an interdisciplinary activity. Service life prediction can be based on two different principal approaches: Deterministic approach and Probabilistic approach

In the context of bridges, Morcous, Rivard and Hanna (2002b) found two unique models, stochastic and artificial intelligence, served for the probabilistic approach, while only deterministic models served for the deterministic approach. They state the suitability of those models, not only for bridges but also infrastructure assets, in another study (Morcous, Rivard & Hanna 2002a). Table 1 shows the three model categories, including the specific techniques applied in each model and the specific methods relevant to each technique. Dasu and Johnson (2003) also characterize these models by the driving force of each model. According to these authors, statistical models and deterministic models are model-driven, whereas artificial intelligence models are data-driven. Moreover, experts decide the structures of each statistical and deterministic model, while the structures of artificial intelligence models are decided by the sample data.

Table 1. Categories of deterioration prediction models

Category	Technique	Method
Deterministic models	Straight-line extrapolation	—
	Regression models	Stepwise regression
		Linear regression
		Nonlinear regression
	Curve-fitting models	B-spline approximation
		Constrained least squares
Stochastic models	Simulation models	—
	Markovian models	Percentage prediction
		Expected-value method
		Poisson distribution
		Negative-binomial model
		Ordered-probit model
		Random-effects model
		Latent Markov-decision process
Artificial intelligence models	Artificial neural networks	—
	Case-based reasoning	—

Source: (Morcous, Rivard & Hanna 2002b)

In their detailed analysis of the advantages and disadvantages of the three models, Morcous et al (2002b) identify some shortcomings of Markovian models. However, Markovian models can be seen as extensively applicable to infrastructure facilities to model their deterioration (Baik, Jeong & Abraham 2006; Butt et al. 1991; Cesare et al. 1992; Micevski, Kuczera & Coombes 2002). These applications suggest that the Markov chain is the preferable method to predict the service life of infrastructure assets by simulating the transition of states (conditions) over time (McDulling 2006; Morcous, Rivard & Hanna 2002b). However, the utilisation of other methods such as straight-line extrapolation, regression-based or exponential deterioration are frequent in applications of water mains (Kleiner & Rajani 2001; Rajani & Kleiner 2001), pavements (Lou et al. 2001) and roofing membranes/ systems (Lounis, Zoubir et al. 1999; Lounis, Z, Vanier & Lacasse 1998).

Analysing deterioration trends at component level, Keshavarzrad (2015) has developed a facility condition index interpreting the overall building condition as a function of the condition of components. Accordingly, he has produced deterioration curves of whole building assets. Past studies indicate focus of the research has limited to deterioration prediction (McDulling 2006) or cost optimising aspects (Mohseni 2012) at component level but no effort is given to utilise the deterioration curve of the overall building deterioration curve to determine optimum intervention of renewal tasks. Theoretical research is a logical exploration of a system of beliefs and assumptions (Edgar & Manz 2017a). Formal theory and mathematical exploration/

investigation can be effectively utilised to generate results through theoretical research (Edgar & Manz 2017a, 2017b). Hence, the current study identified the possibility of applying mathematical exploration in a deterioration curve for the purpose of determining best intervention periods of the renewals.

3 Research Methodology

As discussed in the previous section, theoretical investigation is the viable research approach for the study. In theory, deterioration curve infers that the service life of the building is the time taken for the complete change from condition 1 to condition 5. However, the building or component does not function at the required level of service during the time below the minimum acceptable condition in the graph. Therefore, the time that shows the change from condition 1 to the minimum acceptable condition is called "useful service life (U)" while service life can be interpreted as "designed life". "Remaining useful life (R)" is another term which correlates with useful life. It can be defined as the time taken for the current condition to reach the minimum acceptable condition. The most important feature of a deterioration curve is that maintenance actions such as minor repair, major repair, renewal or replacement can be correlated with condition change of the curve. Renewals always take the building or component back to condition 1 but major and minor repairs do not necessarily change the condition to 1. This is because renewals are intended to bring the building or component to potentially original level. The decision made on a renewal action is referred to as intervention here.

Figure 1 amalgamates all the above facts and gives a clear interpretation of the terms defined above. Several scenarios of interventions can occur, depending on the above terms, but one scenario is particularly referred to in the figure. The only reason for the selection of the scenario in the figure is the clear representation of terms. Other scenarios will be discussed in the rest of the section. Following descriptions are given for the terms in the figure:

$C = Minimum\ required\ condition\ for\ performance$
$U = Useful\ life$
$R = Remaining\ useful\ life$
$D = Planned\ duration$
$t_0 = Current\ year$
$t_D = Last\ year\ of\ the\ planned\ duration$
$t_1 = First\ time\ the\ intervention\ can\ happen\ without\ going\ below\ the\ performance$
$t_2 = Last\ time\ the\ intervention\ can\ happen\ without\ going\ below\ the\ performance$

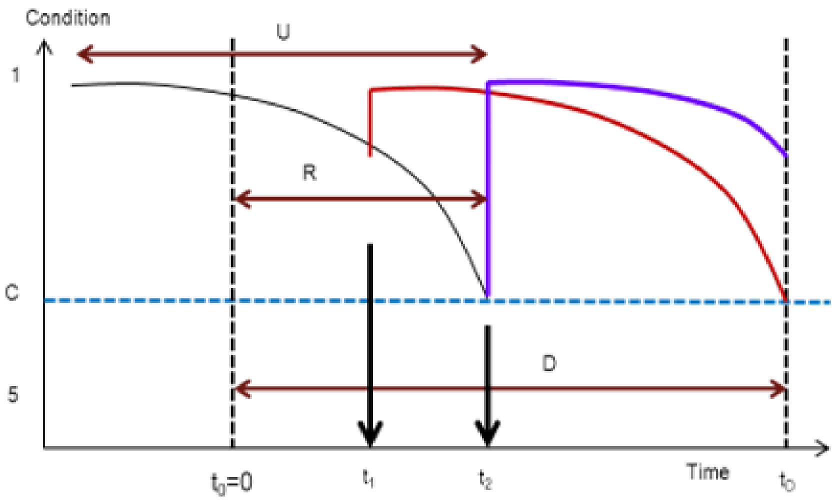


Figure 1. Important factors in relation to the determination of the best intervention periods

Given that three interventions are the maximum number of interventions expected to occur during the planned period, eight scenarios of interventions come into effect, depending on the variables of useful life (U), remaining useful life (R) and planning duration (D). They are:

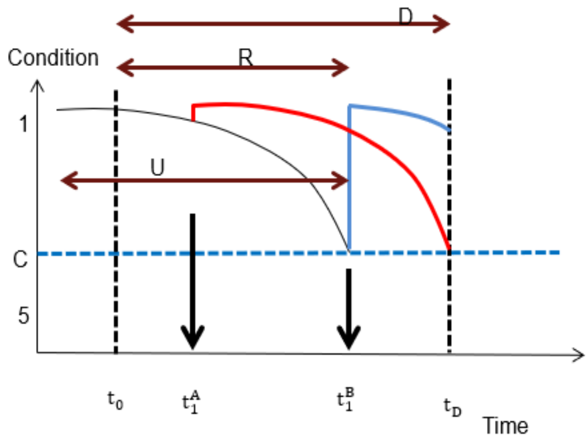
- $Scenario\ 1: When\ U \leq D \leq U + R \ \ and\ R > 0$
- $Scenario\ 2: When\ U + R < D \leq 2U + R \ \ and\ R > 0$
- $Scenario\ 3: When\ 2U + R < D \leq 3U + R \ \ and\ R > 0$
- $Scenario\ 4: When\ D < U\ \&\ R \leq 0$
- $Scenario\ 5: When\ U < D < 2U \ \ and \ \ R \leq 0$
- $Scenario\ 6: When\ 2U < D < 3U \ \ and \ \ R \leq 0$
- $Scenario\ 7: When\ R < D < U \ \ and \ \ R > 0$
- $Scenario\ 8: When\ D \leq R \ \ and\ R > 0$

4 Findings and Discussion

The best intervention periods related to each scenario are discussed under each scenario below.

4.1 *Scenario 1: When* $\boldsymbol{U \leq D \leq U + R}$ *and* $\boldsymbol{R > 0}$

The scenario and the related best interventions are clearly shown by Figure 2 below:



Where;
U= Useful life
R= Remaining useful life
D=Planned duration
C= Minimum acceptable condition for performance
$\mathbf{t_0}$= Current year t_D= Last year of the planned duration
$\mathbf{t_1^A}$= the first time that the first and only intervention can be done effectively
$\mathbf{t_1^B}$= the last time that the first and only intervention can be done effectively

Figure 2. Best intervention periods related to Scenario 1

In the figure, the red curve shows one possibility for maintaining deterioration at above or equal to the minimum acceptable condition. Accordingly, intervention occurs at time t_1^A at which the related specific condition above the minimum acceptable condition is brought to condition 1. Afterwards, it deteriorates normally and reaches the minimum acceptable condition at t_D which is the end of the duration. On the other hand, the blue curve is the other possibility for maintaining deterioration up to the acceptable performance level. According to the figure, the intervention happens at t_1^B at which the related condition is the minimum acceptable condition and it turns to condition 1 through the renewal. After the renewal, it undergoes general deterioration and follows the same shape for general deterioration. It ends with a higher condition than the minimum acceptable condition at the end of the planning duration.

It is obvious that the curves represent two ends of solutions for the same problem. Moreover, the time between t_1^A and t_1^B is the best time to intervene once and maintain the minimum performance by only one renewal. In contrast, renewals beyond that range will require more than one renewal or performance will fall below the acceptable level during the planned period. Times of t_1^A and t_1^B can be acquired through mathematical equations and they are shown as follows:

$$t_1^A = D\text{-}U \tag{1}$$

$$t_1^B = R \tag{2}$$

An example situation is provided for further clarification. Let a building is to plan for 30 years (D) and the building's useful life (U) is 25 years and remaining useful life (R) is 10 years. Then, according to the derived equations:

$$t_1^A = D - U = 30 - 25 = 5$$

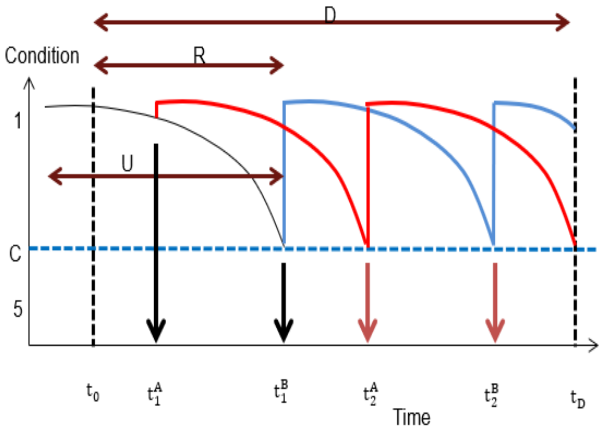
$$t_1^B = R = 10$$

According to the solutions provided here, only one intervention is adequate for the optimum operation of the building. Furthermore, the intervention should be applied between five years and ten years of the operation. If the intervention applied outside the period, then, the building will either operate below the acceptable condition for some time or additional intervention will be required to lift the building operation to acceptable level.

Please note that example situation is only provided with scenario 1 due to space restriction. However, the given example can be replicated for other scenarios according to their requirements.

4.2 $\boldsymbol{Scenario\ 2: When\ U + R < D \leq 2U + R\ \ and\ R > 0}$

The scenario and related best intervention periods are shown in Figure 3.



U= Useful life
R= Remaining useful life
D=Planned duration
C= Minimum acceptable condition for performance
t_0= Current year
t_D= Last year of the planned duration
t_1^A= the first time that the first intervention can be done effectively
t_1^B = the last time that the first intervention can be done effectively

Figure 3. Best intervention periods related to Scenario 2

According to the figure, a minimum of two interventions are required to maintain the minimum required performance during the planned period. The best intervention periods are represented by deterioration curves, as in the previous scenario. The red curves represent the feasibility of a first attempt of a particular intervention, whereas the last attempt is represented by blue curves. Hence, the most appropriate time for the first intervention lies between t_1^A and t_1^B whereas it is t_2^A and t_2^B for the second intervention. Each time figure can be acquired mathematically by the following equations.

$$t_1^A = D\text{-}2U \tag{3}$$

$t_1^B = R$ (4)

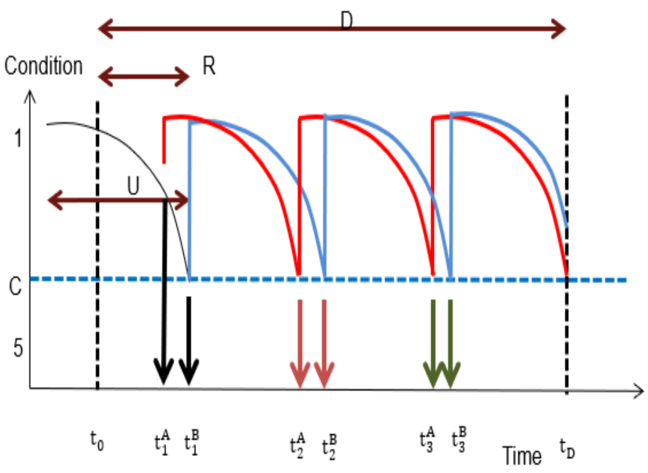
$t_2^A = D\text{-}U$ (5)

$t_2^B = U+R$ (6)

4.3 ***Scenario*** $3: 2U + R < D \leq 3U + R$ ***and*** $R > 0$

The scenario and related best intervention periods are shown in

Figure 4.



U= Useful life
R= Remaining useful life
D=Planned duration
C= Minimum acceptable condition for performance
t_0= Current year
t_D= Last year of the planned duration
t_1^A= the first time that the first intervention can be done effectively
t_1^B = the last time that the first intervention can be done effectively
t_2^A= the first time that the second intervention can be done effectively
t_2^B = the last time that the second intervention can be done effectively
t_3^A= the first time that the third intervention can be done effectively
t_3^B= the last time that the third intervention can be done effectively

Figure 4. Best intervention periods related to Scenario 3

The best intervention approach is very similar to Scenario 2, but the minimum performance during the whole planned period is not achievable without at least three interventions. The red and blue curves serve for the same features as in the previous scenarios. Therefore, the time interval between t_1^A and t_1^B is the best time for the first intervention. Similarly, the best times for the second and third interventions are in the intervals of t_2^A and $t_2^B$and $t_3^A$and t_3^B respectively.

$t_1^A = D\text{-}3U$ (7)

$t_1^B = R$ (8)

$t_2^A = D\text{-}2U$ (9)

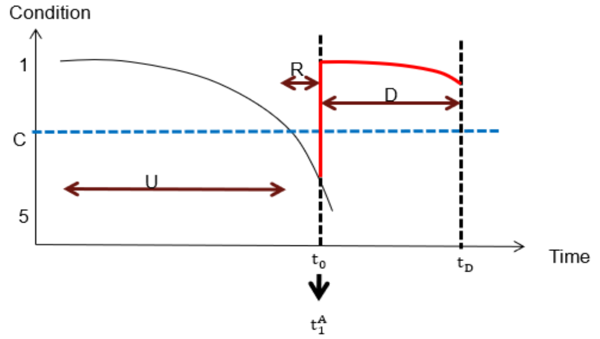
$t_2^B = U+R$ (10)

$t_3^A = D\text{-}U$ (11)

$t_3^B = 2U+R$ (12)

4.4 $Scenario\ 4: D < U\ and\ R \leq 0$

The scenario and related best intervention periods are shown in Figure 5.



U= Useful life
R= Remaining useful life
D=Planned duration
C= Minimum acceptable condition for performance
t_0= Current year
t_D= Last year of the planned duration
t_1^A= the current time that the first and only intervention to be done

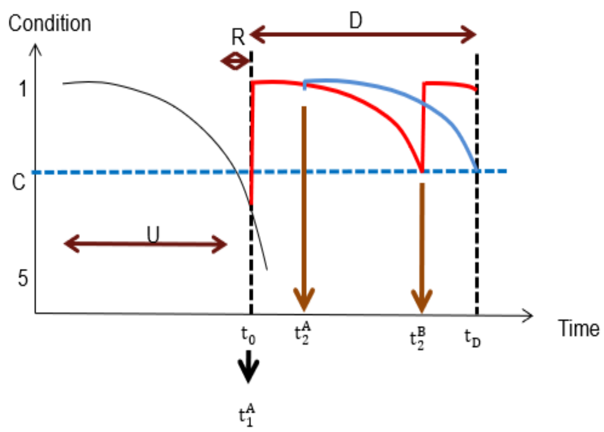
Figure 5. Best intervention periods related to Scenario 4

The scenario is one example of a whole building asset which is not currently functioning to the required performance. Although it is not fundamentally acceptable to go below the minimum performance, a situation like scenario 4 is possible in reality. If the situation is prolonged over time, it will reach the worst condition, which means that the whole building is also about to exceed its designed service life. Beyond this point, the building can be regarded as redundant, because it is no longer capable of functioning. This requires the system to renew the building or upgrade the condition to a level at which the building can function. Based on the current scenario, at least one intervention is possible but the optimum use can be obtained if it happens at the current time. All interventions beyond the current time pass some time below the minimum performance over the planned period. The time of the intervention related to the scenario can be shown by the following equation:

$$t_1^A = t_0 \tag{13}$$

4.5 $Scenario\ 5: U < D < 2U\ \ and\ \ R \leq 0$

The scenario and related best intervention periods are shown in Figure 6.



U= Useful life
R= Remaining useful life
D=Planned duration
C= Minimum acceptable condition for performance
t_0= Current year
t_D= Last year of the planned duration
t_1^A= the current time that the first intervention to be done
t_2^A = the first time that the second intervention can be done effectively

Figure 6. Best intervention periods related to Scenario 5

This scenario is very similar to the previous scenario, but more than one intervention is required to maintain the minimum performance over the planned period. The first intervention should undoubtedly occur at the current time. Optimally, the planned duration can be maintained with another intervention which is restricted to occurring between t_2^A and t_2^B . The renewals are illustrated with blue and red curves. The equations required to find the times of interventions are as follows:

$$t_1^A = t_0 \quad (14)$$

$$t_2^A = D\text{-}U \quad (15)$$

$$t_2^B = U \quad (16)$$

4.6 Scenario 6: $2U < D < 3U$ and $R \leq 0$

The scenario and related best intervention periods are shown in Figure 7.

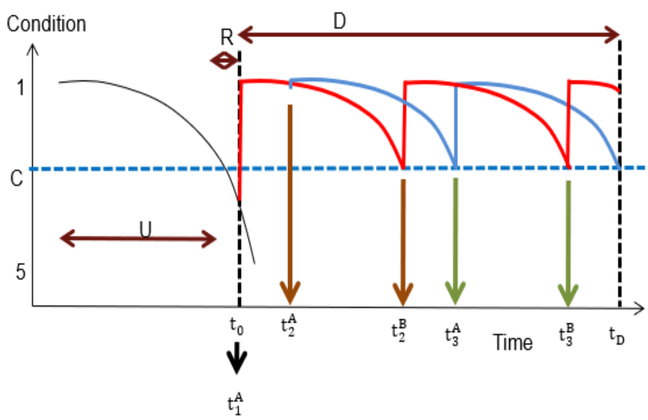


Figure 7. Best intervention periods related to Scenario 6

U= Useful life
R= Remaining useful life
D=Planned duration
C= Minimum acceptable condition for performance
t_0= Current year
t_D= Last year of the planned duration
t_1^A= the time that the first intervention to be done
t_2^A= the first time that the second intervention can be done effectively
t_2^B = the last time that the second intervention can be done effectively
t_3^A= the first time that the third intervention can be done effectively
t_3^B= the last time that the third intervention can be done effectively

The scenario is similar to scenarios 4 and 5 but the planned duration is one useful life more than scenario 5 and two useful lives more than scenario 4. As in the previous two cases, the first intervention happens at the current time for this scenario. Two more interventions after the first intervention give the optimum result for maintaining the performance over the planned duration. Accordingly, the second intervention occurs in the range of t_2^A to t_2^B whereas the third intervention lies between t_3^A and t_3^B. The following equations are used to find the time intervals for all interventions:

$$t_1^A = t_0 \quad (17)$$

$$t_2^A = D\text{-}2U \quad (18)$$

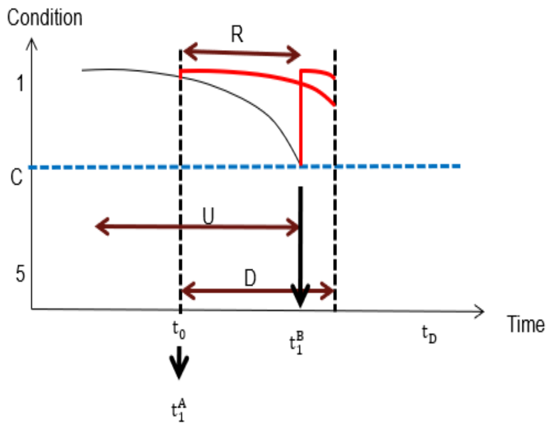
$$t_2^B = U \quad (19)$$

$$t_3^A = D\text{-}U \quad (20)$$

$$t_3^B = 2U \quad (21)$$

4.7 *Scenario* 7: $R < D < U$ *and* $R > 0$

The scenario and related best intervention periods are shown in Figure 8.



U= Useful life
R= Remaining useful life
D=Planned duration
C= Minimum acceptable condition for performance
t_0= Current year
t_D= Last year of the planned duration
t_1^A= the first time that the first and only intervention can be done effectively
t_1^B= the last time that the first and only intervention can be done effectively

Figure 8. Best intervention periods related to Scenario 7

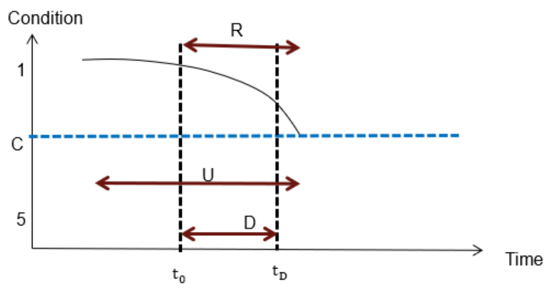
The figure indicates that the building cannot be maintained at the minimum required condition of performance without at least one intervention. The last possibility of optimal use of that intervention ends at time t_1^B so that the first intervention can happen at any time between the current time and t_1^B. Hence, the time interval best suited for the first intervention can be obtained using the following equations:

$$t_1^A = t_0 \tag{22}$$

$$t_1^B = R \tag{23}$$

4.8 *Scenario* 8: $D \leq R$ *and* $R > 0$

Figure 9 clearly shows that no intervention is required over the planned period.



U= Useful life
R= Remaining useful life
D=Planned duration
C= Minimum acceptable condition for performance
t_0= Current year
t_D= Last year of the planned duration

Figure 9. Best intervention periods related to Scenario 8

The following table summarises all the results related to each scenario:

Table 2. Details of interventions in relation to different scenarios of U, R and D

Scenarios	Description about intervention during the planned period	Intervention period		
		1st intervention	2nd intervention	3rd intervention
1. $U \leq D \leq U+R$ and $R>0$	One intervention	t_1^A= D-U t_1^B= R		
2. $U+R < D \leq 2U+R$ and $R>0$	Two interventions	t_1^A= D-2U t_1^B= R	t_2^A= D-U t_2^B= U+R	
3. $2U+R < D \leq 3U+R$ and $R>0$	Three interventions	t_1^A= D-3U t_1^B= R	t_2^A= D-2U t_2^B= U+R	t_3^A= D-U t_3^B= 2U+R
4. $D< U$ & $R \leq 0$	One intervention	t_1^A= Current year		
5. $U < D < 2U$ and $R \leq 0$	Two interventions	t_1^A= Current year	t_2^A= D-U t_2^B= U	
6. $2U < D < 3U$ and $R \leq 0$	Three interventions	t_1^A= Current year	t_2^A= D-2U t_2^B= U	t_3^A= D-U t_3^B= 2U
7. $R < D < U$ and $R > 0$	One intervention	t_1^A= Current year t_1^B= R		
8. $D \leq R$ and $R>0$	No interventions	No interventions		

5 Conclusion

Theoretical investigation on the deterioration prediction curve led to the finding of best intervention period of different scenarios based on useful life, remaining useful life and the planned duration. Considering the possibility of the variance that can be occurred within three parameters mentioned above, the study could enclose eight scenarios. Findings of interventions were captured with the aid of illustrations and mathematical formulae, which contributes to fill the knowledge gap. As practical implications, the findings have contributed for asset managers of local councils to make informed decisions on renewals of their building stock. These informed decisions can further be utilised for planning the capital budget. The method developed in the current research provides a time interval for the best intervention for the renewals of whole building assets. A new approach in future may be researched incorporating the interventions with the total cost (combined with operational costs, routine costs, renewal costs etc.) incurred during the planned period. The solutions of time intervals of the current study combined with the minimum cost will define a specific time for interventions. The study will require practical involvement with local councils to observe actual cost patterns and analyse the time point at which the minimum cost occurs.

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Improving Productivity of Construction Labour in the Republic of Kiribati

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Abstract
Labour productivity within the construction industry continues to be one of the driving forces for successful economic growth. Labour productivity not only creates a stronger economy but also contributes towards a marked improvement in social wellbeing and livelihood for people and communities. In the Republic of Kiribati, one of the main challenges facing the construction industry is the poor labour productivity. This research aims to explore the factors and approaches for improving labour productivity in the Kiribati construction industry. Using a qualitative methodology, questionnaires and interviews formed the methods of data collection. The research involved six major government and private construction firms in Kiribati. In total, 18 in-depth interviews were conducted, and 32 questionnaires were completed by construction participants such as project managers and tradesmen. The results explored the factors that affect construction labour productivity. This research indicated that the Kiribati 20-year Vision (KV20) plan was recognized as one of the key approaches for improving productivity of construction workers in Kiribati.

Keywords
Construction workers, Labour, Productivity

1 Introduction

The construction industry plays a key role in the economic development of a nation, and makes significant contributions to employment, businesses and the Gross Domestic Product. Even though the industry contributes greatly to the economy, the cyclical nature of work in the sector continues to have low productivity globally. Construction labour productivity is defined as one of the main indicators of construction project performance (Aliakbarlou at al. 2018). Therefore, improving construction labour productivity in the construction industry, by investigating effective ways and strategies for increasing labour' performance is essential for improving the construction industry productivity and performance (Hwang at al. 2018).

Productivity and its impact on the quality of buildings is a challenging aspect in many Pacific Islands. It is of paramount importance in the construction industry because it contributes to a nation's long-term material standard of living and also contributes towards a marked improvement in the social wellbeing and livelihood of people and communities. This research investigates the factors that impact on the productivity of construction workers in the Pacific Islands and best approaches for improving productivity. This research is significant for Pacific Islands as labour productivity creates better outcomes for the improvement of people's lives and sustainable economic development.

2 Literature Review

Productivity is defined as the outcome level of production rate in an industry through utilisation of resources such as raw materials, machines, tools and equipment by workers to achieve goals of providing best products, goods and services (Tookey 2011). With growth in labor productivity, for the same amount of relative work, results in an increase in production of goods and services and “a growth in labor productivity is directly attributable to fluctuations in physical capital, new technology, and human capital” (Chappelow 2019, p. 1).

Construction Labor Productivity (CLP) framework was developed by Yi and Chan (2014) and is defined as a “power of being productive” and measuring resources to be utilized well by individual workers, to find out how many inputs were made and how much production output levels were achieved. According to the CLP framework, workers’ productivity depends on the industry, projects and activities carried out by the labourers (Kenley 2014). Level of production rate for each labourer is determined on how long each worker spends on construction tasks with the required outputs or products provided within the allocated time. In addition, Carson and Abbott (2012) suggested partial and total factor productivity index measures which only used limited information and data to calculate level of productivity in the construction industry. There are two main calculations in this method which are index approach and partial productivity to indicate the CLP levels. The index approach estimates index numbers to display changes of productivity level over time in an industry while partial productivity estimates “an index of the volume of construction activity per employee” (Carson and Abbott 2012, p.4). Table 1 presents existing equations for calculating and measuring overall productivity in the industry, construction labor productivity (CLP) and the unit rate for construction labor productivity (CLP unit rate) (Poirier *et al.* 2015, Durdyev and Mbachu 2011).

Table 1: Productivity Measurement Formulas

Productivity equations	
Overall productivity	$Producitvity = \frac{Output}{Resource\ input}$
Construction Labor Productivity (CLP)	$Labour\ Producitvity = \frac{input\ (work\ hour)}{Output\ (quantity)}$
Construction Labor Productivity (CLP) unit rate	$Labor\ productivity\ (unit\ rate) = \frac{Output\ (quantity)}{input\ (work\ hour)}$

There are several factors that impact on labor productivity such as poor project management, lack of proper health and safety practices, and lack of available resources and finances. Key constraints of labor productivity refer to factors that affect construction workers and can become barriers for workers to complete assigned tasks in an industry. Some of these main constraints are discussed below.

Project management related constraints in construction projects cause lower production rates of workers. Carson and Abbott (2012) state that faulty innovation and management failures in managing construction workers lead to lower self-motivation. This in turn impacts on worker’s output to remain consistently low overtime, resulting in reduced production rate. Carson and Abbott (2012) elaborate that when management fail to motivate workers to perform to their highest ability, it leads to lack of competition between workers and consequently lower quality outcomes of work performed by construction workers. Similarly, Naoum (2016) argues that management failure due to project managers limited management experiences, poor leadership styles and poor communication skills greatly influences workers' productivity. According to Naoum (2016), managers incompetence of site supervision causes job dissatisfaction and results in inefficient performance of workers which subsequently impacts on labour productivity.

The availability and accessibility of resources on construction projects also impacts on labour productivity. Resources such as finances, materials, plant and machines, tools and equipment, space and facilities, and technologies, could affect construction workers' productivity in the industry. Ghodrati, Wing and Shahbazpour (2018) mentioned that unavailability of products and materials, including poor quality plants and machinery, is directly related to poor performance of workers and failure to achieve required standards. Ghorati et al (2018) add that the unavailability of materials affects on-site workers' productivity due to increased wait time for materials and halt in the construction time. Furthermore, Naoum (2016) indicated that "the industry suffers from poor levels of investment and innovation…and technology is not embraced fully as with other sectors" (p.403). Consequently, workers lack knowledge of and confidence in using upcoming technologies that are designed to enhance productivity. Therefore, these productivity enhancing technologies remain of little benefit to workers and hinder progress in the sector.

According to Pourier, Staub-French and Forges (2015), late payments and lower rate salary cause job dissatisfaction in workers, which directly affects productivity. Dissatisfaction of workers from late payments and lower rates demotivates them leading to poor performance and many leave the sector to seek employment in other industries. As a result, productivity rate decreases while the industry struggles to recruit new employees. The construction industry is also considered a high-risk industry. The New Zealand construction industry had become one of the highest incidence rates compared to other industries within the country (Stats NZ 2017). Accidents and injuries of workers caused during construction activities enormously affect the production rate of impacted workers. Patkure and Kulkarni (2018) state that careless and unsafe work, alcohol and drug involvement have resulted in higher accidents and injuries rate of workers. This is the most considerable issue of project managers and supervisors on site to analyze carefully because any accidents and injuries to workers would affect the production level in the industry.

It is evident that the construction industry recognizes the importance of improving productivity of workers. Workers' productivity creates better outcomes for improvement for people's lives (Koehn and Datta 2003). The improvements of workers' productivity have a higher possibility of a better living environment and an increased production rate of workers in the construction industry. The productivity of many developing countries is significantly impacted by several factors and the study of strategies that can be used for improvements is important so that changes can be implemented in these countries to increase labour productivity and its interrelated contribution to national economic productivity. Most of the literature available currently focuses on the labour productivity of industrialized nations or countries focusing on large scale economies. There are existing gaps visible when analyzing literature such as lack of focus on smaller economies or poorer countries and island nations. There is deficiency in the availability of literature that focuses on ways labour productivity can be enhanced to assist island nations improve outcomes for their countries and their people. Therefore, this research set out to answer the following research question:

"How can construction labour productivity be improved for Pacific Islands?"

The sub-questions were:

- *What are the main factors affecting construction labour productivity?*
- *How is construction labour productivity maintained in the industry?*
- *How do the construction companies measure productivity of workers in the industry?*"

3 Research Methodology

The main purpose of this qualitative research study was to identify how construction labour productivity could be improved for Pacific Island Nations. The study used the Republic of Kiribati as its case because studying all the Pacific Island nations scattered in the Pacific Ocean was beyond the scope of this research and in-depth study of a given case was most feasible. Kiribati was also chosen as a case because it is the home country of the main researcher who was based there during the time the study was conducted. This research project was conducted in Tarawa, Republic of Kiribati between July to November 2019. Kiribati is an island nation in the central Pacific Ocean and has a total population of 110,000, with more than fifty percent inhabiting Tarawa atoll. The construction section is relatively small in Kiribati with the sector contributing less than 8% to the total national GDP (Webb, 2020) with only a small number of local companies undertaking small scale projects.

The sample size can be determined in relation to the specificity of the sample and the quality of the dialogue (aliakbarlou et al. 2021). The participants were selected on the basis of experience construction industry in Kiribati. Six local construction firms participated in the study. The research methods included semi-structured interviews (18 interviewees) and questionnaires (32 participants). The aim of the semi-structured interview was to collect textual data which allowed responders to provide flexible answers based on personal views and opinions (Gray 2004). The questionnaires were designed to obtain statistical data such as expertise and work experience (Denscombe 2010) and specific questions on productivity of workers within the firms. The data was obtained from two groups of participants: the Site Managers and tradesmen. This was essential to better understand the factors that impacted productivity from the viewpoint of laborers and the management as both are needed for successful project completion.

4 Data Analysis

4.1 Questionnaire Data

A questionnaire was utilized to obtain information from research participants based on their understanding of factors that influenced labour productivity in Kiribati. This was done to corroborate the factors that were identified in the literature and identify if the factors applicable in developed countries were transferable in the context of an island nation.

4.1.1 Demographics

A mix of construction workers participated in this research. Tradesmen included 16 carpenters, two electricians, two plumbers, two painters and two machine operators. Participants from managerial roles included four project managers, two procurement officers, one estimator, one building assessor, and one store man. Majority of the research participants (17) had between 0-5 years of experience with five participants who had 5-10 years of experience, five participants each in the 10-15 years and 15+ years' experience in the construction industry. This sample indicates that a true representation of the current Kiribati construction industry is reflected in this study.

4.1.2 Factors Impacting Productivity of Workers

Lack of resources is the major issue that affects labour productivity in Kiribati (figure 1). Lack of skills, health and safety issues and financial issues also widely impact on the production rate of workers whereas design has limited impact due to uncomplicated architectural drawings in Kiribati.

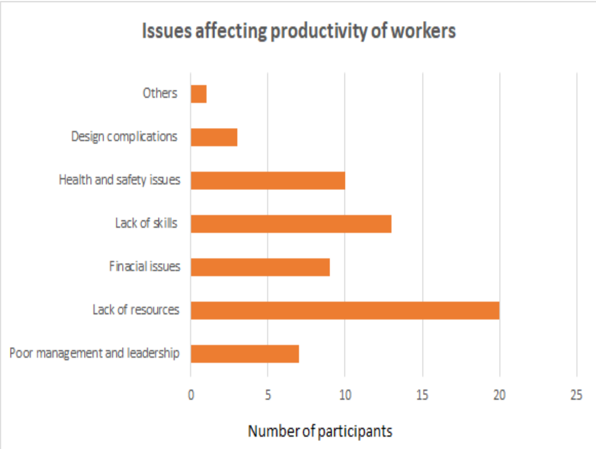

Figure 1. Issues affecting the productivity of workers in the industry

4.1.3 Methods for Calculating Productivity

The participants were asked to select the productivity formulas that were used to measure the productivity of workers in the industry (Table 2). The majority of participants do not use any method for calculating productivity and only a few applied the productivity formulas with the standard productivity formula being the most popular. Only two participants use other methods to calculate workers' productivity such as workforce load.

Table 2. Construction productivity methods used in Kiribati

Measurement methods used in Kiribati construction sector	
Measurement methods	**No. of workers apply the method**
Productivity $=\frac{Output}{Resource\ input}$	8
Labour productivity $=\frac{Input\ (work\ hour)}{Output\ (Quantity}$	7
Labour productivity (unit rate) $\frac{Output\ (quantity)}{Input\ (work\ hour)}$	5
Others	2
None	9

4.1.4 Maintaining Productivity of Workers

The most popular approach for maintaining the productivity of workers was better leadership and management strategies followed closely by having frequent meetings and providing more training opportunities for workers.

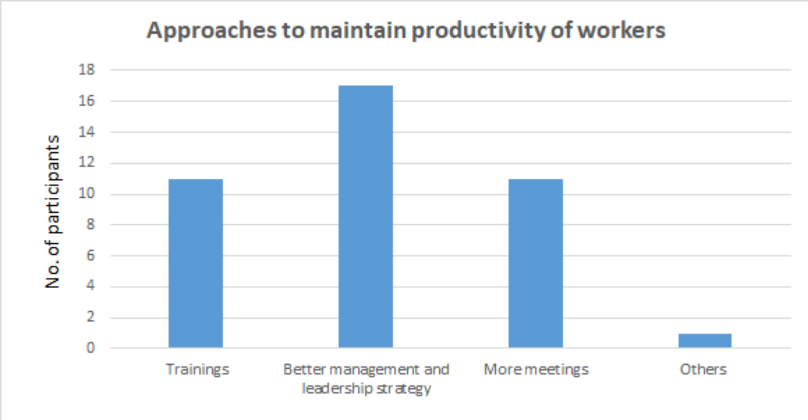

Figure 2. Approaches of maintaining productivity of workers in the industry

4.1.5 Approaches for Productivity Improvements of Kiribati Construction Workers

Participants were asked to identify the strategies and approaches used to improve construction workers' productivity in the industry. LPS is mainly used in 17% of the companies, while BIM has been used by 12% of the companies, mainly governmental organizations and larger firms. 57% of the construction firms in Kiribati simply promote training for improving productivity. 14% of the companies indicated that they employed their own approaches for improving worker productivity such as increasing budget for higher quality resources, monitoring workers' commitments and needs to perform better on the job and increased collaboration and innovation for better teamwork and engagements through training within the industry.

4.2 Interview Data- Project Managers and Site Supervisors

The semi-structured interviews were conducted with two groups of participants. The first group was the managerial group that included five project managers (PM), and three site supervisors (SS). The responders came from four government construction companies or divisions and two private construction companies in Tarawa, Kiribati. The main aspects discussed in the interviews are presented below.

4.2.1 Approaches for Improving Productivity of Workers

Kiribati's long-term development blueprint, Kiribati 20-year Vision (KV20), was recognized as the best approach for improving productivity of construction workers. Most of the project managers believed that KV20 has created an improvement in building quality and increased performance of workers in the industry.

Project Manager (PM3) stated "*that the LPS is also part of their strategy in improving the work quality outcomes with workers' performances in the industry because it is the best and easiest way for workers to understand and get into it*". SS1 and SS3 also used LPS in their industry for higher quality of work for managing and monitoring multiple tasks on-site. Furthermore, PMs and SS1 both believed that the management strategy should be flexible to accommodate construction workers' preferences based on the appraisal review strategy at the end of projects. Collaboration and innovation were also identified for improving productivity of workers as it builds relationships, trust, respect, teamwork and connections.

PM4 had ongoing special contracts with groups of small private companies to work with. This created a connection between companies and collaboration in multiple projects. For example, one private company was the prefabricated manufacturer for every project they collaborated on. Therefore, PM4 believed that this became unique and effective for the project cost and time with higher production rate of construction workers in the industry.

4.2.2 Maintaining Productivity of Workers in the Industry
The PMs and SSs mentioned that training and workshops and daily monitoring of workers have maintained higher standard outcomes in the industry. PM1 and PM3 both have an appraisal review strategy at the end of every project to review construction workers' performance. This appraisal review involved a project manager and site supervisors to review performance of each trade on different projects. The review identifies improvement areas that can be applied in future projects. In addition, PM4 used a Post Contract Evaluation (PCE) for larger projects.

4.2.3 Measuring Productivity of Workers in the Industry
Most of the participants mentioned that the productivity of workers was measured in different ways. SS2 stated that they "*measure workers' productivity by one-by-one tasks by giving tasks to each worker…and measuring the end results of each worker …by looking at its quality and time spent for that task.*". PM3, SS3 and SS4 both used the same method of measuring workers' productivity by completion of daily forms and providing quarterly reports on workers' performance. PM5 said the KPI tool is used to measure workers' productivity as it "*measures each worker's performance at the completion of each given task at a given time for them to complete the work. Then, we assess the outcome product whether it is achieving the required quality and standards or not. This measurement tool is marked out of 10 which is also part of the KV20*".

4.2.4 Benefits and challenges of Improving Worker Productivity
All participants commented that higher quality outcome standards in some commercial buildings, successful cost-effective projects and developed skills of workers, better teamwork through improved collaborations and sharing of ideas within a team, creates beneficial service reputations with private companies (PM3 and SS3). The challenges identified were lack of workers' commitments, high pressure on PMs, higher costs, time consuming tasks and the overloading of the workforce. There were also difficulties and complications in understanding construction workers at site level (PM4) and the friction between workers and managers on the site due to disagreements with change of management style (SS4).

4.2.5 Factors Affecting Productivity of Workers
Lack of resources, lack of skills and lack of safety gear were the common factors that impacted productivity. Most of the safety gears and construction resources such as steel, timber, cement, reinforced steel, including machines and tools, are all imported into the country. Shortage of skilled labor and hiring of temporary tradesmen caused issues such as reworks due to workers' inability to understand designs and drawing (SS3). Financial issues, increased accidents, absence or lateness of workers, miscommunication and disengagements, and higher staff turnover were affecting productivity level in the industry. PM2 stated that weather issues sometimes affected productivity such as rainy days and high tides could cause delays to the project because all workers were focusing on fixing areas or buildings prone to flooding.

4.3 Interview Data- Tradesmen

Nine tradesmen from different companies, including the government departments and private firms, participated in the semi-structured interview. The interviewees were two carpenters and one participant each from the following trades: electrician, tiler, Storman, plumber, painter, and a leading hand.

4.3.1 Skills Development

The tradesmen interviewed all mentioned that they needed training and further studies. The older experienced workers understood and were able to carry out practical work but the skills in theoretical parts of the construction works were very poor. On the other hand, the younger tradesmen were able to understand theoretical parts of the construction works but were deficient in practical works. The tradesmen when queried on specific skills needed in the industry, most stated that pouring concrete always failed to comply with the required standards because it was manually done by temporary labourers.

4.3.2 Factors Discouraging Tradesmen to Work in the Industry

Unavailability of materials, machines, tools and safety gears were major reasons for discouragement for participants as it impacted on their performance. Poor management was another factor as task allocation was beyond their daily workload and mismatched with their level of expertise, resulting from the skills shortages faced in the industry. Tradesman (TM) 8 clearly stated that "*a carpentry works is given to a plumber when a carpenter is not available on site*". One tradesman had experienced many workers' poor attitude towards female workers which may also discourage female workers to remain on-site. These factors may be contributing to the lower productivity of workers in the Kiribati construction industry.

5 DISCUSSIONS

The majority of participants in this research believed that there was an increase in productivity of workers in the Kiribati construction industry and this was evident in slight improvement of commercial building qualities and standards such as offices, schools and some retail shops. Presented here is an analysis of the best approaches and strategies for improving workers' production rate in the construction industry.

5.1 Best Approaches for Improving Productivity of Kiribati Construction Workers

The research results highlight the key role played by Kiribati's long-term development blueprint, Kiribati 20-year Vision (KV20), in influencing the productivity in the country and its effort to improve the quality of life for its people by the year 2036. The KV20 document was referred to frequently as a guideline for improving productivity in the industry. The Last Planner System and BIM were the other two approaches that were commonly used in Kiribati for improving labour productivity. LPS is widely used for improving workers' production rate with better planning for workers' tasks and workload. This supports work done by Pellicer *et al*. (2015) and Fuemana *et al*. (2013) that LPS provides better planning and control in the production system in the construction industry. However, the high costs associated with the implementation and management of BIM and lack of expertise in the system has hindered its adoption in Kiribati. This finding is similar to Poirier *et al*. (2015) where they discovered that some companies found BIM implementation very expensive, and its usage was affected due to poor understanding of the system by lower skilled workers. This research supported this finding as most of the participants also portrayed a lack of understanding of the system.

5.2 Measurement of Workers' Productivity

One of the best approaches in improving productivity of workers in the industry is by measuring workers' productivity to gain an understanding of measures to take to increase productivity levels. Research participants used various calculations to assess productivity; however, as Poirier *et al*. (2011) stated, different ways of measuring productivity rate in the construction industry depend on data availability. Some companies in this research used mainly the productivity method and labour productivity methods (refer to Table 1) because it is more specific to construction workers. This method of measuring worker productivity was also suggested by Yi and Chan (2011)). However, one interesting finding is that the questionnaire participants did not select any of these measurement methods due to lack of data available in the industry. This aligns with Carson and Abbotts' (2012) research that there is limited information and data to calculate the level of workers' productivity in every construction industry. Additionally, Key Performance Indicators (KPI) and weekly performance assessments, which calculated workers' production levels for given tasks and rate of completion of tasks, were also used by several firms.

5.3 Skills Development

Detsimas *et al*. (2016) state that the "investment in workplace training that allows employees to systematically develop and upgrade their skills is essential for the enduring and sustainable success of any construction company" (p. 486). Training and skills development were recommended as the best approaches for improving productivity by all participants in this research. Some workers have been trained at the Kiribati Institute of Technology but there was increased demand for skills upgrade. The construction industry is expanding in Kiribati, the demand of construction workers is increasing but there is a skills shortage in the country. Employing temporary unskilled workers is now on the rise and therefore, increased demand for training of these workers. Curtis (2017) also stated that "when demand is high, highly skilled workers are in high demand, and when demand is low, there is not enough work to keep highly skilled workers employed" (p. 5). The skills that need further training and development in Kiribati are reading and interpreting drawing plans and specifications and understanding the correct ratios for concrete mixing. Identifying specific training requirements is essential as according to Edum-Fotwe and McCaffer (2000), the construction employees require specific skills to perform the task and construction methods are continually evolving. Therefore, training skills must be upgraded regularly to perform these particular jobs.

5.4 Lack of Resources and Skills Shortages Affects Productivity in Kiribati

Lack of resources, lack of skills, safety issues, financial issues and project management issues were some factors that impacted productivity of workers in Kiribati. This resonates with the work of Ghodrati *et al*. (2018) that lack of resources is the main factor for workers' lower productivity rate. Pourier *et al*. (2015) and Carson and Abbort (2012) mentioned that financial issues were at the forefront, while Patkure and Kulkarni (2018) believe that health and safety issues affect the productivity rate of construction workers. Lack of resources was the main factor impacting workers' productivity in the Kiribati construction industry as many resources are imported into the country and only a few raw materials, such as sand and aggregates, are locally available. Materials with lower quality and late deliveries or wrong materials delivery cause delays and influence the production level of workers in the industry. This becomes a significant finding because most of the Micronesian islands are facing the same issue of unavailability of construction resources in the Pacific region (Scalzitti 2005).

Skills shortages in Kiribati significantly impact productivity. Higher staff turnover requires the hiring of unskilled workers that have limited skills and knowledge for construction site levels. Due to a shortage of skilled workers, rework is on the rise as work completed by unskilled workers has reduced the standard of work quality. Design complications hindered workers' ability to correctly interpret drawing plans and specifications. Participants reported higher absences and lateness in the Kiribati construction industry that affects the improvement of workers' performances.

6 Conclusion

To improve productivity in Kiribati, the majority of construction workers require training for skills development, which forms a major part of the island nation's long-term development blueprint, KV20. Most construction firms believe that workers' productivity needs to be improved for better quality and standards, better performance of construction works, cost effectiveness and reduced timeframe for construction projects. LPS is used by firms to monitor workers' work quality outcomes and is helpful for project managers and site supervisors to control and track work activities. However, BIM was considered an expensive system that is not affordable to smaller construction firms. Lack of resources due to high reliance on imported goods, lack of skilled staff, health and safety issues, financial issues, poor commitment of workers and management issues all contributed to low productivity. It is recommended that BIM should be adopted in the construction industry with funding from the Kiribati government so that firms could be able to improve their way of working performances with building better quality buildings. Additionally, more resources should be invested in the training and development of construction workers. This study's findings are mainly based on Kiribati construction industry. It is possible that the importance and ratings of some factors could be different if the study had been conducted in a different country. Hence, as a part of future research, it would be interesting to ascertain whether this study's results can be generalized to other countries.

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Are We Handling Trade Wastewater Discharge Effectively During Building Construction in Australia?

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Abstract

Victorian Water Authorities in conjunction with Environment Protection Authority (EPA) Victoria provide guidelines on approved wastewater treatment and management of onsite wastewater systems. All organisations have a general environment duty to self-manage and report noncompliance. However, construction activities, particularly those involving trade activities like painting, plastering, rendering, and tiling, creates wastewater as a result of tool wash out, which is typically discharged to sewers or the environment through poor handling practices. Thus, paper presents volume of trade wastewater discharge for tools washing during construction of building projects and water saving through a closed loop system in Australia. Results found that 20*l*/min wastewater is discharged due to trade wash out in construction projects and closed loop system saved an average of 93% of water used for tool washing irrespective of the project size. If wastewater is not managed properly, there can be negative impacts to the environment, and as well as it will increase the freshwater usage in construction activities. Thus, this research highlights the importance of effective wastewater management in construction projects. Eventually these outcomes will help the EPA and relevant construction authorities to take necessary actions to minimise the impact of water use and wastewater discharge in construction projects in Australia.

Keywords

Building Project, Construction Industry, Closed Loop System, Trade Wastewater, Water Saving

1 Introduction

Victorian Water Authorities in conjunction with the Environment Protection Authority (EPA) Victoria provides guidelines on accepted wastewater treatment systems and information on onsite wastewater system management in both the industrial and domestic sectors. EPA's wastewater program consists of advisory board to recommend industry on handling industrial and commercial wastewater discharges, sound environmental practices and possibilities on wastewater reuse. EPA's Guidelines for risk assessment of wastewater discharges to waterways offer guidance to industry practitioners involved in risk assessments for wastewater discharge (EPA Victoria 2009). Furthermore, Guidelines for Environmental Management: Use of reclaimed water (EPA Victoria 2021), reinforces sustainable water recycling and underpins the contribution of reclaimed water in Victoria's journey towards a sustainable environment and resource management. These goals can only be achieved by conducting audits for selected reuse schemes (priority or random site basis) and keeping and updating a database of all schemes in Victoria.

Generally, large volumes of water for trade tool wash out in construction projects are taken from the mains and this water is contaminated during the washing process, particularly for trade activities such as painting, plastering, rendering and tiling. A large volume of liquid waste and construction chemical solids from tool washout are discharged to the environment annually, and if not treated, can result in a breach of EPA and Water Authority regulations. This may even be the case if wastewater discharged to the sewer with a Trade Waste Permit, as these discharges can often be non-compliant with the limits required by the permit. On 1 July 2021, the Environment Protection Act 2017 (Vic) was amended, and the Environment Protection Regulation 2021 (Vic) supersedes the existing environment protection legislation. Thus, all organisations have a general environment duty to self-manage and report noncompliance with respect to pollution and ensure that all discharges are within the guidelines set by the EPA. In this context, understanding the nature of wastewater generation due to trade washout activities during construction is of importance. Thus, this paper presents volume of trade wastewater discharge for tools washing during construction of building projects and water saving through a closed loop system in Australia.

2 Literature Review

2.1 Wastewater Discharge and Treatment

A large amount of wastewater generated from industrial, agricultural, and domestic sectors owing to growing demands have led to degradation and contamination of ecosystems across the globe (Srinivas and Singh 2018). Specially if industrial wastewater discharge rates rise, it may cause unimaginable consequences to living beings (Xiangmei *et al.* 2021). Wastewater discharged from industrial and municipal sewage systems is an important cause of water degradation (Piwowar et al., 2021). Thus, polluted water has become a global issue where it causes demise and disorders on the worldwide level and death of 14,000 people per day in both developed and developing nations (Arif et al., 2020). Hence, contaminated wastewater is required to be treated as if pollutants remain within acceptable range prior to its reuse or discharge to the environment (Nzila *et al*. 2019).

Melbourne generates approximately 320 billion litres of sewage per year, of which only about 10% is recycled for a range of non-drinking purposes (Melbourne Water 2018). This shows that there is a significant opportunity to increase the amount of water used from the sewerage system to support the water requirements in the Melbourne region. Industrial wastewater management is often associated with wastewater reclamation and reuse as it not only creates an alternative water resource but also reduces effluent discharges to the environment (Lyu et al. 2016). Thus, adopting the improved water management strategies at institutional, national and international levels is a necessity, which may effectively lower the freshwater demand for industrial purposes while reducing the cost of water, while meeting environmental regulations and the sustainable development goals (Haque et al., 2021).

Typically, large amounts of industrial wastewater are reused with the installation of a wastewater treatment plant (Lyu *et al.* 2016). These plants comprise chemical treatment approaches including nanofiltration, advanced oxidation, reverse osmosis filtration and activated carbon filtration to remove pollutants (Nzila *et al*. 2019). Besides generation of toxic by-products to the environment and huge capital involvement for full scale treatment processes have led these processes vulnerable in use (Nzila *et al*. 2019). The environmental impacts of wastewater treatment plants signify a subject of growing concern on potential applicability of zero liquid discharge for water treatment in which membrane-based technologies are a strategy which fulfils most of these requirements (Tsai *et al.* 2017). Over the past decades, membrane technologies have gained a vital spot in industrial wastewater purification, owing to its high-water quality and low capital involvement (Yang *et al*. 2011). Furthermore, Lin *et al* (2012) also highlighted that, by being effective in removing contaminants and microorganisms in wastewater, membrane processes have gained a growing admiration as a result of stricter rules and regulations and recent initiatives on water reuse. With the arising requirement of the sustainable wastewater management practices for tool washing, filtration system is used for wastewater management on construction sites which provides totally closed loop tool wash solution for all construction and maintenance sites that require washout facilities for wet trades (WASHBOX, 2021). Hristov et al. (2021) also show that the reuse of treated wastewater produces significant environmental benefits greater than the industrial investment on treatment plants.

2.2 Construction Wastewater

Wastewater due to construction can arise from either core construction activities, such as air lifting process of bore piling or peripheral activities such as cleaning of tools and equipment. The concentration of suspended solids in wastewater is one of the biggest pollutants, especially where cleaning of equipment and tools take place (Fan *et al.,* 2013). The concentration of suspended solids in the wastewater can range from 100mg/*l* to over 30,000mg/ *l* depending on the construction process (Wong 2002). In addition to suspended solids the washing of tools can release chemicals into the wastewater, from the paints, coatings and cleaning agents, which can have toxicological effects if not treated properly (van Wezel *et al.,* 2016).

Construction liquid waste should be properly treated and discharged to minimise negative impacts on the environment (Zhao 2020). Accordingly, treatments can be done with physical and chemical methods integrated with coagulation and sedimentation processes, thus reducing or eliminating pollution and also environmental risks (Zhao 2020). Water reclamation, reuse and recycling are now known as main gears of wastewater and water management (Po *et al.* 2003). Hence, water reuse is a critical factor for effective use of water resources without compromising future water needs (Upadhyaya and Moore 2012).

Many countries across the globe struggle to utilise the benefits of wastewater reuse although there is an enormous potential for liquid waste reuse (Lyu *et al.* 2016). Wastewater treatment plants in Mediterranean countries often consider wastewater treatment at the primary level, which is not sufficient as it just removes settable solids from wastewater, making treated wastewater inappropriate for reuse (Kellis *et al.* 2013). Furthermore, low efficiency in wastewater reuse and recycling in Chinese industrial enterprises has resulted bulk volume of industrial wastewater discharge, creating major environmental issues (Xiangmei *et al.* 2021). Even with the latest technological advances in wastewater treatment, the water reuse opportunities have never been better (Po *et al.* 2003).

2.3 Legislative Provisions for Wastewater Management

With the realization of the burning need to minimise construction wastewater, several state governments in Australia have made multiple proposals and even initiated a number of projects for waste reduction, reuse and recycle in construction (Li, 2016).

In order to reduce consequences of improper waste discharge from industrial sectors, legislations on the discharge of waste are being tightened globally (Nzila *et al*. 2019). To overcome this challenge, regulatory provisions on quality of water have been imposed with the intention of protecting the environment. Further, specifications for the treatment of industrial wastewater have been developed with advanced requirements. Moreover, a national guideline named Acceptance of Trade Waste (Industrial Waste) was established in 1994 for trade waste discharged to sewer, which would be highly applicable in the context of wastewater management in the construction industry in Victoria. Besides, the National Waste Policy released in 2018 by the state government would also provide the latest national guidelines related to the given context (Victoria State Government, 2020).

Environment Protection Authority (EPA) Victoria was established in 1971 as an independent legislative authority, under the Environment Protection Act 1970 (EPA Victoria 2021). Enacting the Environment Protection Act 2017 on 1st of July 2021 onwards will enable EPA to implement their strategic plans by ensuring environmental protection in Victoria. Additionally, EPA Victoria currently administrates Pollution of Waters by Oil and Noxious Substances Act 1986, National Environment Protection Council (Victoria) Act 1995 and Environment Protection Act 1970 (EPA Victoria 2021). The new Environment Protection Act will shift the attention from punishing environmental polluters to focus on prevention of damage by implementing a positive duty-based regime (Wit and Plant 2021). Also, it has new 'determinations' and 'permissions' procedures that will provide insights into activities that were not regulated earlier; for instance, a permit will be required for temporary on-site industrial waste treatment and wastewater discharge.

Thus, the legislative provisions and information available in guidelines on the reclamation and reuse of treated wastewater from large scale facilities, necessarily form construction sites, would facilitate a solid platform for effective construction wastewater discharge during building construction in Australia. Hence, it is high time to look upon current construction wastewater discharge practices and introduce strategic and timely relevant wastewater discharge practices to comply with statutory requirements (Srinivas and Singh 2018).

3 Research Methodology

This research intends to determine volume of trade wastewater discharge for tools washing during construction of building projects and water saving through a closed loop system in Australia. In a typical construction project, tools are washed out and the contaminated water is collected in containers for final disposal as illustrated in Figure 1.

Figure 1: Typical 44 Gall drums and plastic wheelie bin type used for trade wastewater management.

To achieve the aim of this research, the volume of water used for tool washing by trades in construction projects were calculated from two projects, which used a closed loop wash station. The two projects were chosen as they were both high-rise apartment projects, which typically has challenges in managing tool washout. The difference in the number of stories between the two projects also provided an opportunity for comparisons across them. More information regarding two projects (project A & project B) are provided in section 4.

Both projects used a novel closed loop wash station, which is a complete on-site washout solution with all waste contained in the unit and all the wash water recycled within the system. The closed loop wash stations that were used for these projects had a volume of 600 litres of water for project A and 200 litres of water for project B in its holding tank that is recycled for the purpose of tool washing. The following figure shows for the closed loop wash station used in these projects.

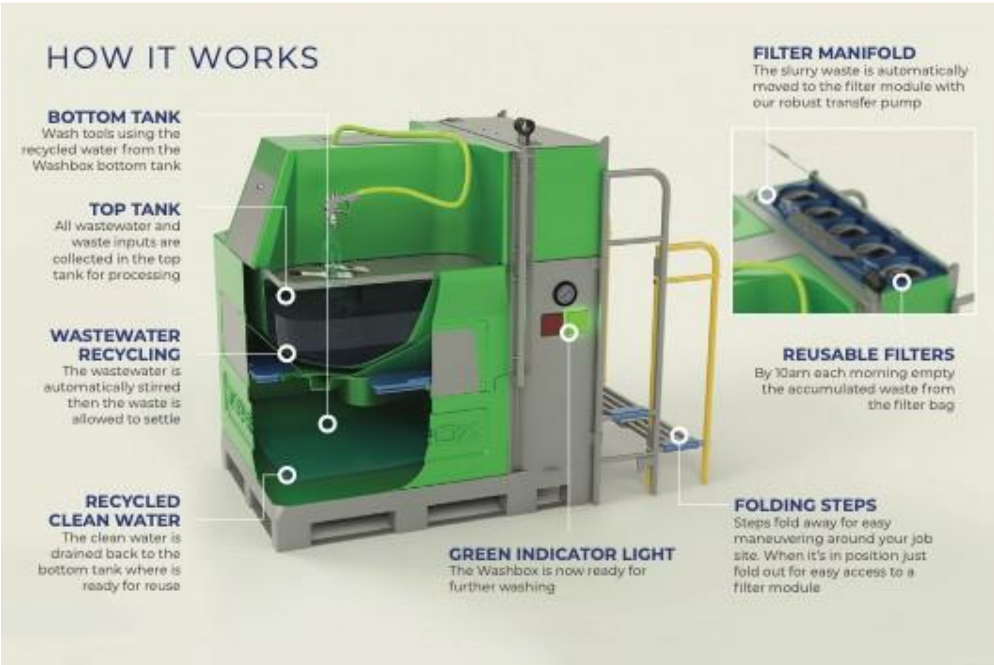

Figure 2: Closed loop wash station

Adopted: https://washbox.global/

The closed loop wash station records the volume of water that is processed by the unit and the working time or amount of time that the unit is used by the relevant site trades for tool washing at a controlled flow rate. The amount of water savings of the technology was calculated by estimating the volume of water that would have been used if traditional tool washing was used. Based on the amount of time the station is used in each project, the equivalent water uses in an uncontrolled environment where washing was undertaken for the same time duration was estimated using the following equation.

$$Total\ water\ savings\ =\ (T\ *\ F) - (V + W)$$

Where, T - Total time the wash station was used (in minutes),

F - Average flow rate of the mains

V - Volume of water used by holding tank of the wash station

W - Volume of refiling

It was assumed that in the uncontrolled environment the total volume of water used was discharged. The average flow rate of the mains was assumed to be $20l$/minute.

Furthermore, solid waste content within the wastewater discharged was also measured using the Closed loop wash station as it removes solid waste into filters. The technology applies a filtration system to remove particles and suspended solids from wash water producing a recycled wastewater and sludge. The recycled wastewater is reused onsite in the Closed loop wash station and then dispatched offsite for treatment. Thus, the Closed loop wash station provides an onsite pre-treatment process separating particles and suspended solids from effluent. The separated particles and solids in the form of a sludge or filter cake may be dried, sampled and analysed for contaminants and then disposed as solid inert waste or a reportable priority waste. Thus, this technology minimises the negative environmental consequences of wastewater discharge and minimise the water usage in construction sites by recycling the wastewater.

As mentioned before, two projects were selected for data collection and information regarding the projects and outcomes are presented below.

4 Findings and Discussion

The following table outlines the information related to the two projects used in this research.

Table 1: Description of projects

Project	Description
Project A	Mixed used development having 959 residential and 252 serviced apartments. The cost of the project is approximately AUS $730 million.
Project B	Multi-storey residential apartment building having 62 units. The cost of the project is approximately AUS $40 million.

As shown in the above table, two projects were used to collect the data related water usage for tools washing and wastewater discharge. In project A, two Closed loop wash stations were used to provide washout facility for trades and one was provided for the total duration of the project (4 years) and the second one was provided for the final months of the projects to assist with the increased number of finishing trades onsite. In project B, only one wash station was used for the duration of the project, located throughout the work progress.

Accordingly, total washing time where station in operation is recorded daily by using data logging Programmable Logic Controller (PLC) in the system. Even though, the holding tank does not required refilling during the operation, due to splashing, evaporation and removing sludge to the filters loses a small amount water from the system, Thus, this required around 20*l* top up or refilling each week. This figure will vary based on the weekly usage. The following data are gathered with respect to two projects.

Table 2: The data collected from two projects

projects	Project A	Project B
Total washing time (Minutes)	10,000	1,800
Total water discharge (Litres)	200,000	36,000
Total water saved (Litres)	187,000	33,000
Equivalent wastewater discharge if Closed loop wash station was not used (Litres/Minutes)	18.7	18.33
Total waste diverted	$4m^3/4T$	$1m^3/1T$

According to above data, average 20litres of wastewater is discharged per minute from construction projects due to trade wash out and the closed loop system saved an average of 93% of water used for tool washing irrespective of the project size.

The closed loop wastewater recycling system was identified to have two key benefits: reduction of water usage and minimising environmental impacts of wastewater discharge. The reduction of water usage is significant as the water used for tools washing is predominantly treated potable water that can be used for more beneficial uses. The closed loop water recycling system thus reduces the amount of potable water that is used on site and then contaminated. The other benefit identified was that the in-situ technology used, negated any wash water being discharged into sewers. This was observed as a vital aspect as municipal sewerage systems are typically not catered to accommodate high levels industrial wastewater. The sludge collected from the wash water could include chemical pollutants that could be disposed of appropriately. On the other hand, if this wash water was discharged to sewers, the chemicals could end up in receiving water bodies or agricultural land where bio-solids from treatment plants are used, causing extreme ecological damage (Jobling *et al.,* 1998).

Thus, it is important to effectively manage wastewater in construction projects in Australia. This can be done through using appropriate technologies to reuse/recycle wastewater and by using filtration system to remove particles and suspended solids from wastewater. Removal of particles and suspended solids from wastewater is mandated by new regulations and this was also highlighted by several researchers (Nzila *et al.,* 2019; Zhao 2020). Similarly, the regulations and relevant authorities responsible for wastewater management can play an important role in this process by checking non-compliance and enforcement of the relevant provisions of relevant Acts. This can be done by conducting audits for selected construction projects (priority or random site basis) and thus, EPA Victoria has a major role to safeguard the effective implementation of proper wastewater management systems in construction projects. Furthermore, this research highlights the importance of undertaking further research related to the followings with respect to wastewater discharge.

- Evaluate the existing conditions/regulations related to trade waste discharge/wastewater discharge in construction projects.
- Level of awareness of industry practitioners on existing rules and regulations related to wastewater management/discharge in construction projects.
- Current monitoring systems undertaken by responsible authorities on wastewater discharge in construction projects.
- Roles and responsibilities of different parties/authorities involved in wastewater management in construction projects. As participation of stakeholders at all levels of the social structure for the decisions at different levels of water management has been recognized as an important aspect in Integrated Water Resource Management.
- Feasibility of adaption of new wastewater management strategies like, Zero Liquid Discharge (ZLD), Industrial symbiosis (IS) in construction promoting circular economy principles.

5 Conclusion

Thus, this paper presents volume of trade wastewater discharge for tools washing during construction of building projects and water saving through closed loop system in Australia. Results found that 20litres of wastewater is discharged per minute from construction projects due to trade wash out and the closed loop system saved an average of 93% of water used for tool washing irrespective of the project size.

Research outcomes establish the need for more in-depth investigation on the current wastewater discharge practices in the construction industry, specifically to determine the challenges and to increase awareness of the impact on new imposed regulations on 1 July 2021 from EPA Victoria for wastewater discharge. Eventually, further research on wastewater discharge will help EPA and relevant water authorities to introduce or take necessary measures, such as revisiting regulations and benchmarking impacts to minimise the wastewater discharge in construction projects.

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A framework to overcome deskilling in the construction industry by improving existing training systems in Australia

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Abstract
Construction industry plays a significant role in the economy by creating the third highest job market and contributing to the gross domestic product in Australia. Deskilling is identified as one of the causes of skill shortage in Australia and the aim of this study is to develop a framework to overcome deskilling in the construction industry by improving existing training systems in Australia. A comprehensive literature review was carried out to identify the best practices related to improving training systems and secondary data was used to identify the current status of labour shortage and the status of existing training systems in Australia.The study found that the design and quality of program resources; and workplace learning are major challenges in implementing effective training systems. To overcome these challenges, training system development by incorporating shorter form credentials; improve enterprise and social skills; standardise registered training organisations; plan work-based learning programs; expand publicly funded programs and fund allocations; and implement five-step process (analyse, design, development, implementation ,and evaluation) for the enhancement of informal training are proposed. The suggested framework is useful for policymakers and training providers to identify the advance standards to reinforce skill needs of the construction industry.

Keywords
Australia, Construction Industry, Deskilling, Skill Shortage, Training Systems.

1 Introduction

The Construction industry is Australia's third-largest industry for the number of people it employs and its share of the country's gross domestic product (GDP). In 2018, almost 1.2 million people were employed in the Australian construction industry (nearly 9.5% of all jobs), and contributes $134.2 billion to the economy and accounts for 8 percent of the country's overall GDP (Construction Industry Facts 2019). Despite all these developments, one aspect of construction remains a constant, the construction worker (Chini *et al*. 1999). Construction skilled labour shortage has become a worldwide issue and it is an ultimate challenge facing the Australian construction industry (Zaki *et al.* 2012). The shortage of skilled labour has impacted adversely on the construction industry from 2007-2011 where nearly two million construction labourers were made redundant, and the National Association of Homebuilders estimated that there are nearly 200,000 construction jobs that have been left unsatisfied due to this labour shortage (Riddell 2017). A recent Boston Consulting Group report claims that 'Australia is likely to experience a serious labour shortage by 2030'-the country will have a shortage of 2.3 million jobs (The Australia Institute n.d.). According to the Australian Bureau of Statistics labour force data, it was predicted that the COVID-19 pandemic would cause nearly 600,000 people to lose their jobs by April 2020. It's conceivable the worst is still to come (Souness

2020). Furthermore, Souness (2020) highlights that this might be a good opportunity for industries to rethink about their skill needs to improve the current skill levels of their labour force. It is the time to alter outdated thinking and perceive that Australia's recovery will be fuelled by cutting-edge technology and digital skills.

The four major causes affecting the skilled labour shortage are economic changes, educational changes, technological changes and union/open shop changes (Chini *et al*. 1999). Technology becomes ever more prominent in working practices the deskilling debate is becoming more crucial (UKEssays.com 2018). Other than that, due to advances in technology, skill sets inside occupations and the jobs themselves are developing rapidly, a situation that imposes tremendous demands on training systems in serving and responding to employers' rapidly changing needs (Richardson 2007). Although the causes of shortages are complex, the dominant factor is the lack of training and apprenticeship education towards the construction industry due to the inadequacy of skilled workforce and technological change since training is the most frequently used strategy by employers to address employee skill issues (Richardson 2007). Hence, this research aims to develop a framework to overcome deskilling in the Australian construction industry by improving existing training systems. There are a number of training providers in Australia that assist people to enhance qualifications and skill levels in different occupations such as technical and further education (TAFE) institutes, private training providers, professional or industry associations, and commercial and enterprise training providers. However, this study discusses only trade workers' labour shortage and it uses training providers within level I (Certificate 1) and VI (Advanced Diploma) in the Australian Quality Framework.

2 Literature Review

2.1 Skill shortage in the 21st century and its impact

A lack of skills is a source of aggravation for businesses and, if acute, the quality and quantity of their production is likely to be hindered (Richardson 2007). The skilled labour shortage exists when employers have recruitment difficulties in filling vacancies, and the skilled labour shortage can occur when existing employees have less experience, specialized skills, and qualifications (Richardson 2007). The above explanation outlines the skill shortage in terms of the degree and nature of a lack of skills. Australia Skills Shortage List (2016) highlights that Australia has often struggled to satisfy its need for skilled workers with its relatively resilient and expanding economy. Current shortages mainly affect skilled tradespeople, and skilled professionals to a lesser extent, particularly in construction trade workers and related fields (Australia Skills Shortage List 2016). More than seven percent of existing jobs in the Australian workforce will be replaced by advances in technology in the next decade and the country lacks the skills needed to fulfil the new roles that will replace them (Redrup 2019). In 2015, Australia's department of employment reported the construction trade workers shortage list as given below (Table 1).

Table 1. Skill shortage list by state for construction trade workers

Shortage by state	**Occupation**
All Australian States	Bricklayer, Stonemason, Painter, Glazier, Roof Tiler, Wall and Floor Tiler and Solid Plasterer
New South Wales; Northern Territory; Victoria; Western Australia	Plumber
Queensland; Victoria	Carpenters or Joiners

Source: Australia Skills Shortage List (2016).

According to the National Skills Commission (2021), it was revealed that all states, particularly Western Australia and Queensland, were experiencing significant regional skills shortages in 2021. In 2021, construction trade employees such as bricklayers, stonemasons, glaziers, roof tilers, wall and floor tilers, solid plasterers, plumbers, and carpenters or joiners faced a skills shortage, with the exception of plumbers in Queensland. Most of the consequences of skill shortages, such as overtime and increased costs, are detrimental for the growth and efficiency of a company and shortages in the skilled workforce cause project plans to be interrupted, forcing the company to work to a greater extent its existing employees (Clarke and Wall 1998). According to Oke *et al.* (2017), the skills shortage has negative impacts on sustainable construction due to cost overruns, time overruns, quality reductions, reworks and accidents. Eventually, a lack of skills in construction contributes to an organization's lack of growth.

2.2 Causes of skill shortage and deskilling

Skill shortage can have many causes and routine of studies have been carried out to find major reasons as shown in the following table (Table 2).

Table 2. Causes of skill shortage by existing studies

Item No	Causes	Reference Source
1	Economic changes, educational changes and union/open shop changes	Chini *et al*. (1999); Costanzo (2018)
2	Retirement & family businesses	Costanzo (2018); Healy *et al*. (2012)
3	Geographical location of company, high wage or salary cost for the company and uncertainty of long-term product or service demand	Healy *et al*. (2012)
4	People migrate from regional areas and large increase in the region's construction work	Wyborn (2016)
5	Poor working conditions and wages and difficulties in attracting and retaining people	Clarke and Wall (1998)
6	Issues related to training programs	Clarke and Wall (1998); Costanzo (2018); Healy et al. (2012); Parliament of Australia (2003); Wyborn (2016)
7	Technological changes	Chini et al. (1999); Parliament of Australia (2003); Wyborn (2016)

Items 6 and 7 in Table 2 are related to deskilling as the major reason affecting labour shortage which is mainly due to less vocational training and advanced technology. Most of the studies identified that lack of training and apprenticeship due to inadequacy of skilled workforce, inadequate training available, lack of expert knowledge and unfitting training as major issues related to training programs. Although the causes of shortages are complex, the dominant factor is the lack of training and apprenticeship education towards the construction industry due to the inadequacy of skilled workforce and technological change since training is the most frequently used strategy by employers to address employee skill issues (Parliament of Australia 2003). In the construction industry, for example, the skill sets have changed significantly over the past ten years. Thus, training programs are needed to respond to the need for new skill sets in a wide range of occupations and industries (Parliament of Australia 2003). As technology becomes ever more prominent in working practices, the deskilling debate is becoming more crucial (UKEssays.com 2018). Technology can have a positive social impact on working practices, disproves the contention that the introduction of technologies inevitably leads to deskilling. Drummond (1993) states that deskilling is 'inappropriate in a quality culture' as it results in waste through inadequate training, jobs which are incorrectly perceived as requiring no skill and also both customer and employee alienation. A quality culture is based on trust and reskilling workers which can be achieved only if training and skill development are improved (Bowen 1996).

2.3 Solutions for deskilling

A routine of studies has been carried out to respond to the deskilling by introducing different strategies in various aspects. Based on the secondary data, it was identified several solutions to this critical issue as given below (Table 3).

Table 3. Solutions for de-skilling

Item No	Solutions	Reference Source
1	Policies to skilled workers staying in their occupations	Oliver and Turton (1982)
2	Speed-up development of qualifications	Joyce (2019)
3	Resolve quality issues with providers	Joyce (2019)
4	Develop construction education system	Chini *et al*. (1999)
5	Formatting existing training systems	Lobo and Wilkinson (2008)
6	Implementing effective training systems	Costanzo (2018)
7	Policies to more workers taking-up training systems	Oliver and Turton (1982)
8	Establish industry-wide training systems prior to foresee potential skill shortages	MacKenzie *et al.* (2000)
9	Setting-up a high-level task force to coordinate and develop a cohesive training and data collection process	The Building and Construction Industry Working Group (2001)
10	Development of a comprehensive information system for skills	Siekmann and Fowler (2017)
11	Expand the number of new apprentices/apprenticeships	Workfast (2017)

Items 3-11 in Table 3 are related to the necessity of improving the existing training systems as a solution to overcome this crucial matter. Training is vital to the success of a company and the ignorance of the value of the training at the workplace will affect unsafe working conditions, high turnover of staff, lower productivity, and depressed workers (Martinelli 2018).

2.4 Challenges in fulfilling skill needs in training systems

Training and development issues are most common that will seriously hinder the efficiency of the training systems. The major challenges faced by the employers and training providers are quality, design and development of programs, workplace learning, and resources as discussed further. Although the quality frameworks require everyone to comply with the same training standards, the system does have some variances (Fortress Learning 2019). Few training providers have sufficient personnel, expertise, and resources to offer training to the standard level with the adoption of innovative technologies. Moreover, with the rapid technological change in the industry, a program that is considered successful may easily become outdated and obsolete and need to be designed to meet the quality standards (Fortress Learning 2019). Furthermore, inefficient apprenticeship programs create issues such as unsafe work environment, high-turnover, low productivity, and ineffective staff management as well trained employees perform tasks according to the industry standards while contributing to the success of a company (Amo 2019). The availability of realistic workplace learning can be another challenge where the learners can practice the skills what they learn in their vocational training (Fortress Learning 2019). Besides, curriculum design changes enable trainers to use modern equipment and facilities and this affects the success of trainers' effectiveness in achieving curriculum goals as well as weakening the training providers' role and purpose (Phius 2014). Nationally recognised training, unaccredited training and informal training are the three different training systems in Australia. Nationally recognised training is a course or qualification developed under the Australian qualification framework that is offered by registered training organisations which excludes higher education qualification (NCVER 2019b). Unaccredited training is a type of training that does not result in a certification that is nationally recognised which has a specified content that implements by TAFE institutes, private training providers, professional or industry associations and supplier/manufacture of products (NCVER 2019b). Informal training is a training that usually takes place on-the-job as part of day-to-day life, through interactions with colleagues such as on-the-job, induction, apprenticeships, internship, coaching and counselling and structured programs (NCVER 2019b). The following section outlines the research methodology adapted in this research.

3 Research Methodology

A comprehensive literature review and secondary data were used in this research to achieve the research aim. Onwuegbuzie and Frels (2016) clarified the literature review process by breaking the review into the following seven overlapping but well defined steps (Figure 1).

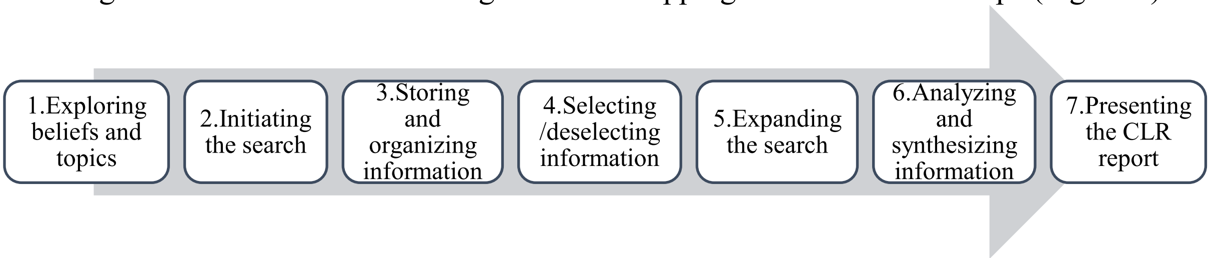


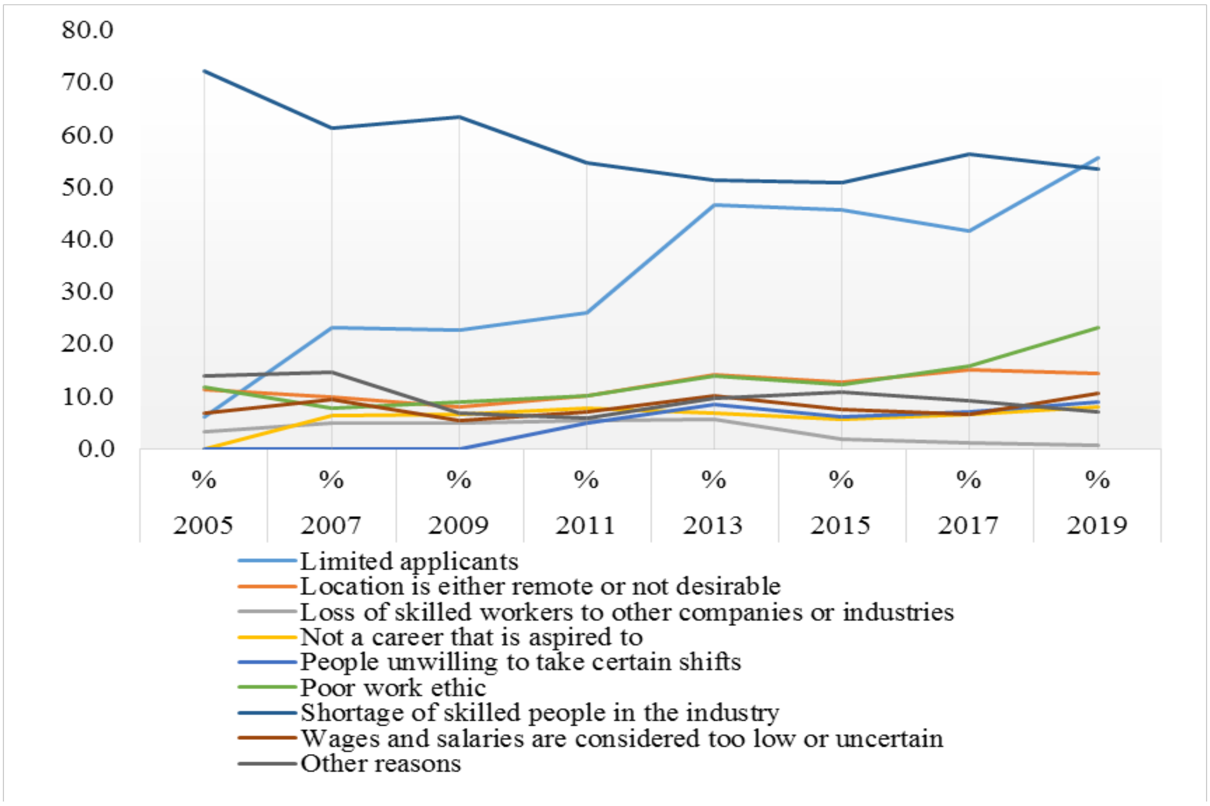
Figure 1. Seven steps to a comprehensive literature review
Source: Onwuegbuzie and Frels (2016)

The comprehensive literature review was conducted under seven steps which can be further divided as exploration phase, interpretation phase and communication phase. The literature review covered causes of skill shortage, barriers in the existing training systems and strategies to improve training systems. Ultimately, comparison and contrasting evaluation was conducted to develop the framework to satisfy workers' skill needs.The secondary data was used from a survey of employer use and views of the vocational education and training (VET) system, which was conducted by National Centre for Vocational Education Research (NCVER) between February and June 2019 to identify the various ways in which Australian employers use the vocational education and training system to meet their skill needs and their satisfaction with the training. This survey was carried out using computer-assisted telephone interviewing with interviewing approximately 8000 to 9000 employers and the sample was selected from the Australian Bureau of Statistics business register. It is also undertaken as a randomly selected sample, stratified by state/territory, employer size and industry (NCVER 2019a). Consequently, in this study, the data was analysed using descriptive analysis and desktop analysis. Descriptive analysis was used to convert raw numbers into meaningful data in qualitative data analysis by applying rational and critical thinking. Descriptive statistics assisted to perform the data in a more meaningful way, allowed the data to be understood more easily. The desktop analysis was utilised as the qualitative data analysis to analyse documented information form in the form of research papers, websites, articles , and other secondary data collection resources as this method is relatively cheap and high in reliability. To conclude, the data were summarized using a combination of tabulated descriptions and graphical descriptions in a clear and concise manner by using Microsoft Excel.

4 Findings and Discussion

Figure 2. Reasons for recruitment difficulties, 2005-2019 (%)
Source: NCVER (2019a)

According to the Australian national occupational shortage ratings, from 2004-2018, except in 2012, at least one or more occupation categories faced skill shortage. The severity of this situation was in 2004-2008 and 2015-2018 time periods. This result is further sustained by Australia Skills Shortage List (2016) that announced the construction trade experiencing shortage in all states which affect skilled tradespeople, and skilled professionals. This results, in more than seven percent of existing jobs in the Australian workforce will be replaced by advances in technology in the next decade and the country lacks the skills needed to fulfil the new roles that will replace them (Redrup 2019). In 2011 and 2013, the construction industry employers had reported approximately 30% difficulty in recruiting skilled employees.



However, the difficulty percentage soared to almost 40% during the years 2017 and 2019 (NCVER 2019a). As reflected in the graph (Figure 2), the major reasons were limited applicants and the shortage of skilled people in the industry. The shortage of skilled people was the highest from 2005 to 2017 (NCVER 2019a).

Moreover, it was found that one of the reasons for the recruitment difficulties faced by the industry from 2005 to 2019 could be the fact that 60.9% of employers failed to share their skill requirements with external organizations (NCVER 2019a). According to NCVER (2019a), the main strategy to meet skill needs is training existing staff and training is the most common strategy to address issues with employee proficiency. To provide more reliability to these findings, in the literature review, most of the studies found that improvement of training systems as the major solution for the deskilling (Table 2-3). However, Ayentimi *et al.*(2018) show that there are discrepancies in the training system such as ineffective apprenticeship programmes, inadequate regulations, underinvestment in education and outdated training programmes. Furthermore, the training is a critical factor for reducing deskilling and ensuring high-quality and rigorous employee training programs to improve the skills of the workforce and develop awareness where it is lacking.

In 2019, 75.6% of Australian construction trade employers used informal training to meet their skill needs, compared with 73.3% who engaged with the training system. The majority of employers had on-job training (75.6%) as required which downs 4.6 percent from 2017 while 59.8% provide appropriate training whenever new technology or equipment is installed down 4.3 percent from 2017. The main strategy employers use to meet skills needs to retrain existing employees on the job, and to hire experienced employees (The Australian Industry Group 2018). It is important to incorporate informal learning activities such as social media engagement, workplace mentoring, ropes courses, seminars and guest speakers to boost employee engagement with the new technology while engaging the five-step process as mentioned follow (Johnson 2019). Firstly, the skill gap analysis by using skill management software is an especially important part of creating effective training. Assessment involves assessing basic employee and work requirements and it is important to identify skills most employees have when they arrive. Subsequently, investigating the level of understanding leads to find the gap where the training is going to fill in (Wormley 2019). It is also important to decide which formats and materials suit the goals and workplace best: induction, apprenticeship, internship, coaching and counselling and structured programs all options. Advanced software, technology devices, and innovative strategies (e-learning trends) can be utilized to enhance training program's quality, interest and engagement as well as to empower corporate training to be a more personalized involvement (Kapadia 2016). Undoubtedly, training ought to be an ongoing issue as most employees will need to stay informed as to industry changes depending on the job. Therefore, it is important to use an outline to identify the goal needed by the employee to accomplish and mechanism to measure employee success (Wormley 2019). Deciding the right people implement training is critical as it could be with a manager, a co-worker or a designated co-ordinator. This can be implemented with outsourcing and use an in-house co-ordinator to work with the company which is useful if there is less expertise or experience to perform effective instruction, or in highly specialised systems or equipment (Wormley 2019). Thus, the effectiveness of the training program can be evaluated by conducting surveys in different timelines (Wormley 2019).

Furthermore, the majority of employers use unaccredited training to their staff to enhance skill needs which is followed by nationally recognized training. The study found that 59% of learning and development professionals spend more of their budget on online training in 2019 than what they did three years ago and less than a third even spend less on instructor-led-training (Continu 2019). According to NCVER (2019a), the three major reasons for the dissatisfaction with the training system are low standard and poor-quality training, specific skills are not taught, and insufficient focus on practical skills. Thus, new partnership models need to be established to ensure that the training is meaningful and employment-focused, (Cushard 2015). Training programs and impact assessment using tools within selected technology is another solution to understand and improve the efficiency of the training programs (Steele 2015). Work-based learning programs by using new tools and technology require the involvement of employers and the industry which leads to achieving competencies through industry experience. Furthermore, identification of skills and knowledge required to implement and evaluate an information system involving extensive use of technologies at the workplace is crucial and plays a significant part in the organisation's effectiveness (Curtin 1999). Similarly, it is important to utilize sufficient tools, equipment and the high-level task force with new technology engagement to boost the effectiveness of resources. In addition to, assigning shorter form credentials, standardising registered training organisations and introducing enterprise and social skills have been identified as AQF innovations to enhance skill needs. The following framework has been developed to address the current issues with employee proficiency and overcome skill shortage in the future (Figure 3).

TRAINING SYSTEMS	CHALLENGES	STRATEGIES
NATIONALLY RECOGNISED TRAININGS *Technical and Further Education (TAFE) , Private, Professional or Industry Association*	**DESIGN AND QUALITY OF PROGRAMS**	
	▪ Outdated Programs ▪ Teaching is not focus on relevant practical skills ▪ Inadequate regulations ▪ Inefficient apprenticeship programs	▪ Guidelines for a wider range of shorter form credentials ▪ Enterprise and social skills ▪ Standardise registered training organisations ▪ Developing training packages ▪ Developing comprehensive information system ▪ Planned work-based learning programs ▪ Design new partnership models ▪ Training programs and impact assessment ▪ Group training companies
	RESOURCES	
	▪ Limited government funding or ambiguous funding systems ▪ Unavailability of adequate and certified trainers ▪ Insufficient facilities and equipment	▪ High-level task force ▪ Raise fund allocations ▪ Bilateral cooperation with the industry ▪ Publicly funded training improvement
UNACCREDITED TRAININGS *Technical and Further Education (TAFE) , Private, Professional or Industry Association and Supplier/Manufacture of Products*	**DESIGN AND QUALITY OF PROGRAMS**	
	▪ Outdated Programs ▪ Teaching is not focus on relevant practical skills ▪ Inadequate regulations ▪ Inefficient apprenticeship programs	▪ Developing training packages ▪ Developing comprehensive information system ▪ Planned work-based learning programs ▪ Design new partnership models ▪ Training programs and impact assessment ▪ Group training companies
	RESOURCES	
	▪ Limited government funding or ambiguous funding systems ▪ Unavailability of adequate and certified trainers ▪ Insufficient facilities and equipment	▪ High-level task force ▪ Raise fund allocations ▪ Bilateral cooperation with the industry ▪ Publicly funded training improvement
INFORMAL TRAININGS *On-the-job, Coaching, Mentoring, Internships, Induction, Counselling and structured Programs*	**WORKPLACE LEARNING**	
	▪ Quality depends on ability of trainer and time available ▪ Low productivity ▪ Create disturbances ▪ High-risk of accidents	▪ STEP 1: Analysis ▪ STEP 2: Design ▪ STEP 3: Development ▪ STEP 4: Implementation ▪ STEP 5: Evaluation

Figure 3. A framework to overcome deskilling in the Australian construction industry by improving existing training systems

5 Conclusion

This study's main contribution is to provide a framework to overcome deskilling in the Australian construction industry by improving existing training systems. The results of the study provide a significant contribution to policymakers and training providers such as technical and further education institutes, private training providers, professional or industry associations, and commercial and enterprise training providers to modify outdated training systems and implementing advance standards to reinforce skills needed in the industry. The results indicate that the design and quality of programs, resources and workplace learning are major challenges in implementing effective training systems. To overcome these challenges possible strategies have been identified in this study. These are training system development by incorporating new technologies and work practices and implement the five-step process (analyze, design, development, implementation, and evaluation) for the enhancement of informal training system. These findings are useful for policymakers and training providers to identify the advanced standards to reinforce the skill needs of the construction industry.

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Plastic Minimisation in Construction: A Pilot Study identifying and quantifying the composition of C&D plastic in construction waste

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Abstract

Construction and demolition (C&D) waste contributes at least 10,000 tonnes of plastic to landfills in Auckland annually. The growing use of plastic in the packaging of building materials, the use of polystyrene and products such as building wrap are contributing to this landfill stream. Most construction waste is not sorted on construction sites, with C&D waste often being co-mingled. This funded research is an exploratory study being undertaken as a pilot project over 12-18 months by academics with three industry partners (a commercial construction company (Naylor Love), a leading building materials' supplier (Mitre 10), and a large recycling company (Green Gorilla), to undertake a comprehensive waste audit analysis of plastic waste, and workplace incentivisation for source separation of waste. The research grant was awarded to Unitec Institute of Technology by the Auckland City Council in December 2019. To date, the research team (principal investigator assisted by another senior researcher and two research assistants, a plastics technician, and an industrial chemist), has audited and recently analysed the first of two rounds of the plastics' recycling bags that were located at three of the construction company's project sites. Mitre 10 and Green Gorilla are providing the research project with statistical data related to the products being supplied and recycled to and from the three project sites. The main aim of the collaborative pilot research project was to investigate how to identify and quantify the composition of C&D plastic in construction waste going to landfill. As the pilot research project concludes later in 2021, the results to date are preliminary, yet positive. The findings demonstrate the value-added results of this collaborative academic and industry partnership, and the commitment to making a real difference that Naylor Love, and Mitre10 in particular have achieved, for minimising plastic and plastic wastes on their projects, and influencing clients customers and other players in the construction industry.

Keywords
C&D, Construction sites, Landfill diversion, Pilot project, Plastics

1. Introduction

The growing use of plastic in the packaging of building materials, the use of polystyrene and products such as building wrap are contributing further to the landfill stream (Geyer et al.2017). Unlike countries such as the UK, most construction waste in New Zealand is not sorted on-site, and construction and demolition (C&D) waste is often co-mingled (Low et al. 2020). Minimal analysis on the recoverability of plastics has been evidenced or published yet, and in addition, knowledge about both the diversion potential, and the potential economic value of plastic waste still needs to be further investigated (Häkkinen et al., 2019). Research undertaken in New Zealand to date has not disaggregated the various types of C&D plastics and assessed them for recycling potential. Therefore, this particular research was a new waste minimisation pilot study initiative funded by a grant from the Auckland City Council's relatively new Waste Minimisation Innovation Fund (Auckland Council, 2021). The aim was to conduct an exploratory study to identify and audit the types of plastic waste generated from three construction sites in Auckland, New Zealand. All three project sites were being managed by the same commercial sector construction company (Naylor Love) in Auckland, who in collaboration with fellow members (who were academic researchers), in the Sustainable Business Network (SBN) organisation, wanted to investigate the varying types of plastics on construction sites and ways in which they might be diverted from landfill now and in the future.

Another aim of the funded research was to also work with C&D and construction supply chain building supplies' providers to identify issues and opportunities for reducing or reusing or recycling plastics at source, as projects progress and complete (NZ Government, 2019). Identification (and to some extent the volumetric quantification) of the composition of the C&D plastic waste stream from the construction sites, was generated from differing stages of the various construction projects. The origins of plastic wastes were determined for each involved stage of construction, to potentially enable plastic reduction prior to arrival on site (at supplier level). Options for reuse and recycling were examined, as well as any significant barriers to effective waste management on active construction sites, which may hinder future reductions in plastic waste types and volumes to landfill.

2. Literature Review

The three Rs of waste management (reduce, reuse and recycle) are fundamental to managing the amount of C&D (construction and demolition) waste diverted to landfill. *Reduction* of waste involves making good planning and design decisions to reduce the amount of C&D waste produced. *Reuse* of existing products for use in a new building or construction project. C&D waste sent to landfill has direct environmental (soil and groundwater leaching), social (odour; loss of amenity value), and financial (cost of disposal) implications, as well as indirect and/or additional costs due to the additional packaging of products, when being delivered to sites by manufacturers, suppliers and distributors. In New Zealand, C&D waste sent to landfills has been steadily increasing, and is not subject to a substantial landfill levy as yet, thus reducing the impetus for reuse and recycling activities (BRANZ, 2020). There are many different opportunities to reduce waste in the construction industry but none of them are sufficient to create a truly circular economy. Ideally, the construction of a new building would first consider how much new-build waste can be designed out through careful planning for incoming materials (Yu et al., 2021).

A variety of methods have been employed to quantify C&D wastes generated on construction sites. Llatas (2011), adopted an estimation model based on waste factors obtained from the European Waste List, whereas González Pericot (2011), analysed waste container delivery notes against waste densities, and linked these to a construction stage to generate a 'descriptive evolution' of the waste generated. Further, González Pericot et al. (2014), described specific training and team incentives for site workers focussed on C&D waste segregation, combined with analyses of waste contractor delivery notes to estimate quantities. Waste which is unavoidably produced in the C&D industry can be recovered to reuse and recycle before entering landfill, and reuse of materials is preferred as it tends to use less energy for processing and has a lower cost than recycling according to Yuan and Shen, (2011). The current waste pathway for buildings tends to be linear -with a mantra of "take-make-dispose," with little priority given to waste management, (Osmani et al., 2008; Andrews, 2015; Osmani and Villoria-Sáez, 2019). The hierarchy of waste management puts reduction as the top priority for waste minimisation, followed by reuse, recycle, and finally landfill disposal (Yuan and Shen, 2011). Reduction in the use of raw virgin materials can occur mainly during the design stage of construction and should be supported by a sustainable procurement strategy. Reuse of waste during construction and the recycling of residual waste in the final construction stages also provide opportunities for waste minimisation (Low et al, 2020).

The relatively low production cost of plastics however means there has been little economic incentive to develop plastics recovery from C&D waste. Plastics are synthetic organic polymers predominantly derived from fossil hydrocarbons (Geyer et al., 2017), and are typically light, versatile and cheap to purchase, but can cause significant environmental harm (Häkkinen et al., 2019). According to Geyer et al., (2017), the building and construction sector consumes 69% of the global production of polyvinyl chloride (PVC) products, and 19% of all non-fibre plastics. In addition, other forms of plastics commonly used in the construction industry include polyethylene (PE), polypropylene (PP), expandable polystyrene (EPS) and polyurethane (PU).

Plastic use in the construction industry can be categorized as either *direct* or *indirect.* For example - construction materials containing plastics, (e.g. insulation, damp-proofing, flooring, roofing, windows and laminated surfaces), building service installations (e.g. pipes and cabling), surface treatments (e.g. paints, varnishes, sealants, glues and resins), covers and tarpaulins are used during the construction process and are considered *direct use* plastics. Plastics used for packaging of construction materials (e.g. foils and moisture barriers, expandable polystyrene (EPS), polypropylene (PP) sacks) only serve their purpose during the transport and storage of those materials and are considered *indirect use* plastics.

A recent study by Kamaruddin et al., (2017), has demonstrated that some plastics generated from the construction sector can successfully be recycled into new household/commercial products, for example, PVC tiles, pipe fittings, hose inner cores, carpet fibers and clear film for packaging. Plastic waste has potential recycling applications in the construction industry, such as cement binders and aggregates, or used as a base and sub-base for road construction, and insulation materials, (Awoyera & Adesina, 2020). However, there are considerable barriers to reuse and recycling, which include health and safety considerations, material contamination, and the need for staff education and training of on-site waste management (Low et al., 2020).

There is also a need for improved understanding of the composition and origins of plastic C&D waste, to identify opportunities for better waste management including advancing the development of reuse and recycling solutions. Whilst previous studies have performed in-depth surveys and analysis of wastes generated for all major material types across typical construction sites, it is believed that this particular pilot study is the first to consider the spectrum of plastic types used in construction, and their descriptive evolution from source to end use. Further options for reuse and recycling were examined by Kamaruddin et al., (2017), as well as the significant barriers to effective waste management on active construction sites which may impact future reductions in plastic waste generation.

3. Research Methodology

The funded research was an exploratory study undertaken as a pilot project over 12-18 months by a project team of a principal investigator (PI), another senior researcher, two research assistants, a plastics' technician, a chemist; and from industry –a large privately owned commercial construction company, a leading building materials' supplier, and a large recycling company. The commercial construction company specialises in vertical construction, including industrial, retail, education, commercial and residential buildings, and was wanting to minimise waste, increase diversion of waste- especially plastics-from landfill, and make a real waste diversion difference on their project sites. The leading building materials' supplier also had a focus on plastic minimisation regarding materials from source and reducing supply chain delivery packaging to customers. The academic–industry partnered team wanted to undertake a comprehensive pilot study conducting a waste audit analysis of plastic waste on a series of commercial builds and help develop Naylor Love's workplace incentivisation with staff for source waste reduction, and/or separation of waste on site, at Mitre 10's supply yards, and at Green Gorilla's recycling centre.

The main aim was to identify the different types and sources of plastic waste generated during construction, and to track the destination of these wastes. Plastic waste was collected from three of the construction company partner's different construction sites across Auckland during 2020, and the two waste audits were carried out with the assistance and cooperation of the three other partner companies: Naylor Love, Mitre 10, and Green Gorilla.

All of the construction sites audited involved a mix of demolition/partial rebuild or completely new construction plastic waste. Waste collections were undertaken over two timelines - Phase 1 was carried out between February and March 2020, while Phase 2 was carried out between May and October 2020. Both of these phases were cut short and/or significantly impacted timing wise, due to Level 4 and Level 3, Covid 19 total lockdowns in the Auckland region.

A construction manager at each site ensured that all construction staff retained any plastic waste materials used and stored them in dedicated containers, which were provided (and later collected) by the waste management company or the construction company. The construction managers also ensured that the construction stage and source of material was recorded for each waste container. This enabled a descriptive evolution of each stage of the generation of waste during the construction work, and the overall audit process.

Plastic waste materials were categorised as either (P) Protection of Building works, (W) Product Wrapped Plastic, or (C) Plastic construction Components, and the waste audit analysis of the plastic waste was undertaken using a Fourier Transform Infrared (FTIR) Spectrometer as it provided precise, high-quality results for even the smallest plastic waste samples. Refer Figures 1 and 2.

There were a few early limitations to the pilot study realized however, when the bags for 'plastics only waste' (supplied by the leading recycling company to the construction company sites) were being incorrectly used for plastic and co-mingled with general waste. Hence the decision to involve the academic institution to design and later fabricate purpose-made reusable bins for onsite collection of plastics, and for other specific waste bins as well.

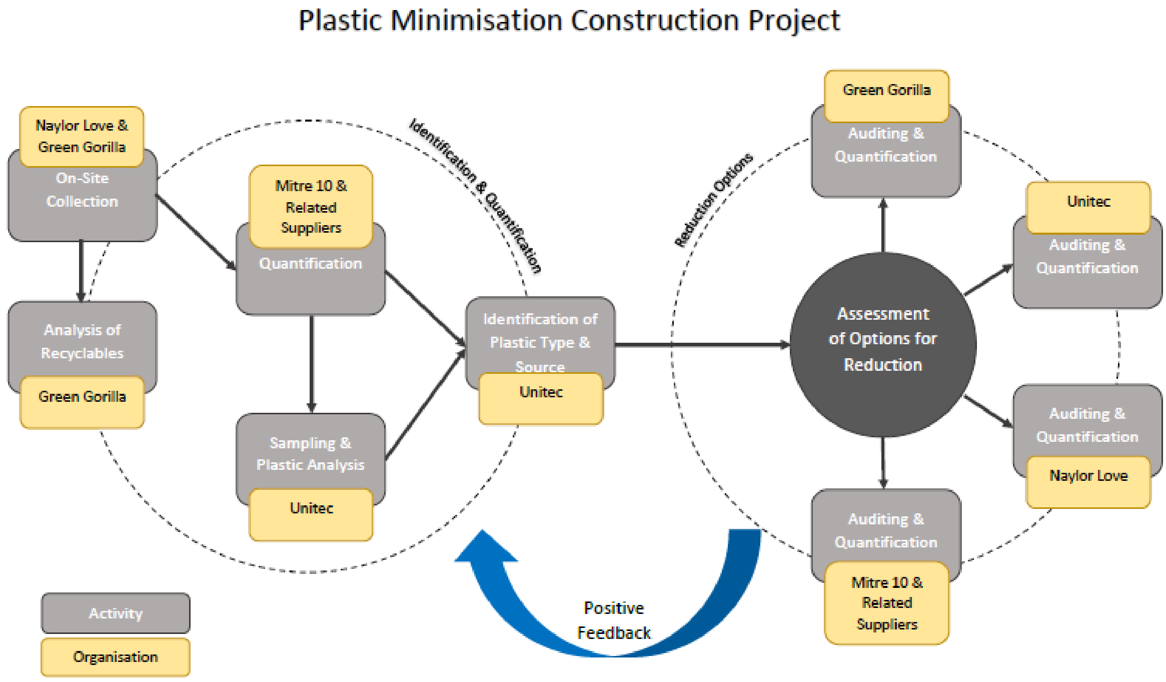


Figure 1: The Research Project Team Tasks Flowchart

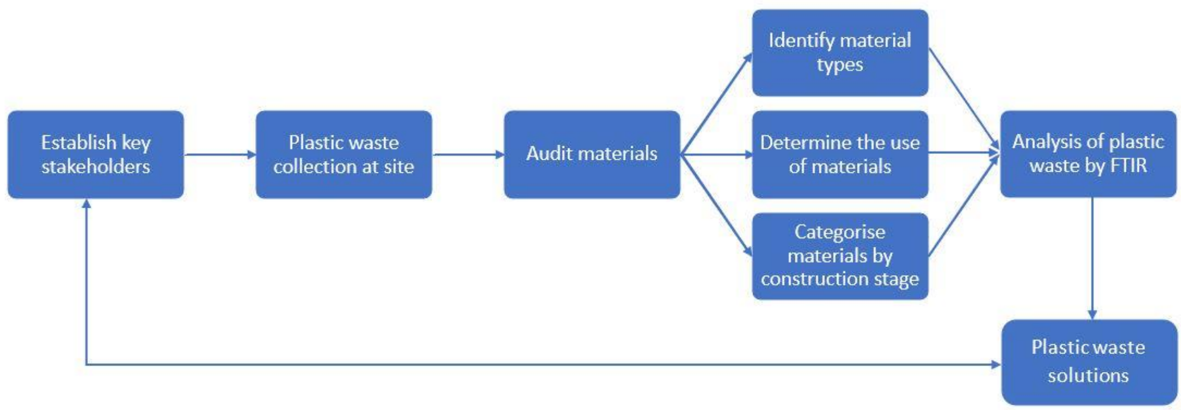


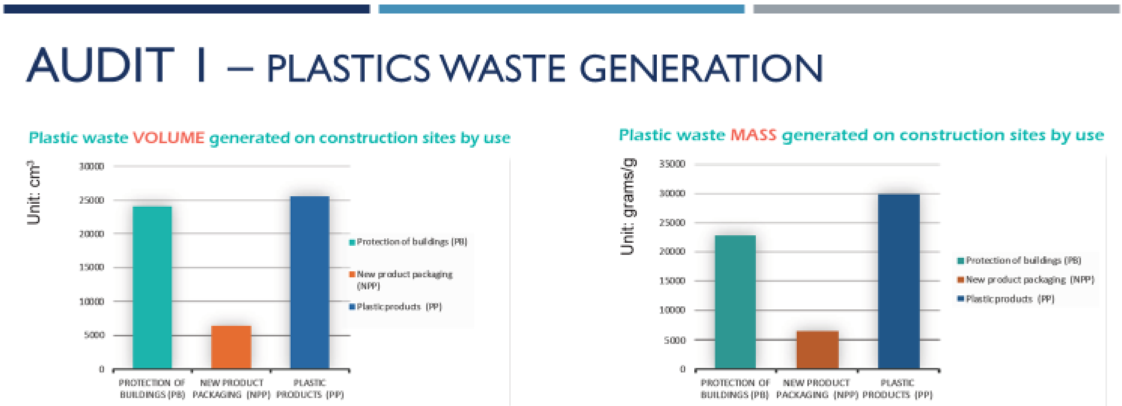
Figure 2: The Plastic Waste Audit Process

4. Findings and Discussion

The majority of plastic waste analysed was obtained during the *services and cladding* stage (99%). Plastics for building protection formed the majority (69%) of the plastic waste during the *demolition* stage, with packaging plastics contributing 30%. Waste generated during the *foundations and framing* stage comprised packaging plastics exclusively. Interestingly, construction plastics were the greatest contributors (53% by mass) to plastic waste generated during the *services and cladding* stage, with building protection and packaging plastics each contributing similar amounts at 23% and 24% respectively, (refer Figures 3 and 4).

Findings suggested that the generation rate of product packaging plastics, based on project floor area, was calculated to be 0.0019 kg/m^2, whereas González Pericot et al. (2014) found that the majority of packaging plastics were generated during the *exterior and weatherproofing* stage and *services and cladding* stage, with a significantly higher generation rate of 0.53 kg/m^2. The current study only analysed plastic wastes across specific stages of each site, not the entire project, which may explain this difference. Other potential factors may include inaccuracies in reporting due to a lack of waste separation, on-site training and staff behaviours; the difference in building types (commercial or residential) involving different amounts of packaging; different construction methods, and differing packaging standards in New Zealand and Spain.

Across all of the samples collected, the three categories of: construction; building protection and packaging were fairly evenly represented. PE (polyethylene) was the most common plastic waste in the collected samples from the three build stages, followed by PVC (polyvinylchloride) being the next most common. As a result of there being so much co-mingling in the plastics-only bins on the sites, which was disappointing, the decision was taken by the research team to restrict the Audit 2 analysis to the 'types' of plastics rather than trying to compare the range of plastics by mass or by volume. Training on-site staff is an ongoing process by the construction managers and supply chain organisation(s), but hindered at times by a seemingly regular flow in and out of transitional employees in these skill shortage times.



Plastic waste quantification

Type of Plastic	Total Volume (m^3)	Total Mass (kg)
PE	4.6×10^{-2}	43.1
PP	7.36×10^{-4}	0.67
PVC	1.4×10^{-2}	19.1
PA	5.07×10^{-4}	0.67
Total	6.1×10^{-2}	63.5

Figure 3 Plastic waste generation and quantification on the three construction sites

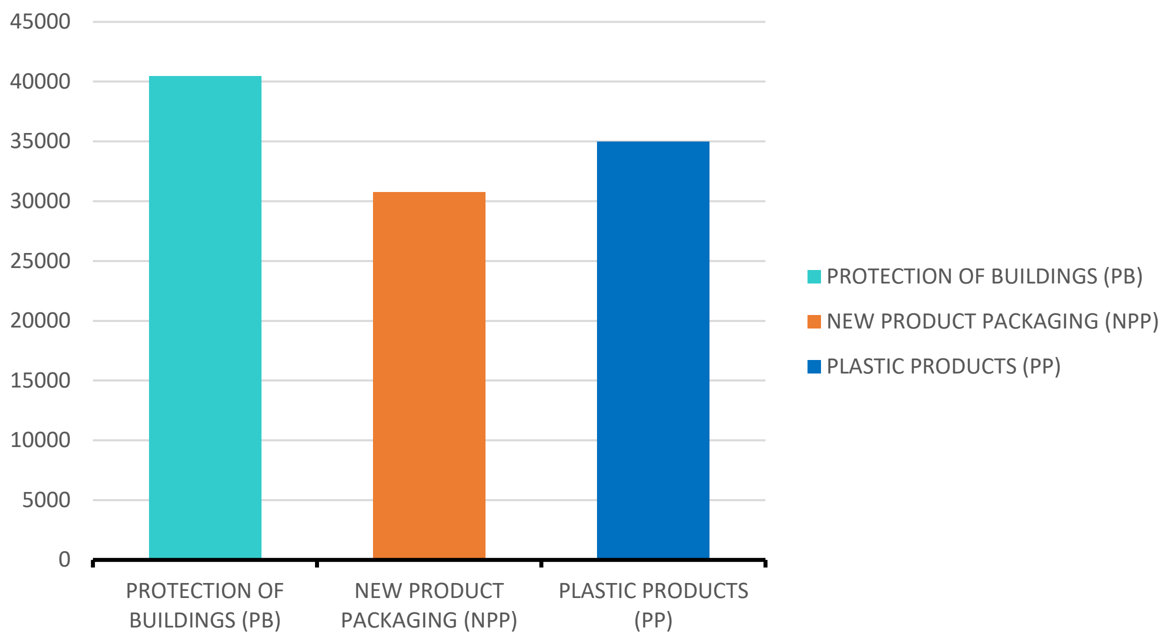


Figure 4: Determination of mass and dominant uses in AUDIT 2 of plastic waste on the three construction sites

4.1 Other outcomes from this research pilot study

The Materials' Supplier on the academic- industry partnered team stated that:

"We are sending excessive amounts of plastic to customers who either do not know how to refuse the plastic covers – or thought it normal practice to have plastic packaging. In a twelve month during 2020, an option was offered on the online customer portal by the building materials' supplier (Mitre10), to choose whether ordered materials were to be wrapped and packaged in plastic, or not- The resultant preference by customers was that an amazing 97% of orders were supplied unwrapped on request, and only 3% were supplied wrapped."

The Construction Company on the academic-industry partnered team – believed that the following key industry impacts occurred during the pilot study to date, being:

- The design and trial of permanent plastic collection bins,
- Training and information posters on waste management and separation processes, and why - for all on and off-site construction and supply chain company staff (refer Figure 5 below).

Importantly, strong connections and relationships between the academic-industry partnered team members have been built, with new and ongoing waste management and landfill diversion project possibilities forming as well, this year. In late April 2021 - a symposium - 'Building Out Waste' was organised in Auckland by the Sustainable Business Network, which highlighted the latest practical innovations, industry updates and inspiration from current case-studies to tackle waste in the C&D sector. The academic-industry partnered team were all in attendance, and were asked to make an informal presentation of some of the early highlights of the plastics minimisation pilot study.

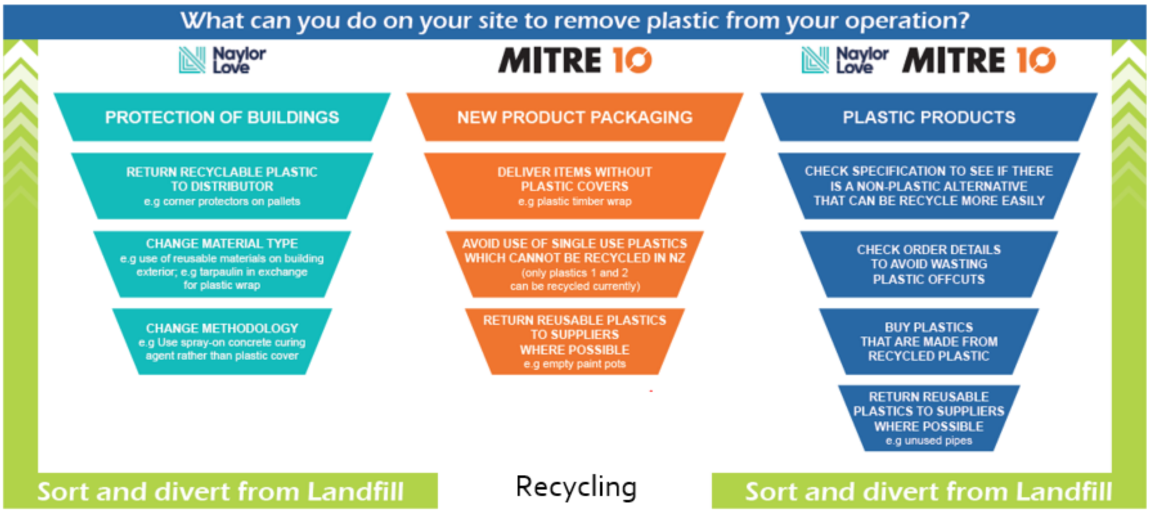


Figure 5: Poster prepared for training purposes by the construction company in collaboration with others in the pilot study project team

In addition and very recently in 2021–two significant and direct impacts of this collaborative academic - industry research have emerged. Firstly, a series of sponsored reusable tarpaulins have been designed and launched, and are in use by the construction company to avoid/mitigate the use of plastic packaging of materials (timber in particular) from the supply source to their construction sites (refer Figure 6 below). Secondly, the academic-industry partnered team won the highly commended Tamaki Makaurau (Auckland) Community Collaboration Zero Waste Award on 29 July 2021 for this academic- industry partnered pilot research, and the notable impacts being evidenced in the city's C&D sector. What has also been obvious is the influence and impacts a team of industry partners and academic researchers can achieve in a small way initially, through shared networking, getting the word out there via various media, construction companies and materials producers, and suppliers in particular. As a result, this pilot study could and is already leading to further innovations and increased levels of landfill diversion of plastics being realized.

Figure 6: Tarpaulins now in use from July 2021 for timber and materials delivery to the construction company's sites

5. Conclusion and recommendations

The practical implications of the pilot study as already noted has included the following:

-have established the predominant types of plastics whether packaging, building protection or products, and the scientific nature of the dominant plastics found during the two audits on the three pilot study construction sites,

- the production of training and information posters on waste management and separation processes, and why it's important - for all on-site and off-site construction and supply chain company staff,

- the design and recent trial of permanent plastic collection bins rather than the usual bags,

- newly launched reusable tarpaulins for timber deliveries to Naylor Love's construction sites,

The rationale and aims of this pilot study have been met, exceeded and expanded as momentum grew over the last eighteen months in the pilot study team members and related networks. All this despite co-mingled wastes at times as well as earlier noted and the limitations of the L4, and L3 Covid total lockdowns, closing down construction sites and supplier operations for several months in 2020.

From the current findings, it is recommended that a future research project will involve examining a single commercial scale construction project, across all the construction stages till completion. This approach would provide a more diverse yet in-depth level of comparative data, that could assist in demonstrating the connections between every construction stage, and the associated plastic waste types, predominance and quantities by volume and/or by mass. The 'take-back' of plastic materials /products produced by the original manufacturers' is another important area of investigative research work that a few companies are implementing here, with the aim of minimising plastic waste, recovering the plastic products to be recycled and diverting plastics from landfills.

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Throw DIRT enough, and some WIL stick: A case study on Collaboration between Academia and Industry

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Abstract
This short paper presents a case study about a new course developed in 2019 which integrated participation from local industry representatives within the development and delivery of the course such that there was no visible gap between academic teaching and industry practice. The course was about Agile Project Management and delivered as 12 credit elective course at Postgraduate level. The paper briefly presents a journey of course development and delivery with justification of embedding Direct Industry Relevant Teaching (DIRT - coined the term to fit with the abbreviation above) into the course content and making it a sub-activity within the broader framework of Work-Integrated Learning (WIL).

Keywords
Direct Industry Relevant Teaching (DIRT), Work-Integrated Learning (WIL), Course Development, Collaboration between Industry and Academia, Teaching and Learning

1 Introduction

According to Smith (2012, pp. 247), "Work-integrated learning may be seen by some as a strategic way for institutions to respond to the demands of the 'enterprise' culture that places pressure on higher education institutions to produce graduates who are 'work-ready' (Precision Consultancy & Commonwealth of Australia, 2007)".

This is interesting to note that if we want to have 'work-ready' students, it is not possible to achieve this without engaging the work-place within the teaching-space. Therefore, the authors have coined a new term called Direct Industry Relevant Teaching in order to showcase the importance and relevance of industry engagement through guest speakers, industry workshops, and site visits during the teaching period under the bigger umbrella of WIL curriculum.

2 Work-Integrated Learning (WIL)

Let us start by understanding the term, Work-Integrated Learning (WIL). WIL is a curriculum design strategy in which students engage in relevant professional work or practice settings during their degrees. It focuses more on the integration of discipline-specific learning and professional work or practice settings. This is achieved within the course they study using specifically designed in-class activities and assessment tasks (including research reports, reflective diaries, etc). These activities and assessments help them apply and learn their discipline-specific knowledge and skills in a real-world context. WIL curriculum could also include placements, internships, etc but WIL is not the same as work experience or work-based learning; the rationale behind WIL goes beyond merely providing the physical environment of a workplace for placements or internships since none of them require students to specifically learn, apply or integrate their discipline-specific knowledge (Smith, 2012).

There are many benefits of industry engagement directly in teaching; firstly, producing work-ready graduates through exposing students to the industry relevant subject areas; secondly, developing strong industry partners base that could be used for future research or courses delivery (both of this is within Australian context for our case study). In addition to the above, the degree programs with industry engagement get popularity and attract more local and international students. The local industry gets to have a say in what is relevant teaching resulting into high graduate employability, placements, and sponsorships.

Other benefits of WIL include that WIL creates the opportunity for universities to design, refine and teach curriculum that: is responsive to current and future needs, to equip students with the knowledge and capability that goes beyond the acquisition of discipline knowledge, and to engage students actively with industry and community partners and enhance work readiness (Smith, 2012; Wingrove and Turner, 2015, pp. 212).

3 Project Management Courses at RMIT University

Project Management (PM) is relatively a new discipline to be taught at undergraduate and postgraduate levels at many universities around the world. Traditionally, project management is grounded in a professional setting within various industry contexts including construction, software development, aerospace, ship building, etc. At RMIT, the core to the delivery of effective learning and teaching within PM is to ensure a strong link between education and industry (Wingrove and Turner, 2015). At postgraduate level, RMIT offers a generic Masters degree in Project Management. The Masters program is designed in such a way that it equips students with soft skills such as teamwork and collaboration, leadership skills, critical thinking and communication skills, etc. It also provides skills in the areas of using IT to plan, and manage projects. The instructors assume and expect that students will take the above mentioned skill sets and apply to their professional context, whether it be a construction project site or software development project. On the other hand, there is an expectation from students, specially from international students who pursue Masters degree that they will get exposure to the Australian industry in various sectors. The exposure would help students find jobs after completing their degree. Therefore, students expect that this degree program will prepare them for professional practice within the project management discipline though WIL component. Although there is no actual placements are offered but exposure to the real world through site visits and industry speakers are key components in preparing them to become work-ready.

3.1 Agile Project Management Course

The irony was that until last year (2018), there was no Agile Project Management course offered in RMIT University at postgraduate level. The authors identified the need in 2018 and started preparing the case for the new elective course. The aim, objectives and rationale for the course was developed and got approved. The next step was to develop the course delivery content.

Both authors have experienced in doing research in the Agile Project Management area, as well as used some of the Agile tools to develop and deliver courses in the past. Therefore, the Agile Project Management course was the great opportunity to develop the course in an agile fashion! A Development Team was formed including both the authors, and two sessional teachers, one doing research in Agile and other one based in industry as Agile Coach. The team worked using Scrum framework (see Figure 1).

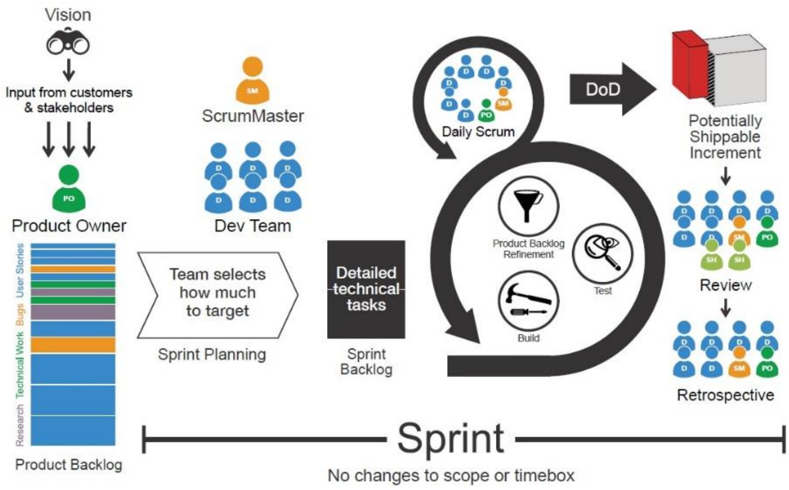

Figure 1. Scrum Framework

3.2 The Scrum Framework

In Scrum, the agile PDCA cycle (Plan, Do, Check, Act) is called a Sprint (3-week cycle was fixed for the sprint). The activities required to develop and deliver the course was brainstormed and kept under product backlog, here the product was Agile Project Management course development and delivery. Work on the product was started early 2019, with 3-week sprint cycle. We had product vision already developed in terms of course approval document. The Associate Dean of the school was our product owner, who was available anytime to answer the queries the development team had. The Scrum Master role was rotated among the development team members. For each sprint, the team had sprint backlog, and estimates in terms of number of hours to complete each task on the sprint backlog. During each sprint, the development team consulted the industry partners for their input and feedback. The team members planned the sprint at the start of each sprint and activities were assigned. Although the team members could not do the daily scrum but was able to meet on weekly basis to perform stand-up ritual. PDCA for sprint backlog item was done in almost 3 weeks, within the sprint cycle timeframe, and review was conducted after every sprint with the key stakeholder, the Associate Dean of Project Management. After every review meeting, the team would do their retro and start planning for the next sprint by refining the product backlog items and moving items to the next sprint backlog. The course was successfully delivered during the first week of September 2019.

3.2.1 Industry Participation with Academia

Since the course was being offered for the first time and it was a very industry relevant course, the course coordinator decided to bring in the industry to run the course along with the academic staff. It was structured in three folds; 1) industry guest speakers; 2) industry style learning workshops; and 3) industry visit to see Agile in action.

All of the above was incorporated in the course design so that students would get Direct Industry Relevant Teaching experience within this format of WIL curriculum. Course time table looked like a 5-day industry style training course with instruction session along with group activities, bunch of visiting guest speakers from the industry, and a few industry site visits to see agile in action in the real world (see Table 1 for a typical timetable for one of the instruction days). The table below (Table 2) shows the names of the industry participants' organisations who helped in designing, developing and delivering the Agile Project Management course.

Table 1. Typical Time Table

Day	**Time**	**Topic**	**Description**	**Presenter**
Day 3 Wednesday 4th September 2019	9 – 12 pm	**Introduction to Scrum**	• Agile in action: Scrum framework • Scrum teams • Developing user stories • Sprint planning and development • Sprint review and retrospective • Scrum examples • Scrum case study discussion • Scrum certification	Malik
	12 – 12.30 pm	**Lunch Break**	-----	-----
	12.30 – 2 pm	**Site visit**	• RMIT University ITS – Agile in Action Address: RMIT Building 88, Level 5	Malik and Keith
	2 – 5 pm	**Scrum workshop**	• User journey mapping for empathy • User stories for requirements capture • Planning Poker for estimating • Understanding UX and CX	Malik and Pete

Table 2. Participants from the organisations helped developing and delivering the Agile PM course

Telstra (Research)	National Australian Bank (NAB)*	ATO (Research)
Suncorp – former employee (Research)	Australian Football League (AFL) – former employee**	RMIT University – ITS department*
Energy Australia**	Australia Post*	RMIT Online*
World Vision Australia*	Flexera**	Accenture (Research)
PwC Australia**	Yarra Valley Water** (Research)	Medibank (Research)
Utilligent**	Victorian Building Authority**	Infosys*, **
Environment Protection Authority Victoria **	Coles (formerly at RMIT ITS)**	Department of Transport (VicRoads)**

* site visits during the course **guest speaker during the course

3.2.2 Some characteristics of the course

• Course content planning, designing, and development was done using Sprints within Scrum Framework (as discussed above).

• Course delivery was done with daily reflections with students at the end of the day (see Figure 2) and retro to improve for the next day by the instructors.

• The teaching was informed through the research done by authors and instructors of the course in the area of Agile PM.

• Since the course was a very first offering, therefore, it was designed and delivered as Minimum Viable Product (MVP) discussed by Eric Ries as a Lean start up strategy (visit: http://theleanstartup.com/principles).

• Assessment was designed to deliver in sprints using Scrum framework; this was again an MVP but more in terms of Prototype rather than the Product. Students were asked to deliver their assessment task in 3 sprints along with recordings of daily (weekly) stand ups, review with the product owners (the instructors) after each sprint and a Retro (both team and individual reflective diary). At the end of the course, during the Retro, the team confirms success of the prototype assessment tasks.

• An online version of the course was also developed in parallel to the face to face delivery, using the PDCA cycle for RMIT online students.

• A good example of a successful partnership where industry representatives were on board – around 15 people from industry who shared their experiences with students (including both the guest presentations and site visits, as well as guidance at Designing, and Development stages – see Figure 3).

• Teaching was done in a workshop mode with loads of activities and playing games to understand the agile concepts (similar to most of the professional trainings conducted out there in the industry – see Figure 4).

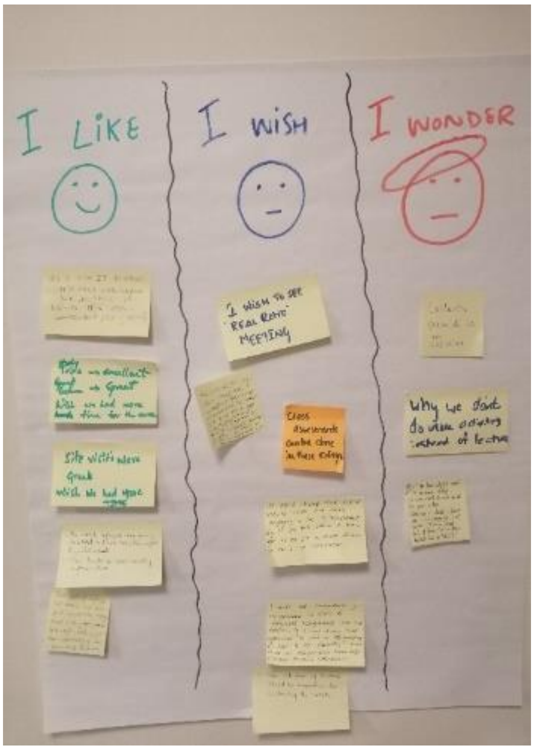

Figure 2. an example of Daily Reflection

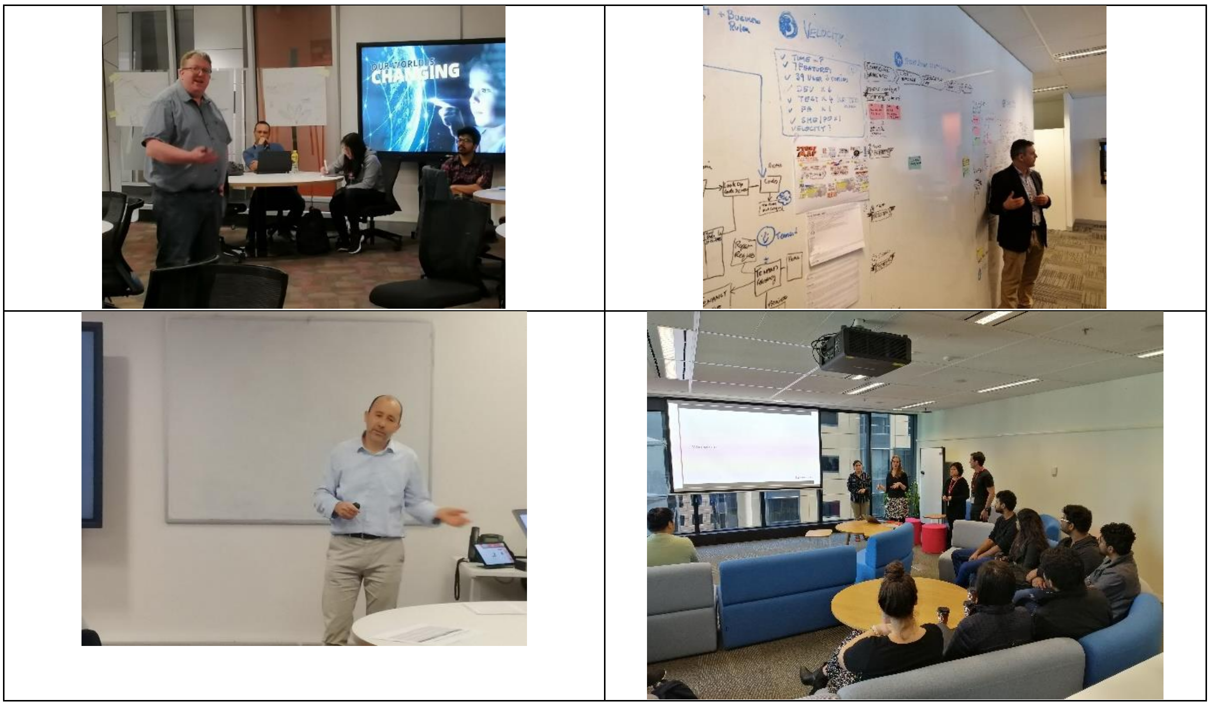

Figure 3. Photos of Industry speakers and Site Visits during the course

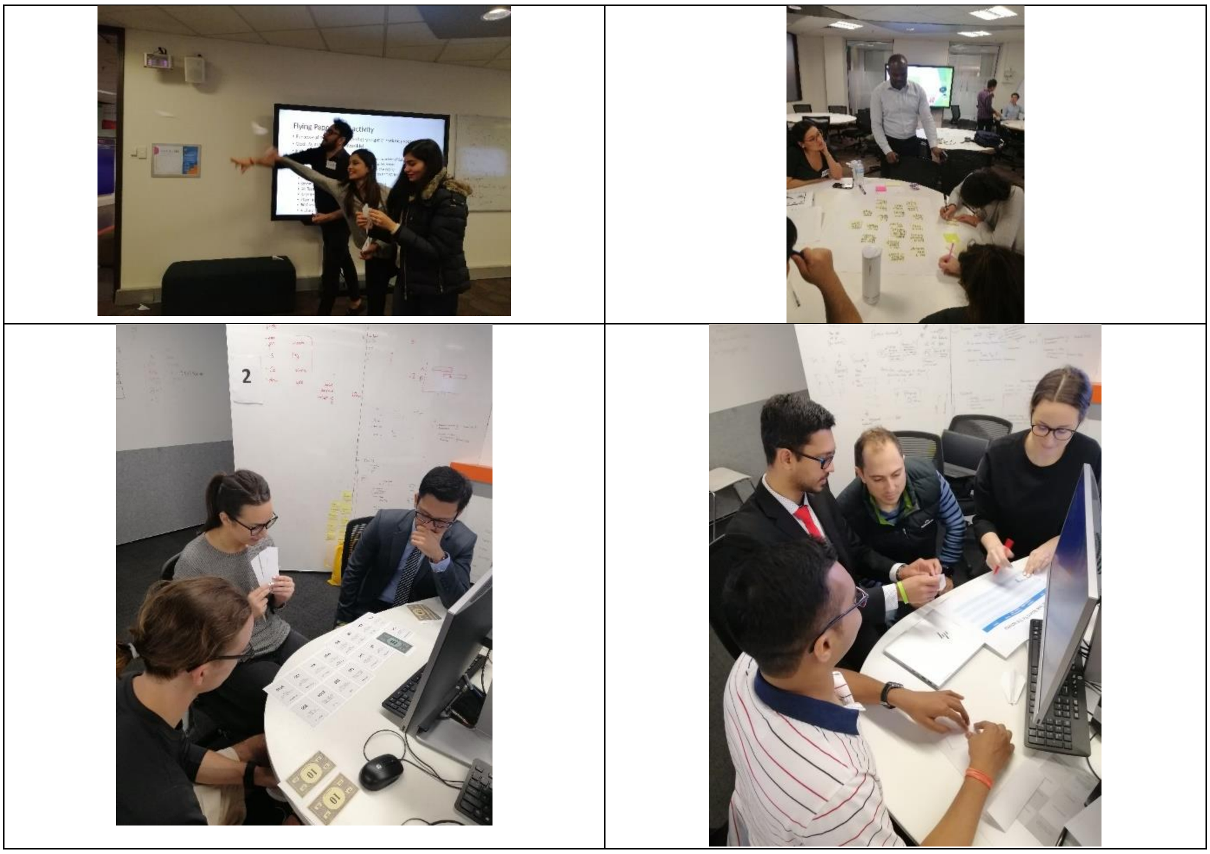

Figure 4. Examples of Workshop and Activities during the course

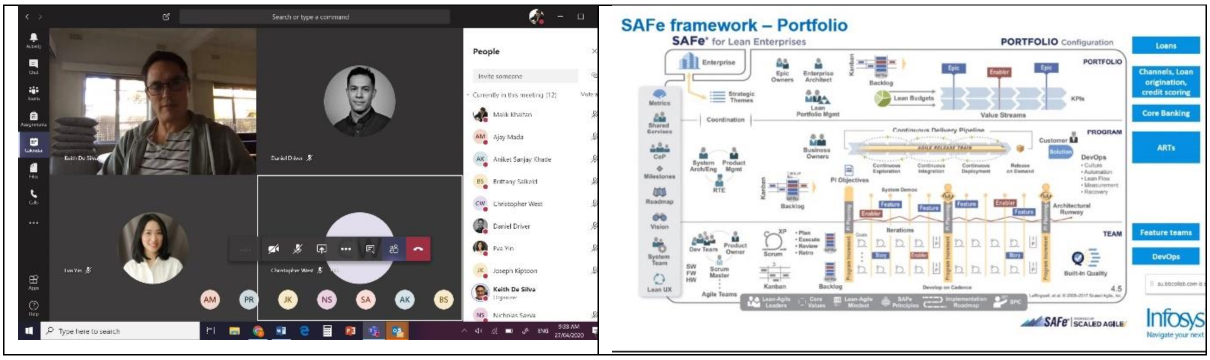

Figure 5. Online Industry Speakers during Covid

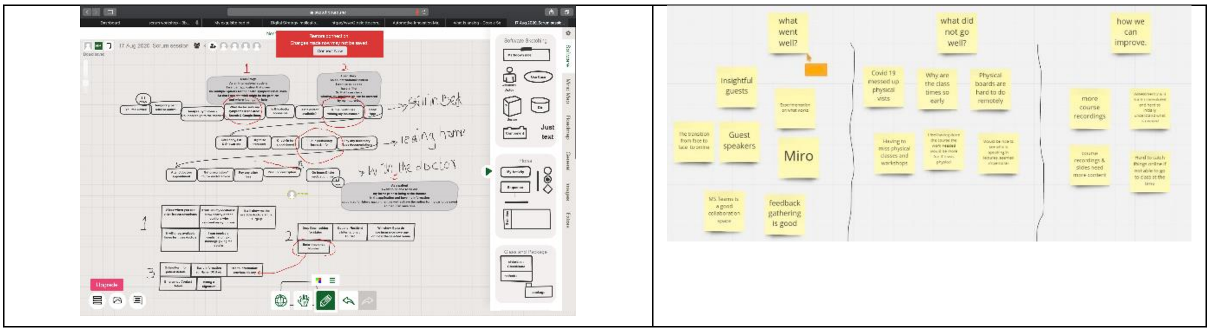

Figure 6. Examples of Workshop and Activities during the online delivery of the course

4 Discussion

This course used WIL as a curriculum design strategy and developed with student centered learning approach in which students engaged in relevant professional practice settings during the course delivery. Tangey (2014) identifies that the term student centered learning is ill defined in the literature, but what is clear is that the term is linked to constructivism (Gharaie and Wingrove, 2019). ‘Constructivism is a learning theory found in psychology which explains how people might acquire knowledge and learn. It therefore has direct application to education. The theory suggests that humans construct knowledge and meaning from their experiences’[1]. The workshop style teaching, the industry site visits, as well as industry speakers, and hands-on class activities to teach concepts of Agile Project Management could be seen under constructivism learning theory where students were given opportunity to develop their knowledge through experiencing the concept in the class and onsite visits. Tangey (2014) also provides a useful way of conceptualising student centered learning and identifies two distinct yet inter related aspects. Firstly, a learning orientated conception of learning, as distinct from didactic knowledge transmission, is one which adopts a holistic perspective of the student (Gharaie and Wingrove, 2019). This humanistic approach, whereby engagement with the student draws upon their wider context of learning, is also borne out in student’s responses about their learning during the course through daily reflection and reviews (see Figure 2). Secondly, Tangey’s learner orientated conception of student centered learning focuses on student’s intellectual development, whereby students are viewed as “active participants rather

1 https://sydney.edu.au/education_social_work/learning_teaching/ict/theory/constructivism.shtml#:~:targetText=Constructivism%20is%20a%20learning%20theory,and%20meaning%20from%20their%20experiences.

than passive receivers" (pp. 267). What students in Agile Project Management course valued were the opportunities the lecturer provided for them through lectures, guest speeches and site visits to apply their developing knowledge and skills during the in class workshops and activities, and to their final piece of assessment. As one student boldly verbalised her feelings to the lecturer whilst on the tram travelling from one site visit to another: 'This is my last course of the degree but my first ever site visits!'

Students also identified during their daily written reflections that the lecturers approach and knowledge contributed positively to their experience of this course. Students experienced that the course content, teaching style, workshops, hands on activities, and site visits are all orientated towards student centered learning approach that enhanced their knowledge related to Agile ways of working. As the literature identifies, if students perceive teaching as 'good' they are more likely to adopt a deeper approach to their learning (Baeten et al., 2010). There is a body of research as highlighted by Gharaie and Wingrove (2019) which identifies a link between student's perceptions of good teaching and a deeper approach to learning with a correlation between the two well documented in the literature (O'Neill and McMahon, 2005, Wilson and Fowler, 2005).

5 Conclusion

The above case study of development of Agile Project Management course is one of the examples of engagement and Collaboration between Academia and Industry in designing, developing and delivery a Masters level course at a university level. The authors termed it as Direct Industry Relevant Teaching, which is one of the facet of Work-Integrated Learning strategies. As discussed, the collaboration resulted into practiced-informed course with insights through guest speeches, and site visits. Students were asked on daily basis during the delivery on what they liked about the course, and areas for improvements. Some feedbacks were taken into account during following days of delivery. One of the main things that students liked about the course was the site visits to see agile in action, which for some of them was the only site visits in their entire Masters course. The course also helped one instructor to complete his ScrumMaster course and another one to find a full time job.

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Using an Agile methodology for continuous improvements and delivery of university courses

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Abstract
It is imperative for the university course coordinators and program managers of various programs (in our case, it is Project Management degree programs) to keep on improving both the content and delivery methods of the courses they teach, from one offering to the next in order to keep students motivated while imparting the industry-relevant content related to various Project Management (PM) methodologies to prepare industry-ready graduates. Therefore, this presentation discusses how two courses from an undergraduate PM program were revamped within the context of recent developments and the adoption of various PM methods in various industry sectors. The course updates were started in mid-2018 to incorporate current industry practices. The process of reviewing the courses was based on a continuous improvement cycle called Plan-Do-Check-Act (PDCA). This PDCA cycle is a key ingredient of many Agile ways of working including the Scrum framework.

Keywords
University courses, PDCA, Agile ways of working

1 Introduction

One of the important objectives for any university level course is to prepare the students as work ready graduates; graduates who have underpinning knowledge of various industry based best and current practices along with traditional ways of working. Within the realm of Project Management, on one hand, students should be sound with the technical knowledge, project-based risk assessment skills and other hard skills required for their relevant industry, as well as on the other hand, students are required to have learnt soft skills and understanding of project management (PM) methodologies used to plan and manage projects within the industry. The soft skills include but not limited to communication skills, critical thinking, collaborative/team working skills, problem solving skills, and critical reflective skills. At the same time, understanding of various PM concepts including Project Management Office, difference between project, program and portfolio and the knowledge of PM methodologies include knowledge of traditional/waterfall PM techniques, Lean Project Management strategies, and Agile ways of working (see Figure 1).

As Gharaie and Wingrove (2019) established that the demand of PM related courses both at undergraduate and post-graduate level is growing with increased number of enrolments at all the offered courses at established university. RMIT university is one of those universities in Australia which has a long established PM programs both at undergraduate and postgraduate levels. In addition to that, many students from business, engineering, media, and management sciences programs are taking PM related electives in order to enhance their knowledge of various PM methodologies in practice within various industry sectors. Hence, it is imperative for the course coordinators and program managers of these programs to keep on improving both the content and delivery methods of these courses from one offering to the next in order to keep students motivated while imparting the industry relevant content related to various PM methods to prepare industry-ready graduates. Therefore, this paper will discuss how two courses from an undergraduate PM program were revamped within the context of recent developments and adoption of various PM methods in various industry sectors.

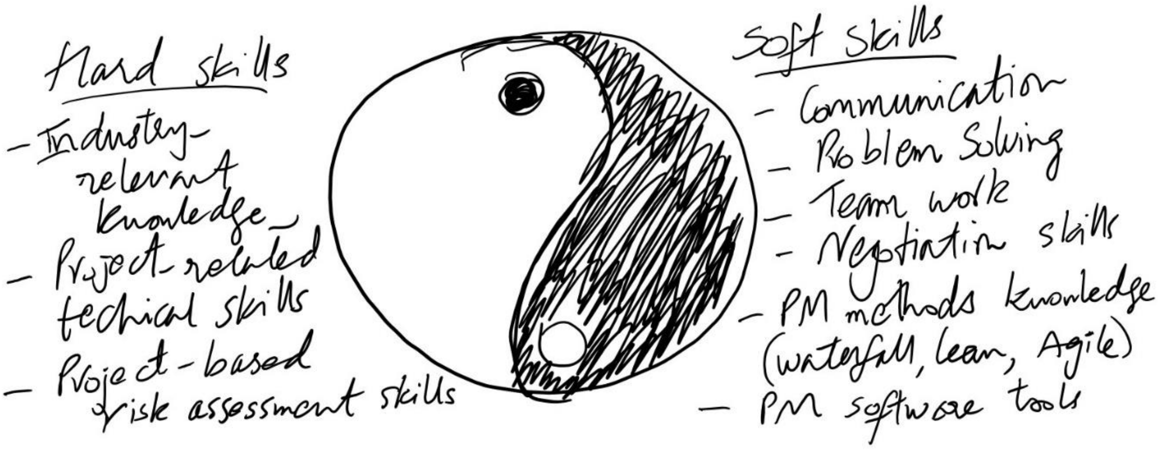

Figure 1. PM soft and hard skills

2 Courses at RMIT PM degree program

The two courses which the first author teaches at the final year undergraduate PM program are 'Advance Project Management' and 'Program and Portfolio Management'. Both of these courses are required courses for the PM undergraduate students. Each of the above courses are taught once a year in an alternative semester and each course is delivered through weekly lectorial (lecture and tutorial/workshop activity). Both of these courses enhance and support one of the important program learning outcomes (PLOs) that states: PLO1: Determine and apply knowledge of complex project management theory to your professional practice and/or further study. In addition to that the course learning outcomes (CLOs) for both of the above mentioned courses have emphasis on analysis, evaluation, and adoption of various PM related concepts and methodologies within both the industry as well as organisational context. Below is an example of a couple of CLOs from Advanced Project Management Course;

- Analyse and apply project management contemporary theories and practices to the management of real life projects
- Apply advanced project management concepts to address industry needs in range of industries and contexts

Hence, the CLOs of both above mentioned courses equip students with industry relevant content and prepare work ready graduates along with other courses taught throughout the degree programs. The first author of this paper is now the current course coordinator as well as tutor of both courses. He took over these courses from a leaving faculty in mid of 2018 and started to revamp these course to reflect current industry practices. The process of reviewing of the courses was based on a continuous improvement cycle called Plan-Do-Check-Act (PDCA). This PDCA cycle is a key ingredients of many Agile ways of working including the Scrum framework. The next section, briefly give an overview on both the Scrum framework and PDCA as part of the framework, which was then used to bring improvements to these courses taught over the last three years (2018 – 2020).

3 Scrum Framework

Scrum is a technique that derives from the player formation concept in rugby games. It is then paired with software product development after an article called "The New New Product Development Game" is published in the Harvard Business Review. The article was written by Hirotaka Takeuchi and Ikujiro Nonaka in 1986. The article describes Scrum as a rapid, flexible development strategy to meet fast-paced product demands, as well as the benefits of self-organizing teams in innovative product development and delivery. Based on the above, Sutherland, J & Schwaber, K came up with the Scrum Framework in mid 1990 (Sutherland and Schwaber, 2011). Scrum is the most popular and prevalent agile method, with strong emphasis on small, inter-disciplinary team functions (Chen, Reichard & Beliveau 2007; De Marco, Demagistris & Hassan 2016). It is not only used within the software and IT industry, but also quite popular in other industries such as HR, Media, Marketing, and Education.

Scrum framework is an iterative and incremental lightweight agile framework with heavy focus on team and customer collaboration (see Figure 2). There are three pillars that form the fundamentals of Scrum practices, events, roles, artefacts, and rules: (1) Transparency – Everything on a Scrum project is visible and available to all parties involved; (2) Inspection – Inspection takes place on a regular basis to ensure that the Scrum project is achieving its goals and missions; (3) Adaptation – Adjustments takes place as required to address any problems or issues (Canty 2015). Similar to the other agile product development methods, Scrum utilises the iterative and incremental approach to deliver quick functionalities in the form of sprints. These iterations are in the form of PDCA, as mentioned above. The PDCA cycle is embedded within the scrum framework in such a way that the entire sprint reflects a longer (2-4 week) PDCA cycle whereas daily scrum (daily stand ups) could be represented as a shorter (1 day) PDCA cycle (see Figure 3).

In Scrum, requirements can change over a period of time; and this aligns to the third pillar i.e. Adaptation (Canty 2015). Scrum focuses on team experiences, leadership, and scope management (Ambler 2009; Ambler & Holitza 2012). It is also a customer-focused framework where the team collaborates with the stakeholders and use frequent feedback and collective decision making to increase business value (Canty 2015; Sliger 2011). The authors prototyped the content redevelopment and delivery of both courses using Scrum framework and the PDCA cycles over the three year period.

As mentioned in the above section, PDCA is used as continuous improvement approach for course redevelopment and delivery, that is embedded within the scrum framework. The PDCA, developed by Walter Shewhart in the 1930s, is a cyclic approach and is proven to enhance the performance and productivity of any project (Forbes & Ahmed 2010; Larman & Basili 2003).

4 Research Methodology and implementation

The first author did not only study the Scrum Framework and PDCA cycle, but they applied it to redeveloping and improved delivery of both of the above courses. This application of the theoretical framework into practice is called action research. Action research is also considered as a reflective process that aims at solving specific problems within a program, organisation or community (Patton, 2002). According to Reason and Bradbury (2008; p.4), "… primary purpose of action research is to produce practical knowledge that is useful to people"; hence, any organization can conduct action research to improve any specific issues or system within the organization in order to solve a real organizational problem (Guthrie 2010; Christer 2010), and it might be related to sales, production or any kind of result. This is in keeping with the aims of the redevelopment and delivery of the above-mentioned courses. This is not just the redevelopment, but also continues improvement as we move forward form one week to the next week in the same semester, and also from one semester delivery to the next semester delivery in different academic year. The PDCA cycle which is embedded within the Scrum tool, helps achieve this goal for the authors. See Table 1 that lists the improvements done over the last 3 deliveries of the two courses and Figures 4-8, that illustrates the use of PDCA cycle within Scrum tool showing continues improvement both on weekly basis in one offering, and continues improvement on semester basis over multiple offerings of the same courses based on the feedback, review and reflection.

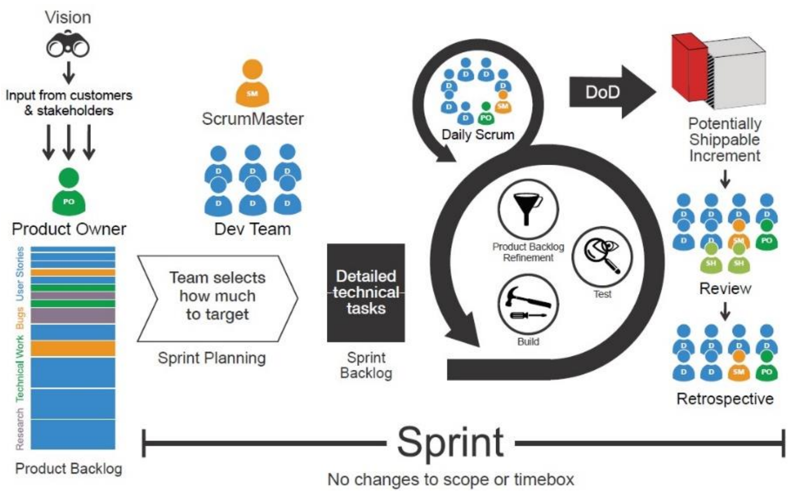

Figure 2. Scrum Framework

Figure 3. PDCA cycles within Scrum Framework

Table 1. Continuous improvements over 3 deliveries of the courses (years 2018 – 2021)

Selected lectures from two courses taught previously	New and Revised lectures / topics for two courses
Agile Project Management lecture	Revised Agile Project Management lecture
	Risks in Agile Projects (New topic)
Scrum lecture	Revised Scrum lecture
	Scrum workshop (New Session)
	Design thinking workshop (New Session)
	Lean Philosophy and Lean Project Management (New Session)
	Lean construction workshop (New Session)
	Lean start up and innovation portfolio development lecture (New Session)
	Lean Six Sigma (New topic)
	SAFe Framework lecture with a case study (New Session)
	Disciplined Agile Delivery (DAD) (New topic for the future offerings)
	Trello as Kanban Board (New topic for the future offerings)
	DevOps (New topic for the future offerings)

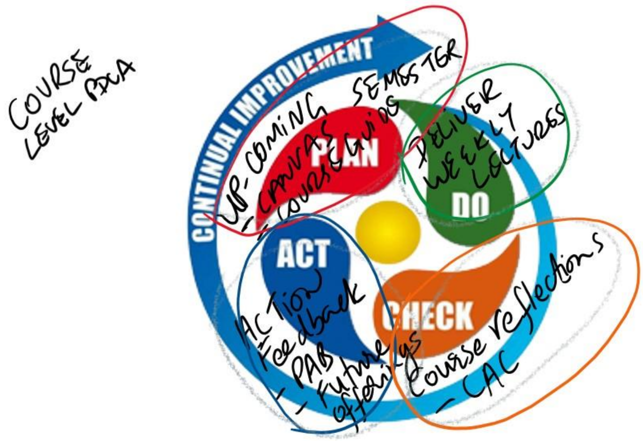

Figure 4. Course Level PDCA per semester

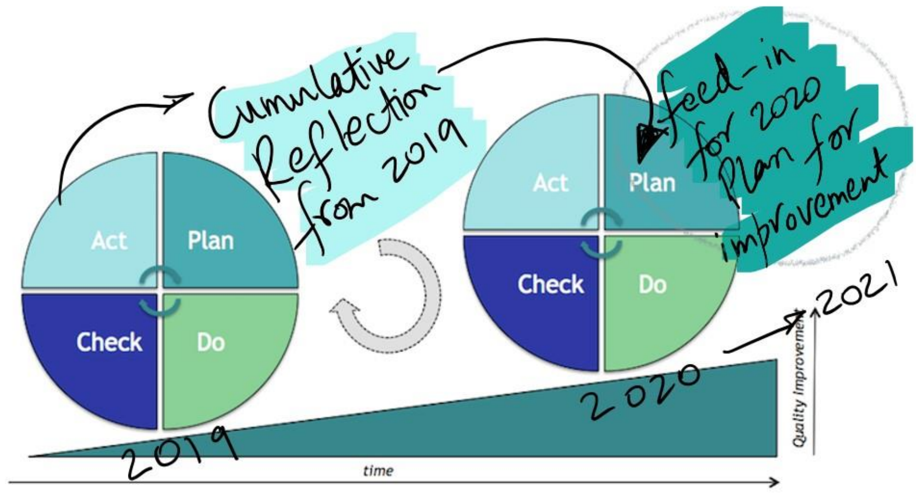

Figure 5. Yearly offerings and improvements of a course using PDCA

Figure 6. Weekly PDCA during course delivery

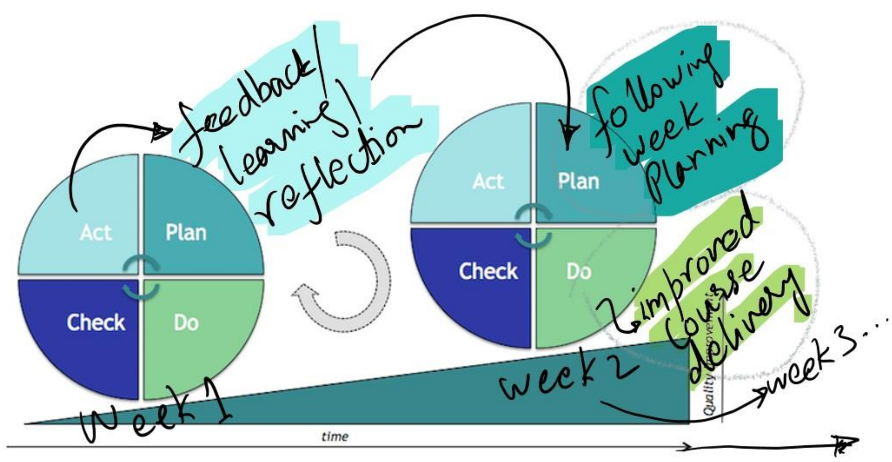

Figure 7. Weekly offerings and improvements during a course delivery within a semester using PDCA

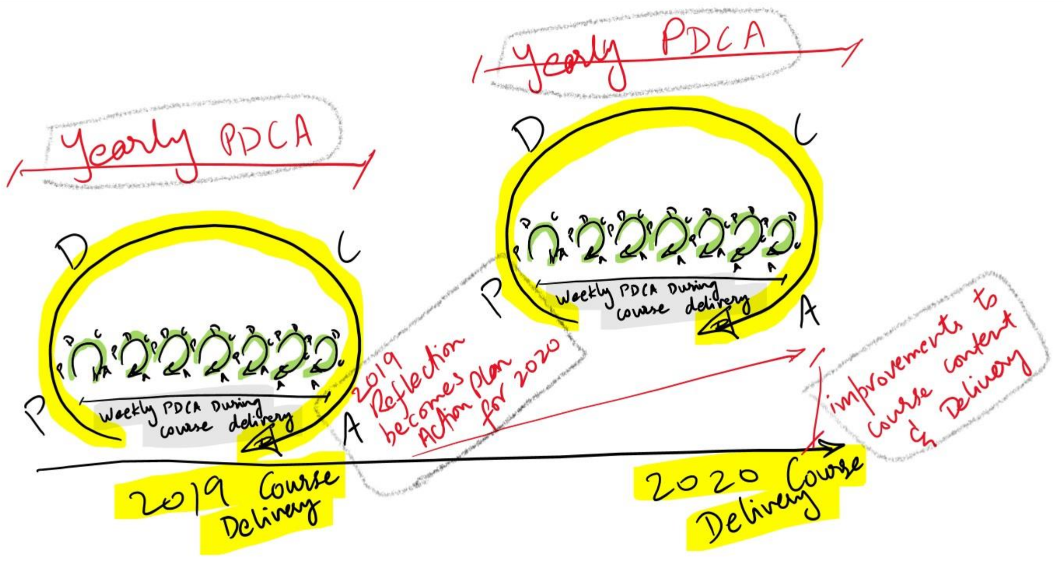

Figure 8. PDCA cycles embedded within the scrum approach (weekly and yearly)

Week by week changes during a semester, there is a weekly feedback that gets converted into actions, such as change of brief to industry guest speakers; adding new case studies as we go; etc. This enables the main author (the lecturer) to bring improvement in course delivery, such as adding more workshop activities, based on the reflection and verbal feedback from students.

Hence, we are applying PDCA here – P is what is planned for a particular week, D is the delivery, C is the reflection, review, and retro to see what went Ok, what went wrong, and how we can improve content, delivery next week, and putting all this into an action plan is our ACT stage, this is then fedback back into the PLAN for following week delivery; hence the cycle continues.

Readers should note that we are certainly not changing the main content in weekly cycles (content gets changed from semester to semester), but weekly PDCA cycle enhances the quality of the delivery according to the needs. The assessment tasks remains then same, so no issues with changes in the course guide. For delivering the course from one semester to the next, the authors incorporate new topics in the updated course guide and content is developed for delivery.

4.1 Updating the assessment tasks

For both the courses, authors updated the assessment tasks – in the past 60% tests and 40% group work, but it was now changed to only 20% test, 30% new individual piece of assessment task, and group work became 50%. In addition to the above content changes, the authors also introduced a new assessment task related to the Agile PM.

4.2 Industry-relevancy of the courses

The content re-developed for both of the courses is highly industry relevant. In addition to the content, the first author also invited several guest speakers to make the sessions more interesting. Table 2 provides details of industry sessions as well as site visits since 2018.

Table 2. Industry guest speakers and site visits (since 2018)

PMO site visit	EPMO at RMIT- site visit and guest speaker - 2019
Agile in action	RMIT ITS site visit and case study - 2019
PMO session	EPMO at RMIT – guest speakers - Marina Direk and James Doubell - 2020
PMO session	Simon Phillips (RMIT University) – 2021 – online
PMI	Dr Tiendung Le and Katy Dimitropoulos – 2020/21 - online
Program Management	Vikki Kapoor (PMI president – 2019 and 2020) face to face and online
Portfolio Management	Troy Severino (RMIT University) – 2019 – face to face
Portfolio Management	Simon Phillips (RMIT University) – 2020 – online
Portfolio Management	Kevin Feeney (Red Cross – 2020) – online Michelle Leeder (Red Cross – 2018-19) – face to face
Program Management	A former student at VicRoads to deliver a guest session in 2022
Agile in action	Pete Omotosho - Workshop – 2021 – online
Agile methods	sandip Rananavare - DAD framework introduction – 2021 – online

4.3 Online course delivery during Covid-19

As readers are aware, most of the teaching activities were conducted in online mode during the Covid-19 lockdown in Melbourne (and of course, in other parts of the world). Authors checked with students how they were finding the online offering of the courses, and Figure 9 was the response from one of the sections.

Figure 9. Students feedback on the online teaching

In some cases, the online delivery enabled students to use a lot of freely available interactive tools such as Miro, Mural, Whiteboard, etc and communication tools including, MS Teams. Figure 10 shows a difference between the in-class activity verses the same activity when it was done using the interactive tools during online delivery.

One of course group workshops was to draw a user journey map, and identify the pain points/needs within it and write user stories corresponding to them. In the face to face offerings, students used the post-it notes and butcher papers; whereas in the online version, the interactive and drawing tools were great to use – see Figure 11 as an example where students drew a user journey map, identified the challenges and wrote stories.

Despite all the challenges of delivering and attending online lectures, students coped with the change and from time to time provided their feedback in the form of ‘Retro’ for the lecture sessions as well as for the entire course delivery. See an example of retro in Figure 12.

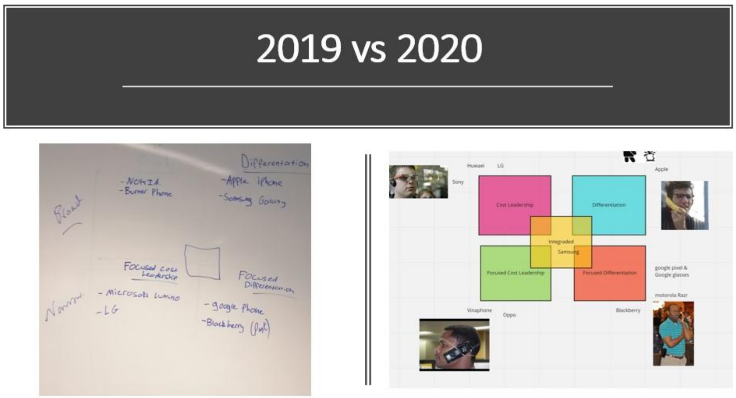

Figure 10. Comparison of Student work pre- and during Covid-19

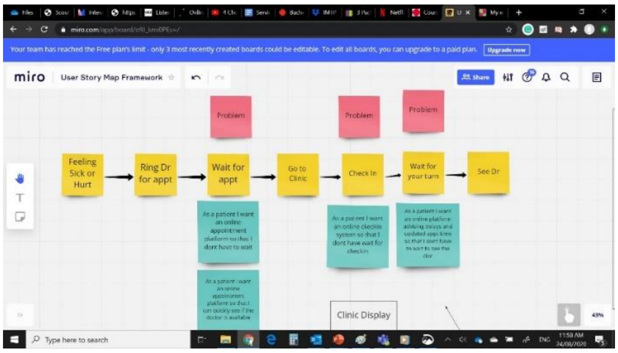

Figure 11. An example of an online workshop activity

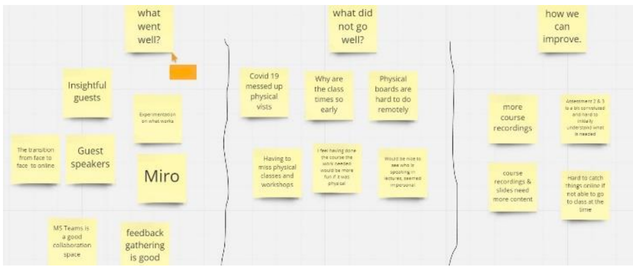

Figure 12. Student feedback on the course

5 Conclusion

The paper demonstrated how Agile tools such as PDCA and Scrum have been applied for re-development and delivery of courses in a university setting, as part of a degree program. We saw how continuous improvement was carried out on a weekly basis during a semester whilst lectures being delivered, and also the concept of how we could continuously improve from one semester to another. The authors have seen satisfaction among students increased both for the content and delivery for both the courses mentioned over a 3-year time frame. This was achieved by deploying simple PDCA cycle and Scrum fundamentals to achieve a structured way of continuous improvements.

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A Systematic Review of Risks in Modular Integrated Construction Practice

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Abstract
Despite considerable advantages, stakeholders remain dubious in adopting Modular Integrated Construction (MiC) practices due to the perceived risks. With its unique business model, MiC differs from conventional construction methods (CCMs) in its approach. Currently, the adoption rate of MiC practice is still low in many countries, which calls for evaluating the risks associated with it. Therefore this study focuses on identifying the risks systematically linked to MiC, by reviewing related published literature from 2006 to 2021. A systematic literature review methodology is adopted following the PRISMA protocol. A total number of 51 articles were critically analyzed in this study. The result reveals a continual upsurge in the risk studies about MiC, with the peak of such studies in the last few years. This study classifies MiC's risks in project stages, namely into design and planning, offsite manufacturing, logistics and transportation, and on-site assembly. Furthermore, this research identifies distinguishing factors that affect such project stage risks. Finally, this study proposes a conceptual framework that highlights strategies to overcome the project stage risks, based on Building Information Modelling (BIM) integrated technologies. This research will promote the adoption of MiC through enhancing the understanding of MiC's various risks.

Keywords: Building Information Model, Modular Integrated Construction, Risks, Review.

1. Introduction

Conventional construction methods (CCMs) account for significant contributions in the Architecture, Engineering, and Construction (AEC) industry for many years (Darko *et al.*, 2020). However, the rise of industrialization in the last decades has paved the way for modern methods of construction (MMC) which makes the process of construction much easier, less time-consuming, low overall cost, more sustainable, and low labor-intensive. The rise of Offsite Construction (OSC) (Arashpour *et al.*, 2018) methods is an example of this; OSC is defined as the process of planning, design, manufacturing, fabrication, and preassembling of various building elements, components, and modules in an enclosed environment – often known as factory production, before installation on the final site, to rapidly support a permanent structure (Goodier *et al.*, 2006). This is sometimes also referred to by other names, such as offsite manufacturing (OSM), offsite production (OSP), offsite fabrication (OSF), modern methods of construction (MMC), prefabrication and industrialized construction, volumetric and non-volumetric preassembly, component subassembly, penalized assembly. But, the most configured form of OSC is Modular Integrated Construction (MiC) (Wuni and Shen, 2019).

Across the wide spectrum of OSC methods, MiC is considered to be a comprehensive one based on the concept of "factory assembly followed by on-site construction"(Harvey, 2014).

The installation process of MiC is like Lego bricks assembly in which a stack of different modules is placed on top of each other to complete the structure. The rise of MiC is seen in recent years due to the vast benefits it offers in comparison to CCMs. For instance, Kamali and Hewage, 2016 mentioned the lifecycle benefits of MiC, and Wuni and Shen, 2020c documented the critical success factors for MiC projects for the construction industry.

Although MiC has numerous benefits, it still carries various risks. Though some risks are common and also occur in CCMs, others are unique in nature and need to be addressed in a different way as the conventional risk management models may not work in MiC projects (Darko *et al.*, 2020). For the successful implementation of a MiC project, it needs a unique business model (Wuni *et al*., 2019) and philosophy of manufacturing production instead of traditional construction design and supply chain (Goodier *et al.*, 2006). This results in unique risks in projects following the MiC approach such as crane breakdown issues, inadequate data coordination, modular installation faults, modular production system failures, manual inspecting, and unwrapping among others (Wuni *et al.*, 2020). Also, these risks result in sub-optimal project outcomes such as cost overruns, time delays, and low quality. All these factors result in the low productivity of the MiC method, hampering its wider adoption in the construction industry (Darko *et al.*, 2020). Although a few studies have examined the different risks in OSC methods, (Jiang *et al.*, 2018; Wu *et al.*, 2019; Abdul Nabi and El-adaway, 2021; Jeong *et al.*, 2021) they focused on generic topics lacking in detail about risks specific to MiC method, or in a systematic manner about project stage risks.

Therefore, this study focuses on a systematic review of the published literature about risks in MiC methods from the year 2006 to the present. The research objectives of this study are (i) to investigate the risks and risk factors in MiC and categorize them within project stages, and (ii) to propose a conceptual framework stating the strategies to overcome the risks. The results of this study will assist in better understanding the risks at different project stages and promote the implementation of MiC methods. Furthermore, this study shall also contribute to assisting stakeholders including researchers, policymakers, academicians, project developers, and industry professionals in understanding bespoke risks in MiC. The following sections of the paper present an overview of MiC risks, followed by the methodology adopted. The findings and discussions are presented in section 4, with conclusions in the last section.

2. Overview of Risks in Modular Integrated Construction

The unique model of the MiC method involves innovative ways to design, procure, engineer, and deliver projects (Wuni *et al.*, 2019). As per Luo *et al.*, 2019, due to the involvement of various stakeholders in the MiC project, such as architects, engineers, designers, manufacturers, suppliers, logistics companies, and developers, the process of supply chain gets fragmented due to stakeholders objectives and goals. Despite the advantages which make MiC a sustainable model of construction, there are several risks associated with it that affect the success of the project. The skeptical nature of various stakeholders to adopt the MiC method in their projects is widely due to the uncertainty and risks associated with it which ultimately affects the productivity of a MiC project (Luo *et al.*, 2015). Problems like schedule delays of components and modules, the late freeze of design, and errors during the installation process of modules can reduce the productivity of MiC and be counterproductive to an optimal outcome (Wuni and Shen, 2020a).

As per U.S. Bureau of Labor Statistics, U.S. Department of Labor, 2009, MiC projects results in higher rates of injuries – accidents and incidents of the workers – due to non-standardization of laws and absence of relevant codes, thus affecting the low productivity and adoption of MiC methods across various countries. Potential falling, awkward working postures, low back pains, fall injuries, and work-related Musco-skeletal disorders (WMSDs) are among the common safety risks among workers in the construction industry (Bureau of Labor Statistics, 2019). Although these risks are common among MiC methods and CCMs, the rate of severity in MiC methods is more compared to CCMs. Bureau of Labor Statistics, 2019 reported that the injury and incidence rate is 10.2 per 100 workers in MiC methods as compared to 5.2 per 100 workers in CCMs. Considering this fact, Fard *et al.*, 2017 also reported in their study that out of 125 accidents in MiC projects, 50.4% were hospitalized injuries, 38.4% were fatal in nature and 11.2% were non hospitalized injuries. Also, the problem of production plant failure and variabilities in the geometry of modules may impact the process of MiC construction on site (Shahtaheri *et al.*, 2017a). Similarly, delay causes in the MiC projects are also due to deprived stakeholder management, inadequate worker experience, and disorganized connection of modular components (Ji *et al.*, 2018). All these risks make MiC adoption intimidating for the stakeholders as the complexity involved at each step of the project limits the adoption process. To handle these risks, novel methods and techniques should be adopted for better risk assessment and management of the MiC projects (Xue *et al.*, 2018).

3. Research Methodology

A two-stage review process is adopted in this paper namely the articles retrieval process and content analysis procedure. Preferred reporting items for systematic reviews and meta-analysis (PRISMA) are used for articles retrieval (Moher *et al.*, 2009). The second stage is the content analysis of the retrieved articles which allows focusing critically on the selected literature among the pool of publications (Sepasgozar *et al.*, 2020).

3.1 Articles retrieval

PRISMA process involves four stages of obtaining relevant articles from the literature. These are identification, screening, eligibility, and inclusion. The four steps are briefly explained below. Figure 1 depicts the process of PRISMA protocol.

3.1.1 Identification

The keywords for the study are identified and *Scopus* is used as the search engine as it is considered as the most authoritative database engine for academic search (Aghaei Chadegani *et al.*, 2013). The keywords input in the *Scopus* search engine used TITLE-ABS-KEY as follows: (hazard OR risk OR safety OR uncertainty*) AND (prefabrication OR “offsite construction” OR “off-site construction” OR “modular construction” OR “modular integrated construction” OR “offsite production” OR “precast construction” OR “modern construction” OR “industrialized construction”). The number of articles retrieved after this search string is 1228. The date of the search was 13 May 2021.

3.1.2 Screening

The screening was carried out based on articles LIMIT-TO (DOCUMENT TYPE, “article”) AND LIMIT-TO (LANGUAGE, “ENGLISH”) AND LIMIT-TO (SOURCE TYPE, “journal”). Also, the papers earlier than the year 2006 were removed as there were only a few articles related to offsite construction in general without focussing on risks associated with it. Some duplicate items were also found and removed. After the screening process, 138 articles remained for the eligibility phase.

3.1.3 Eligibility

In this phase, the abstract of each article was studied and papers lacking the focus on risks in MiC methods were removed. A total of 51 articles remained after the rigorous study and moved forward to the inclusion phase of the study.

3.1.4 Inclusion

A total of 51 articles were included for the study and critical content analysis was conducted to develop a comprehensive understanding of the risks related to the MiC process.

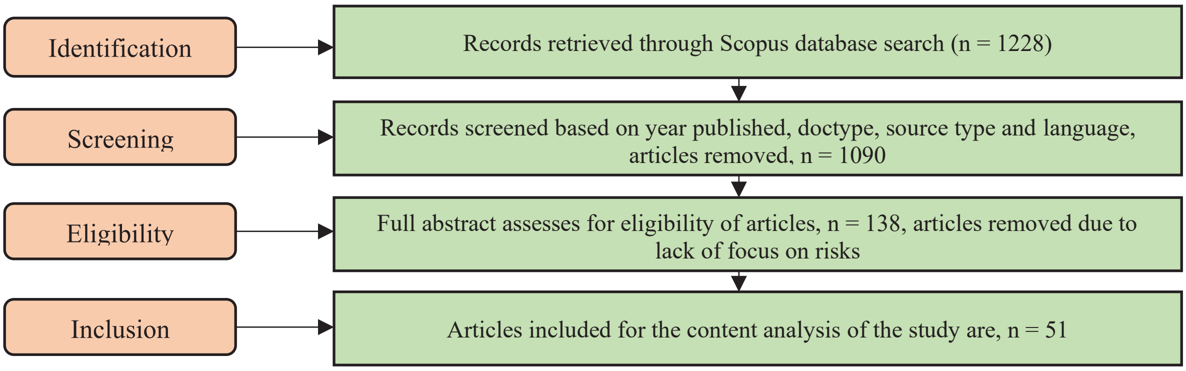

Figure 1. PRISMA approach to retrieve the relevant articles

3.2 Content Analysis

The review process of all 51 articles was carried out in a rigorous way to form themes and classifications as it is an effective way to structure a dataset for fruitful results (Sepasgozar *et al.*, 2020). The content analysis of papers revealed four themes in which the risks in MiC are divided based on project stage risks which are discussed in the next section.

4. Findings and Discussion

4.1 Annual trend of research publications on risks in MiC process

The articles based on risks in the MiC process are fragmented and previous researchers touched upon different aspects and shortcomings in the MiC process. Table 1 shows the focus of the articles along with references. The total number of relevant articles focusing on risks in the MiC process is 51 starting from the year 2006 till the date of retrieval. Figure 2 shows the column chart for the spread of papers since the year 2006. It is depicted that till the year 2016, the number of articles remained around 2 to 3 per year, then, a rise has been seen in years 2017 and 2018. Again, the number of articles declined in 2 years, which can be predominantly due to the pandemic situation around the world which has affected research work as well. As the risks in the MiC process are rising, the study becomes timely to give a reality check to the stakeholders regarding the occurrence of disruption due to risks in the MiC process.

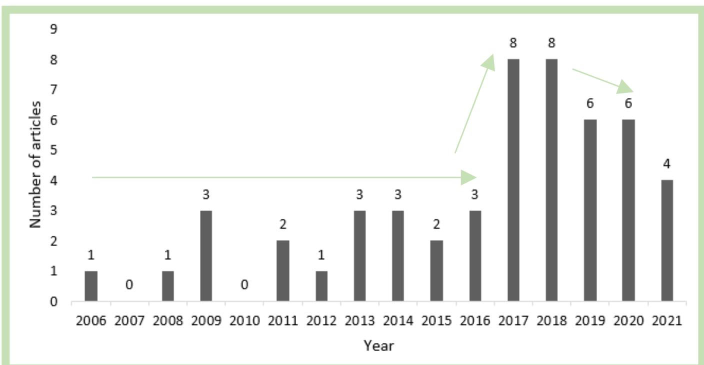

Figure 2. Annual publication trend of risks articles in MiC

Table 1 – Articles retrieved with the focus of study

Articles focus and reference		
1. Barriers of prefabrication in public housing. (Chiang *et al.,* 2006)	18. Schedule risks of OSC in Hong Kong. (Li *et al.*, 2016)	35. Schedule risks analysis in prefabrication construction. (Li *et al.*, 2018)
2. Risk sources in industrialized projects. (Hassim *et al.,* 2008)	19. Thermal comfort risks in prefab buildings. (Adekunle et al., 2016)	36. Risk management framework in MiC. (Enshassi *et al.*, 2019)
3. Risks in industrialized projects in Malaysia. (Hassim et al., 2009)	20. Schedule risks modeling of prefabricated buildings. (Z. Li *et al.*, 2017)	37. Critical risk factors in MiC methods. (Wuni et al., 2019)
4. Relation between lean and safety in industrialized housing. (Nahmens et al.,2009)	21. Risk management in MiC using dimensional and geometric tolerance. (Shahtaheri *et al.*, 2017b)	38. Review of risks in MiC methods. (Wuni et al.,2019)
5. Drivers and constraints of OSC. (Blismas et al.,2009)	22. Risks in an optimum selection of modules in MiC. (Salama *et al.*, 2017)	39. Site logistics planning using BIM in prefabricated buildings. (Bortolini et al.,2019)
6. Lean and safety integrated kaizen to improve OSC. (Ikuma et al.,2011)	23. SWOT analysis for OSC in China. (Jiang *et al.*, 2017)	40. Workplace design in MiC using ergonomic assessment. (Li *et al.*, 2019)
7. Low back injury risks in prefabricated construction. (Kim et al., 2011)	24. Risks mitigation through RFID and BIM in prefabricated buildings. (Li *et al.*, 2017)	41. Risks perceptions in OSC methods. (Wu *et al.*, 2019)
8. Work-related Musco-skeletal disorder. (Kim et al.,2012)	25. Capital cost risks in prefab buildings. (Xue *et al.*, 2017)	42. VR for ergonomic risks in MiC methods. (Dias *et al.*, 2020)
9. Barriers in OSC in China. (Mao *et al.*, 2013)	26. Schedule delay analysis of prefabricated houses in Hong Kong. (Li *et al.*, 2017)	43. Lifting simulation of modules through gaming in MiC. (Sydora *et al.*, 2020)
10. Risks of MiC using AHP analysis. (Li *et al.*, 2013)	27. Investment risk in prefab construction. (Li *et al.*, 2017)	44. BIM-based risk management in MiC projects. (Darko *et al.*, 2020)
11. Statistical evaluation of criteria for prefab construction. (Azman *et al.*, 2013)	28. Barriers of transition to OSC in China. (Gan *et al.*, 2018)	45. Barriers to adopting MiC methods. (Wuni et al., 2020a)
12. Kaizen impact on Modular homes. (James *et al.*, 2014)	29. Constraints of prefabricated construction in China. (Jiang *et al.*, 2018)	46. Fuzzy modeling of critical risk factors of MiC. (Wuni et al., 2020c)
13. Barriers of MMC. (Rahman, 2014)	30. Crane planning and optimization of Modular buildings. (Taghaddos et al.,2018)	47. Evolution of prefabricated building through game analysis in China. (Li *et al.*, 2020)
14. Barriers of OSC in China. (Zhai et al., 2014)	31. Delay risks in prefabricated buildings in China. (Ji *et al.*, 2018)	48. Challenges and Feasibility of Mic in China. (Zhang *et al.*, 2021)
15. Safety concerns of Modular buildings. (Fard *et al.*, 2015)	32. Logistics planning of Modular construction. (Hsu et al.,2018)	49. Identifying accidents through safety risk factors in Mic projects. (Jeong *et al.*, 2021)
16. Implementation risks of Industrialised construction methods. (L. Luo *et al.*, 2015)	33. Constraints and mitigation of PPVC methods. (Hwang et al.,2018)	50. Risk factors affecting cost and schedule in MiC projects. (Nabi et al., 2021)
17. Cost risks factors in Modular construction in Korea. (Lee et al., 2016)	34. Cost risk analysis in stakeholder perceptions in OSC. (Xue *et al.*, 2018)	51. Crane operation and planning in MiC. (Hussein et al.,2021)

4.2 Project stage risks in the MiC process

As a result of critical content analysis, the risks have been classified broadly into project stage risks. Although, the MiC methods do not have any standards and codes associated with them (Darko *et al.*, 2020), the typology of the risks studies is also fragmented. Authors in this study classified the risks in MiC methods based on criteria resulting from a review of the existing literature.

Based on the content analysis, the risks in the MiC process have been divided into four stages, which cover a wide range of risks associated with MiC methods. The four main project stage risks are design and planning risks, off-site manufacturing risks, logistics and transportation risks, and on-site assembly risks. All these risks affect the productivity of the MiC project at each stage starting from the inception of a project to completion. Figure 3 illustrates risks associated with the MiC method.

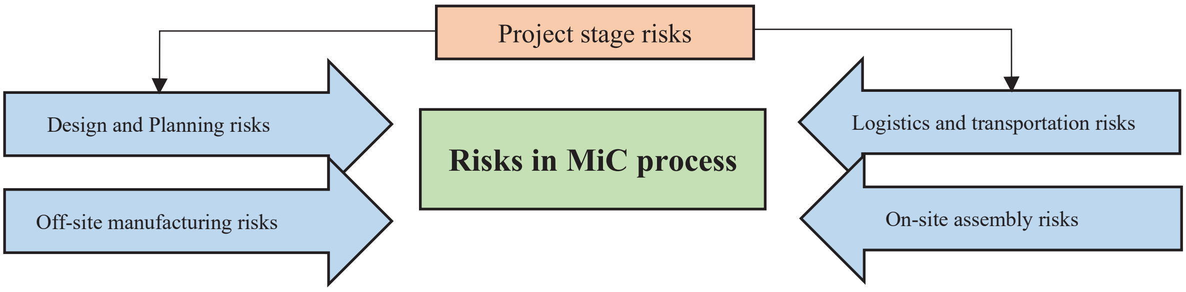

Figure 3. Risks of MiC classified based on project stages

4.2.1 Design and Planning Risks

The initial process of the project is design and planning, risks at this stage are vital in the smooth running of the projects. It is very important to manage potential risks at the design and planning stage to avoid any further risks caused by them (Darko *et al.*, 2020). As modules for MiC have fixed sizes and dimensions, any errors in design are a significant threat to the manufacturing process. Also, problems like design changes, inefficient approval processes, and data transition, all fall under design and planning risks (Alwisy *et al.*, 2012). The application of BIM and its associated visualization techniques can prove to be imperative in eradicating these risks. It is an efficient strategy to automate the process before the shop drawings of modules are used by the manufacturers (Alwisy *et al.*, 2019).

4.2.2 Off-site Manufacturing Risks

Risks like inadequate production planning, errors in the manufacturing process, poor inventory control, inefficient material quantity, production line balancing, and lack of proper concurrent engineering process are common in the manufacturing stage (Wuni and Shen, 2020b). In addition to this, lack of efficient use of factory space, changing in production planning, and equipment overuse or underuse are also important factors that hinder off-site manufacturing setup (Gan *et al.*, 2018). Earlier studies have mentioned these risks and applied different ways to reduce them, for example, Ritter *et al.*, 2018 used BIM-RFID-based process management for balancing the issues of the production line in a factory setting. Again, BIM integrated with other techniques can be vital in managing these risks.
The use of Radio frequency identification (RFID) techniques with BIM can acquire real-time data of the production process which can assist in understanding the problems and optimization can be performed. Other than that, 4D-BIM visualization of the production process can be used to manage the module manufacturing process. For instance, Lee and Kim, 2017 used 4D-BIM

simulation to improve the module manufacturing productivity, and Li *et al.*, 2017 used the BIM-RFID technique to mitigate the risks and improve the process of manufacturing.

4.2.3 Logistics and Transportation Risks

The logistics and transportation process of MiC modules along with ancillary items is the most critical and serious process (Bortolini *et al.*, 2019). Risks at this stage are vital as it can hinder the ongoing work at the site and affects the productivity of the MiC process significantly. The logistics risks in the MiC process are mostly dependant on the proper logistics management. It is the prime risk in the logistics and management stage. Other risks which revolve around it and have a direct effect due to it are incorrect modules delivery, lack of information, workers error due to inconsistency in information, mismanagement of modules in the buffer zone, delays in delivery of modules to on-site, weather disruptions, and restrictions in transportation due to size and weight (Wuni *et al.*, 2019).

BIM-RFID integration is one of the measures which can make the logistics process more efficient and smarter. It allows real-time sensing and tracking of information related to modules easily and can ease the communication process (Li *et al.*, 2017). Along with this, a BIM-based geographic information system (GIS) is also an efficient way to smooth the delivery process of the modules on site (Niu *et al.*, 2019). Although, BIM-based visualization techniques have not been researched in this area, simulating the process of logistics and transportation as a game-based virtual environment would be an inspiring step. Workers could gain experience about the process in a virtual environment, which can reduce their intimidation and hesitancy about the risks eventually.

4.2.4 On-site Assembly Risks

After the delivery of modules on-site, the task of assembly planning starts. As assembly planning is strictly a domain of the manufacturing process, it is rather new for the stakeholders of the AEC industry (Wuni and Shen, 2020b). Predominantly referred to as assembly sequence planning, it includes the planning of assembling the modules and getting the most desired output in terms of space utilization. Proper assembly sequence planning tends to reduce the risks and eventually reduces the detrimental effects caused by it, such as cost overruns, time delays, and compromises in quality. The risks related to improper onsite planning such as inefficient assembly sequencing and scheduling are common in MiC (Zhou *et al.*, 2021).

In addition to this, risks related to errors in modules installation also affect the assembly process on site. Module lifting requires heavy tower cranes at various points on the site and managing the risks related to them becomes vital as they involve huge capital. In this regard, the risks related to crane layout planning and lift path planning are quite common and they adversely affect the overall productivity of the MiC method. Strategies involving BIM-based automation of sequencing, BIM-based RFID for installing arrangement have been used by the researchers (Li *et al.*, 2017), although the inaccuracies still exist in the overall process of onsite assembly.

4.3 Framework for addressing risks in MiC

The content analysis of the 51 articles results in identifying several gaps and based on that, an application framework is proposed. Figure 4 reflects the strategies to apply at different stages of a MiC project. BIM being the central connecting point with all the techniques is significant in automating the process of designing the modules in the initial stages of design and planning, which is proved to be an efficient strategy to automate the process before the shop drawings of modules are used by the manufacturers (Alwisy *et al.*, 2019). Also, BIM integrated immersive technologies (ImT's) (Khan *et al.*, 2021) can have crucial aid to understanding design problems initially, thus smoothly easing the project. Other than that, RFID techniques enabled by BIM can assist in the monitoring of the progress and allowing persuasive data exchange between different stakeholders in all the stages of the MiC project.

In addition to this, a BIM-based GIS system is also an efficient way to smooth the delivery process of the modules on site (Niu *et al.,* 2019). Future studies should focus on implementing and leveraging artificial intelligence (AI) and machine learning (ML) techniques coupled with the internet of things (IoT) for enhanced operations and management of different tasks in the MiC process. Overall, all these phenomena should be promoted in future studies as they are the integral components to drive the AEC sector into Industry 4.0 (IR-4.0) spectrum.

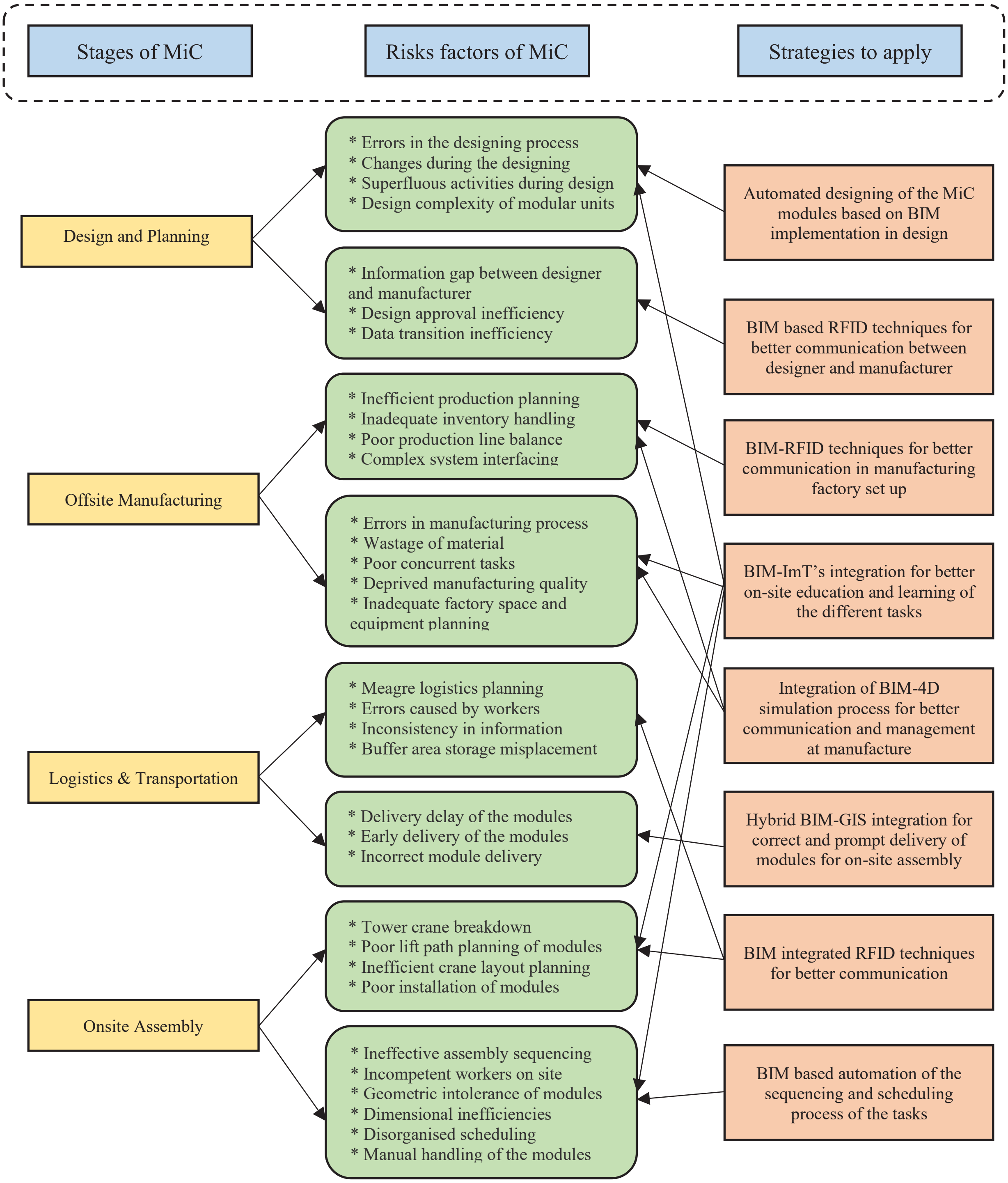

Figure 4 – Application framework for risk mitigation in MiC projects

5. Conclusion

This study utilized the PRISMA approach and critical content analysis to review the literature on the risks of MiC practices, based on articles from 2006 to the present year (2021). Previous studies discussed various risks of MiC projects as discussed earlier, but a holistic review in terms of stage-based risks was missing. A total of 51 articles were studied, and based on content analysis the risks were categorized based on different project stages, namely design and planning, offsite manufacturing, logistics and transportation, and onsite assembly.

The findings reveal that manifold types of risks exist in MiC practices, which impede their widespread adoption among multiple stakeholders. The study also underlined various factors accountable for respective stage risks. This study proposes an application framework highlighting the strategies to overcome those risks. BIM and its associated technologies are suggested to relegate factors responsible for each stage. Integration of BIM with RFID, GIS, and ImT's are recommended to implement towards leapfrogging the drawbacks in MiC practices especially considering MiC to be in a fledgling phase in many countries. In addition to this, the likes of AI and ML techniques coupled with IoT are also recommended for boosting operations and management of different tasks in the MiC process. The limitation of this study lies in the sample size of the studies, however, a broad landscape of risks associated with MiC has been addressed with the number of papers critically analyzed.

Therefore, this study is a valuable contribution towards understanding the MiC risks and application strategies to counter them. It contributes to the knowledge domain in the MiC sector which is beneficial for researchers, practitioners, and professionals. Future studies can focus on implementing the proposed strategies, to pave the way towards enhancing MiC practices.

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How Sustainable is NZ Construction Industry for Migrant Workers?

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Abstract
While the construction sector in New Zealand grows exponentially, the dependence on migrant workers to achieve the infrastructural requirement in the industry increasesThat said the sustenance of these migrant workers in construction-related careers and opportunities is not guaranteed. This study explored the factors governing a migrant's choice of working in the New Zealand construction industry. It investigated the reasons for migrating to New Zealand and factors that negatively influence the future of migrant workers in the construction industry. Fifty (50) migrant workers participated in a questionnaire survey to assess their perception of working in the construction industry. Family and environmental factors were perceived as the most influential factors that encouraged the migration of workers to New Zealand. In contrast, high income and ease of migration influenced their interest in the construction industry. Also, it was found that the most significant factors that could affect the sustenance of migrant workers in the industry were lower-income for workers, higher availability of skilled workers and changes in the immigration policy as the factors that can affect the rates of migration. The outcomes of this study offer a significant contribution to the existing pool of knowledge on the subject and are important for policymakers towards increasing the retention of migrant workers in the construction industry
Keywords

New Zealand Construction Industry, Migrant workers

1 Introduction

The construction industry's contribution to New Zealand's economy is significant, not just for the economic boost it provides but due to its emergence as the backbone of infrastructural development in the country. According to a report by the Construction Strategy Group (2016), New Zealand's construction sector is one of the largest sectors in terms of employment, contributing 8% to the country's GDP. With the rapidly increasing population and increasing demands for housing, the construction sector in New Zealand is growing at a rapid rate. According to a report of the Ministry of Business, Innovation & Employment (2017), New Zealand will witness an increase in investment in Construction as high as $42 billion in 2020, thereby raising the demand for jobs related to Construction for the coming years till 2022. Furthermore, it has been estimated that the demand for workers related to Construction shall increase by an 11%, thereby requiring an additional 56,000 to 571,300 workers.

The additional demand for construction workers remains unmet due to the lack of a skilled workforce such as builders, plumbers and carpenters. As per a report published by the Ministry of Business, Innovation, and Enterprise, there has been an escalation in the shortage of workers, including builders, tradespeople, and other built environment professionals. The current estimated shortage of construction workers is as high as 17,000 (Under Construction, 2017). This shortage is even more peculiar when it comes to high-value roles in Construction. As a response, international migrant workers from other countries like Australia, China and the United Kingdom are employed to conventionally meet the lack of skilled workforce in the construction sector. However, sustenance of this category of workers to continuously migrate beyond national boundaries into New Zealand needs to be guaranteed to meet present and future construction needs in the country.

As defined by the International Organisation for Migration (IOM), a migrant is a person who moves into a country other than that of his or her nationality or usual residence so that the country of destination effectively becomes his or her new country of usual residence (IOM, 2019). The suitability of a place for being selected by migrants is both a complex and diverse phenomenon. This is because of the influence of many varied factors. These factors influence the aspiration and desire to migrate. Classical theories suggest that people tend to migrate for various reasons. There is evidence that the ease of immigration and presence of acquaintances in a country drive their focus to a country of interest (De Hass, 2010; Fujita, 2007; Arango, 2018). This suggests that identifying factors that shape a nation's image among potential migrants is crucial to attracting a large number of skilled workforces from one nation to another, thereby leading to the transfer of knowledge and skills beyond geographic boundaries. The influence of these factors on migrants' decision to work in the NZ construction industry serves as a pointer for the New Zealand government to sustain the supply of the much-needed skilled international workforce.

Although previous studies have explored the phenomenon of international migration from a theoretical perspective, this study brings forth empirical evidence that contributes to bridging the gap between demand and supply of skilled workforce in the construction sector of New Zealand. This study is important for enhancing the existing knowledge on the subject and provides practical solutions to the shortage of skilled workforce.

2 Literature Review

2.1 New Zealand's construction sector and the future of construction-related career

The construction sector in New Zealand plays a key role in the country's economic development and fulfils the infrastructural needs. As a significant contributor to the nation's GDP, it is also regarded as the sector with one of the highest employment opportunities, which are why the presence of international migrants is inevitable in the construction sector of New Zealand. According to Stuff, NZ (2018), about 256,000 persons have been currently employed in the construction industry. About 55,000 to 60,000 additional workers would be expected in the country in the next five years (Stuff, NZ, 2018). These figures are significant as approximately 70% of the skilled workforce shortages are witnessed in the construction sector only. This suggests that the use of international migrants would carry a promising potential to meet and bridge the gap between the recent shortage in demand and the supply of skilled construction workers. This is validated because the government and construction companies have been looking forward to meeting the escalating shortage by harnessing the potential of international migration. According to New Zealand Now (2019), the construction industry is experiencing a boost due to two primary reasons: the increasing population in Auckland and recovering from the consequences of earthquakes in Christchurch, Kaikoura, and the Canterbury region. This growth in Construction has increased the demand for construction works and has created new roles for the skilled workforce such as quantity surveyors, designers, forepersons, project and site managers (New Zealand Now, 2019).

In 2015, more than 244 million international migrants were estimated to live in a foreign country (International Organisation for Migration, 2018). In 2017, the UN Department of Economics and Social Affairs (2017) estimated that the figure was as high as 257.7 million. According to Castelli (2018), migration is a complex phenomenon, where various factors act together to inform the final individual decision to migrate. The existence of vast theories concerning the interests of migrants suggests that it is not possible to consider the phenomenon of international migration with the help of a single theory. This complex nature of international migration is owing to the diverse range of factors, namely differences in wages, search for favourable employment opportunities, family considerations, structural needs of the receiving economy, ease of migration and presence of favourable immigration policies, the existence of interpersonal network and acquaintances at the destination, and much more.

2.2 Factors influencing migrants' interest

Existing literature and theories on international migration reveal a diverse range of discourses on the factors that drive the interest of migrants. Broadly, these factors drive the interests of international migrants in terms of socio-economic development in both nations regardless of the type and nature of work they engage in. These factors can be classified into five (5) major groups, namely:

- Family Factor
- Economic Factor
- Environmental Factor
- Developmental factor
- Other factors

2.2.1 Family factors

Family factors pertain to the reasons associated with the migrant's close relatives that encourage their desire to migrate. The influence of the ethnic group, support from one's family – both economic and social – is of the utmost importance for the individual to make the final decision to migrate (Castelli, 2018). For instance, it is not far-fetched to assume that the educational and financial aspirations of one's family are a common reason for migration across borders to countries where a higher level of education and financial stability is guaranteed. According to Wickramasinghe & Wimalaratana (2016), migration should not be viewed in isolation of the role of the household in governing the interest of migrants to a particular country. Also, the Network theory by Arango (2018) suggests the availability of interpersonal networks in the host country also influences the interest of migrants. The concept of the network theory maintains that interpersonal networks linking migrants with familiar people who inform them and aid their employment chances offer them necessary help in the form of accommodation in a foreign land and necessary financial support.

Furthermore, Myrdal's Cumulative Causation theory introduced in 1956 (Fujita, 2007) explained the rise in the number of international migrants in a location with due course of time. According to this theory, the first person having migrated is the one providing inputs in the form of social capital to their acquaintances, thereby ultimately promoting the movement of familiar and close ones (Massey et al., 1993). This is because of the ease of finding employment and reduction in the risk observed in the host countries. The presence of family and friends may have contributed to the migration of international workers into New Zealand and their interest to work in the construction industry.

2.2.2 Economic Factor

According to the neo-classical theory, international migration is driven by the lack of balance between demand and availability of labour. This theory presents that if a country pays low wages to its workers, thereby leading to their productivity, they tend to migrate to a country that pays them relatively more (Massey et al., 1993). Furthermore, this theory indicated that mere elimination of differences between wages could inhibit the migration of people from one country to another. In addition to this, Harris and Todaro (1970) presented that most of the international migrants decide to move to another country due to their search for job and career opportunities, while income being a secondary factor influencing their interest

On the other hand, as proposed by Michael Piore, the dual market theory rejected the earlier theories that international migration is the cause of permanent demand existing in industrialised nations (Piore, 1979). The author classified the demands into two categories, namely push and pull factors. While push factors consist of wages and unemployment considerations, pull factors involve the expectations to be fulfilled by migrants in the receiving nations. According to this classification of factors, migration is predominantly controlled by pull factors of the industrialised nations that happen to attract workers from other nations to meet their needs. In contrast to the previous theories, Piore (1979) emphasised that the movement of workers beyond home nations is governed by the needs of the receiving economy rather than wage differences or household considerations for a better environment.

Furthermore, the Migration System theory explained international migration in a broader manner. According to this theory, migration and development go hand in hand, resulting in changes in both home and host nations (De Hass, 2010). This change can be of economic, social or cultural origin and leads to socio-economic development. In other words, while migrants benefit from the socio-economic standing in the host country, their contribution adds to the socio-economic development in the host country. Regarding the NZ construction industry, the influx of international migrants could potentially contribute to meeting the infrastructure needs in the country.

2.2.3 Environmental Factors

The environment can impact migrant flows by directly affecting the hazardousness of a place and indirectly by changing the economic, political, social and demographic context with very complex relationships (Black et al., 2011). These environmental influences have been categorised into fast and slow pathways (Gray, 2009; Laczko & Aghazarm, 2009). Fast pathways are rapid environmental changes such as weather shocks and natural disasters that can be viewed as covariate risk (Gray & Bilsborrow, 2014). Soft pathways of environmental influence are subtle issues such as land quality and long-term climate norms that affect the productivity of natural resource-based livelihood activities (Gray & Bilsborrow, 2014).

New Zealand as a country is ranked the 1st in air quality and 5th greenest in Asia-Pacific (ValueChampion, 2019). According to the study carried out in 2018, the country leads the way with 24.6% renewable energy production with its capital -Wellington, having the lowest average PM 2.5 concentration (6 $\mu g/m^3$) of any capital. Hence, it is a potentially preferred country for migrations affected by poor environmental conditions in their home countries.

2.2.4 Developmental Factors

While it has been shown that the developmental growth of host countries has been linked to migration rates (Kapur, 2003; Ratha, 2003), the same can be attributed to the home country. For instance, governments of migrant-sending countries have put renewed hopes on transnationally oriented migrants and 'Diasporas' as potential investors and actors of development (De Haas & Plug 2006; Gamlen 2006). The effect of this influence on migrants is evident in their reasons for migration. They will likely choose countries that offer development enhances which can be replicated or adapted to their home countries. Most migrants tend to return home after years of living abroad and implement some policies that improve livelihood in their local areas. Immigrants also provide an economic contribution to their host countries in the form of labour markets, economic growth and public finance. According to OECD (2018), immigrants help to increase public revenue and have higher labour force participation and employment rates than native-born workers, irrespective of the low quality of jobs they do.

Also, the importance of policy framework in the host country has been mentioned as a factor governing the movement beyond national boundaries. The institutional theory (North, 1990) explained that there is a lack of coordination between these industrialised countries – host countries - and people seeking employment and immigrant visas; the gap is bridged by the existence of institutions addressing the concerns of migrants. For example, migrant workers often face discrimination, exploitation, deception. They sometimes abuse in their host countries due to the lack of the vulnerable position of migrants in the labour market and the lack of enforcement of labour standards in countries of destination (UN, nd). This suggests that the presence of a policy framework favourable to migrants influences their interests and the ease of crossing boundaries, the flexibility of immigration laws, and the country's social context.

2.2.5 Other Factors

There are other several reasons why people migrate. Reasons such as wars and dictatorship in home countries like the cases of Syria and Afghanistan, where people have been denied basic human rights and access to education and to a dignified life (Castelli, 2018), are evident in recent years. Other reasons are subtle such as poor infrastructure, religion, sexual identity and health challenges. De Haas (2005) noted that besides rising incomes and improved transportation and communication infrastructure, factors like education and access to information and social capital initially tend to increase people's aspirations and abilities to migrate.

The construction industry's future is highly (as it currently stands) dependent on the potential of international migrants in the construction sector. Sustenance of international migrants' interest in working in this sector is key to meeting the housing expectation of the sector. But then, despite the inflow of these workers into the country, their potential to remain and advance their careers in Construction is uncertain as there is little evidence of their interests in New Zealand's construction sector. This is further aggravated because some international migrants face challenges that may deter them from lasting longer in the sector and may pull out if a downward pull is experienced. The examples are evident in the New Zealand news outlets. For example, Stuff, NZ (2021) reported that some construction migrant workers are lured to the country by promising lucrative jobs; instead, their wages are stolen and their rights are trampled. Employment New Zealand (2021) noted that a construction company was found to deduct their workers' wages without their knowledge. One News Now (2019), four construction companies were found to be deviating from the regulatory framework of providing minimum standards and rights to migrants. It was reported that discrimination in providing a similar and safe environment, differential pay, and other holiday rights were deliberately inflicted upon migrants, making them subject to exploitation. This can have a negative impact on the rates of international migration. Hence, there is a need to assess the interests of international migrants specific to the construction sector in New Zealand.

3 Research Methodology

This study aims to investigate the perception of construction migrant workers on factors that influenced their interest to work in the construction industry. It is expected that the findings of this study will lead to a main study that investigates the livelihood of international construction workers and their potential of relocation or permanent stay in New Zealand deeply. To achieve this aim, we hypothesise that:

"the interest of international migrant workers in the NZ construction industry is influenced largely by the current construction boom. Their interest will likely change if a downward trend in Construction is experienced in the industry".

We tested this hypothesis using a questionnaire survey on construction international migrant workers. This questionnaire was made up of close-ended questions to ensure consistency of results and open-ended questions, providing the opportunity for deeper investigation of responses (Rasheed et al., 2019). The questionnaire was designed to address the objectives of this study. A convenience sampling method was employed, and Fifty (50) migrant participants currently working in the construction industry were randomly selected from Auckland city to participate in this survey. To ensure that information retrieved from the participants is representative of the larger population, we ensured that the migrant workers had worked in the country for at least three months. Auckland city is the most populous city in New Zealand and an attractive hub for international migrants. This city is regarded as suitable for this study (Rasheed et al., 2017).

Among the 50 respondents that participated in this survey, 35 (70%) were male, while 15 (30%) were female. Twenty-eight (28) were between 18 and 25 years old (56%), while 22 were above 25 years old (44%). Regarding ethnicity, 29 of the migrant workers were from China (58%), 9 were Malaysians (18%), ten were from "other" ethnic groups, namely South Africa and Korea (20%). The remaining two respondents were Fijian and Indian (2% each). Twenty-eight (28) of the migrant workers were single (56%), 21 were married (42%), and one was divorced (2%).

Regarding the occupation of the migrant workers (figure 1), most of the respondents were carpenters and quantity surveyors (10 each). Nine (9) respondents were in "other trades" such as handyperson, plumbing etc., and 8 were labourers. Project managers and painters were four each, while tilers were three amongst the respondents. The least number of respondents was for foremen (2). Regarding the respondents' years of experience in the New Zealand construction industry, most respondents (78%) had worked for two or fewer years, while 20% had worked for three or more years in the industry.

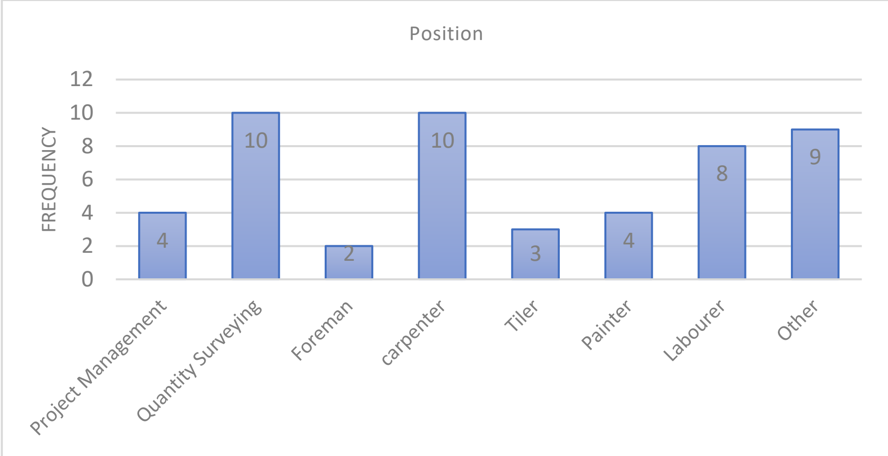

Figure 1: The positions occupied by respondents in the construction sector of New Zealand

The participants' responses were analysed using simple frequency analysis, based on their perception and opinions on the study question asked. The findings are presented and discussed in relation to their gender, age, ethnicity, marital status and occupation. This is to provide sufficient results that delve into the objectives of the study carried out.

4 Findings and Discussion

Two questions were asked. The first question asked the participants to select the factor that influenced their decision to migrate to New Zealand. Based on the literature review carried out, various factors that influence immigration were grouped into the five major factors.

The findings show that most of the respondents identified family (40%) and environmental factors (39%) as reasons they chose to migrate to New Zealand. These were followed by developmental factors (11%) and economic factors (5%). Specifically, the respondents who were female, over 25 years old and married identified family factors most as the influencing factor for migration to New Zealand. The respondents who were male, 18 – 25 years old and single regarded environmental factors most as the reason they migrated to New Zealand. There was not a significant difference in opinion amongst the different ethnicities. For occupation, the project managers, tilers and painters regarded family factors most while carpenters and labourers regarded environmental factors most. There was no difference in opinion between environmental and family factors for the various ethnicities, quantity surveyors, foremen and "other trades" as they regarded environmental factors as the major factor influencing their migration to New Zealand.

Table 2: The respondents' perception of factors influencing their migration to New Zealand

Factors Influencing migration		Family	Economic	Environmental	Developmental	Others
Total		33(40%)	4(5%)	32(39%)	11(13%)	2(3%)
Gender	**Male**	23	2	24	6	2
	Female	10	2	8	5	0
Age	**18-25**	13	1	15	6	2
	Above 25	20	3	16	5	0
Marital Status	**Single**	15	2	16	6	1
	Married	17	2	15	5	1
	Divorced	1	0	1	0	0
Ethnicity	**Chinese**	14	2	14	9	2
	Malaysian	8	0	8	0	0
	Indian	1	0	1	0	0
	Fijian	1	1	1	0	0
	Other	9	1	8	2	0
Occupation	**PM**	3	0	1	2	0
	QS	4	1	4	3	0
	Foreman	1	0	1	0	1
	Carpenter	6	0	8	2	0
	Tiler	3	0	2	0	0
	Painter	4	2	3	0	0
	Labourer	5	0	6	3	1
	Other	7	1	7	1	0

Comments related to this question supported the findings as most of the participants noted that family connections were a major reason for migrating to New Zealand. Some of the participants mentioned that the presence of an acquittance or family influenced their interest in the country. The participants also acknowledged that New Zeeland offers a better environment than their home countries and that the availability of employment and education opportunities for children was a reason for migration.

The second question asked the respondents to state why they chose to work in the New Zealand construction industry. Their responses were grouped into high income, ease of migration, interest in Construction and others. The results showed that high income was the major reason migrants chose to work in the construction industry (45%), followed by ease of migration (33%). Some of the respondents identified their interest in Construction as an occupation (11%) as a reason for working in the industry. Specifically, all categories of respondents identified the high income for Construction related jobs as a reason to work in the industry except for some. The married respondents and foreman regarded ease of migration as the major reason. The project manager, labourer, foreman, Indian and Fijian had no preference over high income and ease of migration. Both were equally identified as factors influencing their choice to work in the construction industry.

Table 2: The respondents' perception of factoring influencing their choice to work NZ construction industry

Factors influencing the choice to work in the construction industry			High Income	Ease of Migration	Interest in Construction	Others
Total			32(45%)	24(33%)	14(19%)	2(3%)
Gender	**Male**		21	14	8	2
	Female		11	10	6	0
Age	**18-25**		16	9	9	2
	Above 25		16	14	5	0
Marital Status	**Single**		17	7	9	2
	Married		14	16	5	0
	Divorced		1	1	0	0
Ethnicity	**Chinese**		15	11	10	2
	Malaysian		7	5	3	0
	Indian		1	1	0	0
	Fijian		1	1	0	0
	Other		8	6	1	0
Occupation	**PM**		1	1	0	1
	QS		5	2	5	0
	Foreman		0	1	0	1
	Carpenter		5	4	3	0
	Tiler		2	1	0	0
	Painter		4	3	0	0
	Labourer		6	6	3	0
	Other		9	6	3	0

The participants commented that they get paid higher than expected in the construction sector. Better still, working in the construction industry offers them the opportunity to gain residency owing to their work experience as construction migrants in New Zealand.

5 Conclusion

This study aimed to investigate the factors influencing the interest of international migrants in New Zealand's construction sector. It is acknowledged in the existing literature that despite being a significant contributor to the economy and employment, this additional demand for construction workers is still unmet due to the lack of a skilled workforce such as builders, tradespeople, etc. Drawing on the existing literature and responses obtained from construction migrants, this research found that New Zealand enjoys a central place as the destination country among the construction workers and the international students seeking to acquire education and find employment.

This research has implications for the New Zealand government to keep strengthening itself on the identified factors and adopting measures to prevent the backward development of the construction sector. This will facilitate the rates of migration and help resolve the shortage of skilled workforce in the country. Hence, the findings of this research present several implications for the governmental departments to bridge the gap between demand and supply by fostering international migration.

We recommend that the government enhance the rates of international migration to eliminate the shortage of skilled workforce in the construction industry. Firstly, the government needs to assist the interests of international migrants by making them aware of construction opportunities. These opportunities requiring identified skills should be advertised adequately to eliminate any chance of lack of communication of opportunities. Secondly, the government needs to ensure that the international migrants are protected against discrimination in providing a similar and safe environment, differential pay, and other holiday rights. Thirdly, the government needs to adopt stringent measures to ensure that the negative factors affecting the movement of skilled migrants do not develop in the construction sector. As identified in this study, the significant factors negatively influencing the construction sector are lower income for workers, higher availability of skilled workers, changes in the immigration policy, economic recession and surplus supply of workers/labour. Through careful monitoring and thoughtful policy measures, the development of these negative factors can be minimised. Therefore, this report recommends the government undertake extensive measures to resolve the issue of shortage and support the interests of international migrants.

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Hybrid Learning of Theoretical and Practical Structural Mechanics in a Workshop

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Abstract
In the building design and construction industry, there is a serious shortcoming in that the educational phase of building practitioners has been spent almost exclusively inside a classroom environment. There is an enormous and recognisable benefit in exposing students to the work site to observe and participate in what happens at the coal face of construction activity. However, the rules of occupational health and safety weigh heavily on the academic instructor and workplace supervisor, impeding the frequency of such site visits. This results in education being highly theoretical and largely disconnected from the construction 'real world'. As a result of this demarcation, employers have had to increasingly teach fresh graduates how to navigate the work space. There is a need to rethink built environment education, by a radical change of implementing the converse: getting students to work within the safety and supervision of a teaching space. There were successful attempts at an introductory unit to structural mechanics with a learning-by-making approach, with both lecture-mode theoretical and hands-on practical deliveries. The mixed modalities offer a premise to rethink the hybridisation of the future learning environment, taking advantage of the position of dual sector universities to offer vocational education (VE) and higher education (HE) simultaneously. This hybrid approach takes a decisive break from conventional pedagogy to introduce work ethics and skills that cannot be developed inside a classroom setting. This approach not only enhances learning, but expands the skills of graduates which make them more work-ready, and thus more employable, by requiring workplace-like attitudes in their learning.

Keywords
learning-by-making, workshop-based learning, theory & practice, built environment

1 Background

"In theory, there is no difference between theory and practice, but in practice there is a great deal of difference." (Ariely, 2009)

When I was at the University of Tasmania (UTAS) I had the privilege of working with, and subsequently taking over, the units developed by an extraordinary lecturer, Justin Beall (Figure 1). He was an architect and scientist, the innovator who developed two units from scratch that fused theory with practice at the (then) UTAS School of Architecture: BTD1 Introduction to Structural Mechanics and BTD2 Bioclimatic Design.

Figure 1. Justin Beall (left), the innovator behind integration of learning-by-making into the building technology curriculum. Loading to destruction of student made beams and trusses was accomplished by a custom-built pneumatic ram equipped with load cells and deflection sensors.

This paper is an acknowledgment of Beall's contribution to learning-by-making, and how I was able to successfully replicate its principles to another unit. The paper further envisions how the pedagogical method of workshop-learning can be especially applicable to dual-sector universities which have the untapped opportunity of synthesising the lecture theatre with the trades floor.

2 Learning by Making

The UTAS School of Architecture has had a long history of LBM (Learning By Making) initiatives (Wallis, 2005) ranging from bus stop construction, trailer-based micro housing (Burnham & Green, 2009), and installations for wildlife (Hornblow, 2017).

LBM achieves the same constructive alignment of knowledge and understanding (Biggs & Tang, 2007), but achieves this through a radically different modality of making. The same phases of quantitative learning (identify, undertake simple procedure, describe, combine, etc) and qualitative learning (analyse, relate, apply, hypothesise, reflect, etc) are still accomplished, but the primary theatre of activity moves from the classroom to the workshop.

The pedagogical method behind LBM derives from an ancient Chinese proverb, anglicised as "Tell me and I forget, teach me and I remember, involve me and I learn" (Richards & Rodgers, 2001). Although LBM builds on VARK modalities of visual, auditory, reading/writing and kinesthetics (Fleming & Mills, 1992) — in that it recognises and places particular emphasis on kinesthetic learning — LBM should be distinguished from mere kinesthetic learning for a few reasons. LBM had not been developed to suit a particular learner style as advocated by VARK, but instead recognises that it enhanced learning in all types of learners by the inclusion of a kinesthetic aspect. This kinesthetic learning is not just an incidental inclusion of physical activity around traditional modalities, such as making a student walk around the classroom to reduce monotony, or other physical exercises that have been suggested for improved learning of science (Mcglynn & Kozlowski, 2017). Instead, LBM places the student into the complete fabrication experience from design to production to understand the physical nature of building (verb) a building (noun). The workshop learning was focussed on elucidating threshold concepts: concepts that were foundational to the understanding of other concepts (Meyer & Land, 2006)

The School has been in the unique position of having a large-scale state-of-the-art workshop beside the traditional teaching and design studio areas, allowing students to move conveniently between modes of instruction. The BTD1 Introduction to Structural Mechanics classes began with a 1h lecture followed by 3h in the workshop broken into approximately three 1h parts: physical experiments, prototyping (Figure 2) testing (Figure 3) and documentation, analysis, reflections and externalisations (Figure 4).

Figure 2. Left: Experiments on load-deflection of various materials. Centre:: understanding arch depth and side thrust by working on the reverse principle of catenary structures. Right: Design and fabrication of a prototype for a challenge test.

Figure 3. Column challenge was to build the strongest possible column with limited amounts of cardboard and bamboo skewers. Left: Loading rig. Center: Prototype of a column before testing. Right: Prototype after testing.

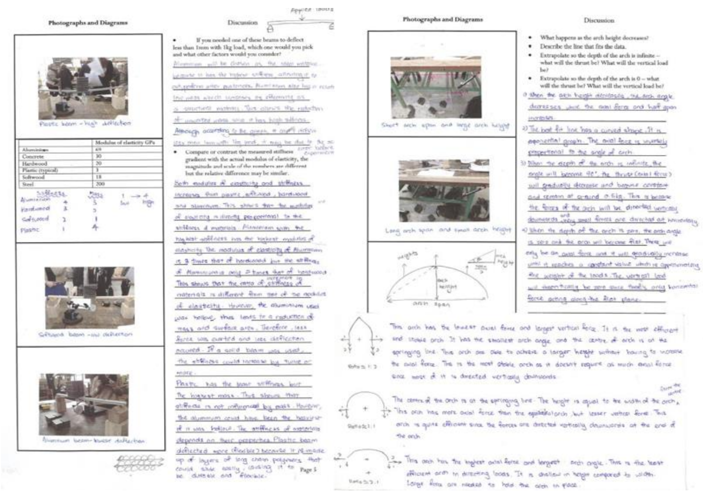

Figure 4. Sample pages of workshop practical book completed by student.

3 Workshop Progression

After a thorough safety induction, students were permitted to use the workshop and selected power tools. As the students became more competent and confident with manual handling, tool handling and safety processes, the class moved from working with modelling materials such as bamboo skewers and cardboard, to building realistic components such as trusses, beams and walls at real-world scales

Although students were expected to execute basic structural calculations they were also made aware of the limitation of simulation software. For instance, in the design of trusses, software-determined axial loads provided the opportunity to reinforce overloaded elements. Students nevertheless quickly learned that although a truss element appeared no different in the simulation software whether it was loaded in compression of tension, the reality was that the failure modes were very different. Compression elements were observed to fail by buckling at the mid-section of the element, whereas a tension-loaded element failed at the connections. Without the regular cycle of design and destructive testing, students would have found these important concepts hard to grasp, and even harder to remember.

Walls were first built at half-scale for the economy of materials and time. These were tested laterally to simulate a racking force. Even a task as simple as tightening the strap bracing confronted students with the balance needed to find the sweet spot of tension: too loose and the wall would be skewed off plumb before the strap was tightened sufficiently under load to offer resistance, too tight and the top and bottom plates could be damaged.

After each structural test, students were required to note the failure mechanism and theorise the sequence of failure by analysing the ruins for propagation of forces and identify weakness in construction, Figure 5.

Figure 5. Half-scale wall testing. Typical walls built to AS1684 specifications. Left: Before test. Centre: During test with racking force applied. Right: Details of ruptured junction.

In the process, students were not only able to quantify the distribution of forces by computer simulation (theory), but to appreciate that workmanship and material inconsistencies had a profound impact on the final outcome (real-world).

In the final session, the class would build a small shed in compliance with the residential timber framed construction standard AS1684.3 (Standards Australia, 2010). Within 12 weeks, students, some of whom started off having never handled a hammer, had progressed to a stage where they were able to undertake safe construction of a code-compliant timber frame building with a profound appreciation for the role of every element and fastener used in construction, Figures 6-7.

Figure 6. Shed construction. Initial stage construction where groups were each responsible for a separate component.

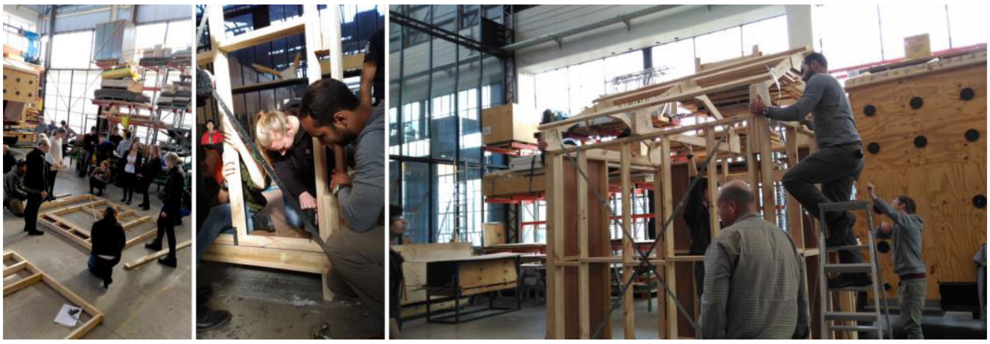

Figure 7. Shed construction. Assembly of components together where groups now have to negotiate theirs with other groups' components.

The sheds continued to be a workshop feature in BTD2 Bioclimatic Design, where the timber frames were insulated, wrapped, blower door tested, lined and clad. Completed sheds were forklifted into student selected sites around the campus for thermal experiments, Figure 8. At the end of the experiments, the sheds were sold to recover the cost of materials.

Figure 8. Shed experiments. Left: students indicate to workshop staff how the orientation is to be changed for a particular experiment on solar gain from different azimuths. Centre and right: thermal mass experiments of a milk carton trombe wall.

The workshop learning environment was immensely successful and received rave student feedback. The deep engagement of multi-modal student learning was accompanied by accelerated learning and maturity into their professional roles. It was a particular attraction for international students, where it needs to be explained to an Australian reader that in most of Asia, the average hardware shop is nothing like Bunnings, but is typically a family-run business with premises no bigger than 7-Eleven.

4 Extensibility of workshop learning to other units

The workshop activities offered a number of unique advantages and synergies.

1. The workshop was a safe and controlled environment for students to be initiated to real-world work site conditions they would invariably have to participate in subsequently.
2. Tactile and kinesthetic learners were able to make real-world connections that were harder to engage within a classroom. Concepts that were hard to grasp through a powerpoint presentation could be plainly understood with the right physical demonstrations.
3. In the workshop the knowledge that was first introduced in the instructional activity becomes synthesised through application of principles. The learning experience was more consolidated and memorable.
4. The real world was full of unpredictability and the workshop initiated students to this reality. Planning, sequencing, coordination, communication and resolution become imperative in such a work-based environment.
5. The workshop allowed learning outcomes to be demonstrated in a different form. Students who had limited drawing skills could prototype a construction element and photograph it as a way of demonstrating their investigations and understanding of key concepts.

Having observed first-hand the immense utility of the workshop in complementing studies in BTD1 and BTD2, I attempted to replicate the formula in another unit, BTD7 High Rise Structures and Services, with the following salient ingredients:

1. Start with theory and use the workshop to reinforce the theoretical concepts
2. Identify the threshold learning concepts that students struggle the most with, then design experiments for them to observe a real world application of those concepts
3. Include a themed challenge with a build-test regime in each workshop session
4. Test to destruction, and incorporate a forensic review of failure

On this basis a series of workshop sessions were designed around high-rise structural concepts culminating in a test for which each team was assigned a different high-rise form, Figures 9-10. Once again students were immensely engaged and expressed their understanding by articulating their structural considerations with much more precision than in previous classes without the workshops. Interestingly, the additional understanding did not involve additional effort on the students' part. A student summed it up, "We had so much fun we didn't feel like we were studying!"

Figure 9. Pasta tower. Vertical load experiments to determine optimum diagrid dimensions to resist buckling.

Figure 10. Pasta tower test. Towers made from pasta and built up to 1m height, to be tested laterally to simulate wind loading.

5 Observation & discussion

Competitiveness. Mutual competition between students turned out to be a great motivator, but caveats needed to be in place for avoiding an over-competitive environment. A focus on outcome encourages research and imitation into the best designs, whereas a focus on discovery encourages experimentation and learning by cycles of action research.

Kinesthetic learning. Kinesthetic learning has been known to improve student thinking and retention in practical courses such as nursing (Wagner, 2014) and found to assist students with overcoming difficulties in understanding scientific concepts (Ross & Tronson, 2012). In a world dominated by digital media, and the dominant form of interaction being that of frictionless touchscreens, the students have thrived on the uncommon opportunity for physical feedback and kinesthetic intelligence. Simple experiments like hot gluing sticks of fettuccine, then flexing it in different ways to observe how it bent and failed gave much richer feedback compared to digital modelling.

Play-based learning. Despite the seriousness with which safety has to be taken, there was an inherently play-based learning involved in this pedagogy of making and breaking structures. The concepts of play helped students navigate the fear of failing, risk avoidance, and extrinsic goal orientedness (Nørgård et al., 2017). The workshop environment was new to students, which made it a great leveller of educational and experiential backgrounds. With some guidance from tutors, the groups quickly saw that they needed cooperative group dynamics to accomplish the experiments and challenges each week. The successful groups were those which worked out a democratic way to maximise the complementary strength of all members. In the real world, with its manifold complexities, individuals appreciate the need for counter checking and listening to one another. Soft skills such as negotiation, vocalisation and collaboration, which were not part of the formal learning outcomes, became essential skills in this environment.

Project-based learning. In some groups, deliberation brought with it the problem of over-theorising without building anything. In this regard, the time limit for the prototype imposed a deadline with which they could organise their workflow, ensuring that adequate time was allocated for fabrication. As an example, very early in the workshop students realised the importance of workmanship: a poor design that was well crafted always outperformed a good design poorly crafted. One essential incidental learning was that design was an infinitely long process, and they had to commit to fabricating a design at some point. What was important was the ability to prioritise the most important factors by that commitment point. By giving the students the dual role of designer and builder, they had a much deeper appreciation of workflow, time dependencies and project management.

Having a fixed cycle of activities, it helped students to understand the expectations. Each session became its own mini-project that required collaborative design and construction. Effective teams learned that this involved setting out a brief, drawing to communicate, discussion with proper terminology and professionalism, building with a focus on timed deliverables, and fabrication with attention to details.

Challenges to the workshop environment. It was noticed that international students from Asia tended to be more reserved in speaking their mind in a group. Tutors made groups aware that with some individuals their opinions had to be solicited rather than for the group to assume that anyone who had a thought automatically spoke up. Conversely these more reserved students were encouraged to interject a conversation with their opinions and were assured it was accepted practice to hold and express a differing opinion.

6 Possibilities of replicating workshop learning in other institutions

For all its benefits, the question to a larger application of workshop learning is whether it could be implemented in other institutions which do not have the luxury of workshops annexed to the teaching spaces.

Whilst it is rare for an architectural program to have UTAS's workshop facilities, there are a number of TAFE organisations in Victoria which have training facilities for building trades. These facilities are not currently being used by the same Registered Training Organisations building practitioner courses for building surveying, construction management and building design. Instead, these courses are delivered in classroom settings with no activity on the trades floor.

Furthermore, there is added impetus to renew the VE (vocational eduction) curriculum by fusing HE (higher education) cognitive skills. This has been highlighted in an expert review of Australia's VE training system, where it was noted that:

> "Serious consideration needs to be given to applying a new overall brand to vocational education at the same time as upgrading the architecture of the VET system. As we have seen, there has been damage caused to VET's reputation in recent years. Consideration needs to be given to re-branding the system to signify the changes that are occurring and encourage learners, their families and school teachers to re-rate

vocational education away from being a second choice to university study." (Department of the Prime Minister and Cabinet, 2019)

Figure 11. Victoria University Polytechnic Sunshine campus. The trades floor of the building trades with partially completed timber framed structure built on half-height walls for safety of the students.

Victoria University Polytechnic offers both building practitioner and trades courses. Figure 11 is a photograph of the trades floor taken from one of the classrooms in the Sunshine campus. The irony is that although the instructional and practical facilities were only separated by a glass window, the building practitioner courses have never been hybridised with the workshop learning environment.

The main impediment to a workshop-based delivery is the commitment needed to develop an effective curriculum together with the testing facilities that need to be customised for workshop demonstrations. On top of the opportunity to hybridise theoretical and practical course delivery, for dual sector universities there is the added possibility of hybridising VE with HE. This is especially worth considering since VE courses are already given substantial advanced standing as a pathway to a compatible degree course. The former VC of Victoria University mooted, "We ought to be able to have students studying vocational and higher education subjects at the same time" (Dodd, 2020).

There are significant rewards of student engagement in an authentic working environment as presented in this paper that is corroborated by research in Australia and Hong Kong (Devlin & Samarawickrema, 2010). However, student satisfaction alone will not be able to justify such a major investment in curriculum renewal. Instead, economical viability is most likely to be achieved by designing a unit capable of replacing multiple units from multiple courses where there will be common activities applicable to all cohorts, and course-specific requirements in the workshop book to separately meet the elements of competencies in each course, as mapped in Table 1 for units at Victoria University and Victoria University Polytechnic. Common aspects of teaching are delivered through lectures and workshop sessions, whereas the aspects that are course-specific can be managed by tutors looking through differentiated lines of questioning in the workshop book, where there will be a separate version for each course.

Table 1. Map of possible structural units in Victoria University's VE and HE courses that can be covered in a redesigned building structures hybrid double unit.

Level	Course	'Common unit'	'Course-specific unit'
VE	CPC60121 Advanced Diploma of Building Surveying	CPCCBC4010 Apply structural principles to residential and commercial constructions	CPCCBS6112 Conduct and report on initial construction inspections of Class 1 and 10 buildings to three storeys
VE	CPC50210 Diploma of Building and Construction (Building)	CPCCBC4010B Apply structural principles to residential low rise constructions	CPCCBC5004A Supervise and apply quality standards to the selection of building and construction materials
VE	22268VIC Advanced Diploma of Building Design (Architectural)	VU21588 Apply structural and construction technology to the design of residential buildings	VU21598 Select construction materials for building projects
HE	NBBS Bachelor of Building Surveying NHCM Bachelor of Construction Management (Honours) NBDS Bachelor of Building Design	NBC1103 Basic Structural Mechanics NBC1104 Structural Principles in Construction	
HE	NGBS Graduate Diploma in Building Surveying	NBS6003 Building Engineering	

7 Conclusion

Workshop-based learning builds on a heritage of learning-by-making pedagogy that accelerates learning around difficult to grasp structural concepts. Salient ingredients of workshop learning for the introduction to structural mechanics unit could be replicated successfully if the following salient ingredients were maintained: instructional alignment, elucidation of threshold learning concepts, themed challenges and testing. In line with the challenges facing tertiary education, especially in the VE sector, the hybridisation of workshop and classroom learning can offer great utility, especially if it can be further hybridised to a unit that can involve participation from both VE and HE students from the built environment.

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The Influence of COVID-19 on Health and Safety Management in ConstructionIndustry in New Zealand

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Abstract

The proposed research aims to examine behaviour change among practitioners in the NZ construction industry in response to the COVID-19 pandemic within the context of health and safety management. The research investigates the Knowledge, Attitude and Practice towards COVID-19 among practitioners in NZ construction industry, which are the necessary steps for behaviour change. It is conducted through an online survey in June 2021. The results showed (a) most respondents (76%) have correct knowledge about the disease though a significant 86% of respondents incorrectly answer the question on of human vulnerability to Covid-19, (b) practitioners are generally optimistic that COVID-19 will be defeated and that control measures put in place are satisfactory, and (c) practitioners generally practise the COVID-19 construction protocols developed by industry leaders except for wearing masks and PPE. In this regard the early success achieved in NZ in eliminating community cases may ironically have resulted in complacency among practitioners. The findings have implication for WorkSafe the NZ Regulator for health and safety in workplace and CHASNZ the NZ construction industry leader that developed the COVID-19 guidance, on the need to enhance strategies to combat the disease in the industry since COVID-19 is still rampant in many countries.

Keywords: COVID-19, Construction Industry, Health, Safety, control measures

1 Introduction

The construction sector is often seen as an industry with dirty and dangerous workplaces marred with high illness and accidents rates. In New Zealand exposures to health risks at workplaces cause up to 900 deaths and 6000 hospitalisation cases every year (Butchard, 2019). Of these, about 25% of the deaths and 30% of the hospitalization cases are due to respiratory diseases. In 2010 the construction sector registered 185 deaths and 731 hospitalization cases due to respiratory diseases caused by exposure to asbestos, dusts and other airborne particles (WorkSafe and ACC, 2014). The current COVID-19 pandemic which also infects the human respiratory systems has caused enormous challenge to the health and safety management system of the construction industry worldwide. Many countries have instituted health and safety guidance at workplaces to control the spread of the disease. In New Zealand, WorkSafe the Regulator for health and safety at workplace has broadened her responsibility to make sure businesses manage the risks of infection of workers (Wood, 2020). Within the construction industry, the Construction Health and Safety NZ (CHASNZ) a trustee of industry practitioners has developed comprehensive COVID-19 construction protocols as guidance (CHASNZ, 2021). Following these protocols practitioners are expected to further develop rules to suit their practices. This paper reports on research to investigate how COVID-19 has influenced the health and safety management in the NZ construction industry (NZCI), particularly the likely behaviour change of industry practitioners under the guidance of the CHASNZ protocols.

The research made use of the knowledge, attitudes, and practices (KAP) theory to gauge whether and how practitioners have changed their behaviours under the guidance. According to KAP theory the process of human behaviour change can be divided three steps: knowledge acquisition, attitudes generation, and formation of practice from which human behaviours are effectively changed. It has been widely reported that the use of KAP method for control of infectious disease among local population who participated in the care and maintenance of their health actively has produced remarkable results in disease prevention, control, and rehabilitation (Wang *et al.*, 2020). Therefore, it is believed that if practitioners in the NZCI have closely followed the COVID-19 protocols there would be observable changes in their health and safety behaviour. However, thus far there has not been research on the knowledge, attitudes and practices towards COVID-19 among practitioners in NZCI, which are the necessary steps for behaviour change. A recent study by (Zheng, Chen and Ma, 2021) revealed that "*most respondents had the correct knowledge about COVID-19, practitioners generally showed an optimistic attitude about winning the battle against the COVID-19 pandemic and were satisfied with control measures in place, and practitioners tended to practise preventive measures instituted*." A similar study for NZCI will be the first steps to understand the current state of its practitioners in preparedness and results of implementing the CHASNZ protocols. This is important as the practitioners in the industry could be at considerable risk of infection from COVID-19 due to the nature of work. Using an agent-based modelling (ABM) method in simulating the spread of the disease at construction site it can be shown that without control measures up to 90% of the work force can be infected (Araya, 2021; Zheng, Chen, & Ma, 2020).

2 Literature Review

2.1 The COVID-19 Pandemic and its Economic Impact

COVID-19 is an infectious disease caused by the coronavirus SARS-CoV-2. It is usually spread among the population through droplets or aerosols which are formed when an infected person coughs, sneezes, or talks. The probability of infection is higher in crowded or indoor places. It was declared a pandemic by The World Health Organisation (WHO) on 11/3/2020 (World Health Organization, 2020). On 21/3/2020 New Zealand implemented the 4-tiered COVID-19 Alert Level System to control the spread of the disease after she reported her first case on 28/2/2020. For more than a year the pandemic has ravaged worldwide. By end of June 2021 total global reported cases has exceeded 180 million with more than 3.9 million deaths. Almost all countries have put in place national response to control the pandemic. Before achieving herd immunity through mass vaccination all nations focussed on control of the spread through varying degrees of restricted socioeconomic activities. While most countries have used mitigation and suppression methods to control the spread New Zealand adopted the strategy that imposes total social economic lockdown (except essential services) aiming to eliminate transmission from person to person (Wilson, 2020). The pandemic has caused enormous hardship to the world population and most countries have experienced economic contractions in 2020. New Zealand's real GDP contracted 1.7% in 2020 (New Zealand Treasury, 2021). Reserve Bank of NZ has estimated that output in the construction sector would reduce by 81% and 15% from normal level under Alert Levels 4 and 3 respectively. Many countries reported projects suspension, delays and cost overruns in their construction industries with consequential job losses and contracts disputes (Gamil and Alhagar, 2020). In NZ the construction sector can continue operation provided enhanced health and safety protocols are observed.

2.2 COVID-19 Control Measures in Construction Industry

Since the onset of the pandemic construction industries in many countries has recognised that the best way to effectively manage the risk posed by COVID-19 is to include the associated control measures in their existing health and safety management systems. With this approach the effectiveness of COVID- 19 mitigation measures would be readily amplified (Stiles, Golightly and Ryan, 2021). The WHO took the lead to issue basic guidance for construction workers to mitigate infections, which includes wearing masks, use of alcohol-based sanitizer for hand hygiene, regular disinfection of workplaces and practising social distancing. Many countries also developed COVID-19 health and safety guidance for the construction industry at national level. For example the Construction Leadership Council in UK published a Site Operating Procedure to be added to their existing health and safety management process (Ogunnusi *et al.*, 2020). A study by Shibani, Hassan and Shak (2020) reported that many construction companies have adopted additional simple protocols such as health screening (e.g. temperature measurement), restricted site access by personnel or public, additional COVID-19 signages and cleaning or disinfection of shared equipment. Some companies provided additional facilities at sites such as setting aside holding zones for incoming construction materials and isolation wards for suspected cases at work camps (Majumder and Biswas, 2021). There are also companies who practised extreme measures e.g. keeping workers camped at site and disallowing daily commute to and from homes (Biswas *et al.*, 2021). Changes in construction management or scheduling is common. For example in UK, some companies rescheduled work tasks and redeployed workers in smaller formation than usual (Jones, Chow, & Gibb, 2020). Trade men were arranged to work in sequence and not allowed to work side by side, with improved housekeeping in between. The use of technologies for virtual site visits or remote meetings have become more common. For example there have been increased reliance on video chat or meetings via internet together with 3D BIM visualization thus reducing the need for physical interactions (Jallow, Renukappa and Suresh, 2020). Some construction companies reported mixed experience with regards to the WHO Covid-19 guidance. For example some construction firms in Middle East countries reported that as the nature of their works necessitate workers to work closely they have difficulties in strictly adhering to the basic WHO guidelines (Umar, 2021). Yet an UK study considers the WHO guidelines inadequate and long term plans to protect the construction workplace are required (Suresh, Renukappa and Stride, 2020).

Overall, experiences among construction industries worldwide on the implementation of COVID-19 protocols are mixed (Simpeh and Amoah, 2021). To control spread of the disease on-site most construction companies have introduced prescribed measures with some having extra ones, but some companies have fallen short in implementing recommended protocols particularly in the areas of screening, site access and handling of material and equipment deliveries on-site.

2.3 Control of COVID-19 in New Zealand Construction Industry

Construction activities in New Zealand have in general continued under Covid-19 Alert Levels 1 to 3 (Baker, Kvalsvig and Verrall, 2020). Due to the need to observe additional health and safety protocols workers productivity have dropped and projects have experienced delays of about one month on average (Heslop, 2020). There were also supply chain problem as local and oversea manufacturers reduced production. As the sector comprising 67,000 companies with 170,000 employees is a major contributor (7.8%) to NZ's GDP (Granwal, 2020) it is important to keep it going safely. In this regards the Construction Health and Safety NZ has published comprehensive COVID-19 construction protocols for safe site operations for various Alert Levels (CHASNZ, 2021). The protocols include information on how to implement safe operation at site such as posters, checklists, forms for health declarations, correct procedures on contact tracing and usage of face masks, PPE and sanitizers, as well as registrations for site entry, exit and travelling, etc. Different types of sites e.g., residential, commercial and infrastructure constructions will have different categories of protocols.

So far studies conducted oversea revealed that in the construction industry management of the threat from COVID-19 has been dealt with within existing health and safety systems. However, clear understanding of the best ways in implementation is still lacking as stated by Stiles, Golightly and Ryans (2021), "*while the UK guidance is strong in risk management, understanding of how best to implement the guidance is not yet stable*.". In NZ the impact of applying CHASNZ protocols in the NZCI has remain unknown until this study. Therefore, a research is proposed to investigate how the implementing of these protocols has affected the health and safety management system in the NZCI.

3 Research Methodology

3.1 Survey Platform and data collection

The target population of the survey are the construction industry practitioners in New Zealand. The survey has been distributed through the New Zealand Institute of safety Management (NZISM) to its members to participate in the survey. NZISM is an association of professional health and safety practitioners in New Zealand from all business areas of construction industry. It is a nationwide body with 14 branches. Therefore, sending out survey through NZISM would ensure greater reach of industry practitioners.

The Microsoft Office 365 Forms is employed to collect data using an online structured survey through the internet. Considering the possible sources of data, a convenience sampling method as against probability sampling was adopted for practicality.

3.2 Survey Designs

The survey consist of closed end questions and they are mainly statements on the pandemic and related protective measures, for which prescribed answers are provided for respondents to choose from (Fellows and Liu, 2015). An introduction to the purpose and subject matter of the research is included. It is then followed by 4 sets of surveys:

i. Test on Knowledge of participants towards COVID-19 (respondents required to choose answers to statements provided: either yes[1], no[0], or don't know[0]).

ii. Test on Attitudes of participants towards COVID-19 (answers to be based on Likert scale 1 – 5, participants to rank confidence or satisfaction levels on statements provided ranging from strongly disagree to strongly agree)

iii. Test on Practices of participants towards COVID-19 protocols during works (answers to be based on Likert scale 1 – 5, participants to rank their experience levels on statements provided ranging from strongly disagree to strongly agree)

iv. Survey on socio-demographic data of participants (answers to include his/her gender, age, working experience, business of respondents and position role in company, practice or project location, type of project). These questions are important in understanding the response to the pandemic from a broad range of practitioners.

The first three sets are in the form of rigid statements and are presented to the survey participants to test their knowledge, attitude and practices towards COVID-19 on their understanding of the CHASNZ construction protocols, A few statements on general knowledge of the disease, causes and prevention, public impacts etc are included.

3.3 Data Analysis

The normality of the data collected will be assessed through statistical analysis in excel. In addition, t-test has been used to assess the Knowledge, Attitudes and Practice levels to see whether they differ statistically across different demographic characteristics of respondents. 30 valid questionnaires were collected from various construction industry sectors.

4 Findings and Discussion

4.1 Knowledge of Respondents Towards COVID-19

Table 1 shows the knowledge of respondents toward COVID-19. The average knowledge accuracy rate of seventeen questions was 76% (SD = 0.198). Correct answers were highlighted. Such results indicated average knowledge of industry practitioners toward COVID-19. In addition, two knowledge questions deserved attention, i.e., "Additional PPE needed to be worn at all times on site." and "At Alert Level 2, face to face duration cannot be more than 15 minutes" since 65% and 69% of the respondents reported wrong or unsure answers respectively for these two questions.

Table 1: Knowledge of respondents towards COVID-19

Knowledge of respondents towards COVID-19	Correct %	Incorrect %	Don't know %
Only some humans are vulnerable to Covid-19. (Ans: incorrect)	14%	76%	10%
Covid-19 transmits from person-to-person through droplets, contacts and aerosols etc. (Ans: correct)	96%	0%	4%
Symptoms of Covid-19 can include cough, fever, shortness of breath sore throat and temporary loss of smell. (Ans: correct)	86%	3%	10%
It takes 2 to 10 days for symptoms to appear. (Ans: correct)	73%	10%	17%

If I have cold, flu, or Covid-19 symptoms, I stay at home and call my doctor or health-line (Ans: correct)	93%	3%	3%
Some Covid-19 cases are asymptomatic but remain contagious. (Ans: correct)	90%	3%	7%
If I am tested covid-19 positive, I seek and follow advice from testing staff. (Ans: correct)	93%	7%	0%
An effective cure/medication for Covid-19 has been discovered. (Ans: incorrect)	31%	55%	14%
The use of masks or face coverings can reduce risk of infection. (Ans: correct)	100%	0%	0%
Vaccination can help to stamp out the pandemic. (Ans: correct)	75%	18%	7%
Using NZ COVID Tracer App helps contact tracing and stop virus spreading. (Ans: correct)	83%	14%	3%
At Alert Level 1 physical distancing is not required. (Ans: correct)	69%	28%	3%
At Alert Level 2, face to face duration cannot be more than 15 minutes. (Ans: correct)	31%	38%	31%
Under Alert Level 2 work can only be carried out with more than 1 metre physical distancing. (Ans: correct)	79%	11%	11%
All workers should follow the Personal Health Flow Chart to confirm that they are safe to be on site. (Ans: correct)	69%	7%	24%
Sign in registers is recorded by one person where possible. (Ans: correct)	82%	4%	14%
Additional PPE needed to be worn at all times on site. (Ans: incorrect)	55%	34%	10%

	Correct Answer	**Incorrect Answer**	
Average Accuracy rate	76%	14%	10%

4.2 Attitudes of respondents (practitioners) towards COVID-19

Table 2 depicts the respondents' attitudes toward COVID-19. Likert scale 1-5 was adopted in the test on Practices of participants towards COVID-19 protocols during works. The average score was 4.13 (SD = 0.32), respectively, indicating an overall positive attitude that the pandemic would be successfully addressed. It is also encouraging to see the majority of the surveyed industry practitioners can effectively continue their work during the COVID-19 outbreak, and out of all respondents had high-level satisfaction with the measures taken by the government and their companies in controlling the virus spread.

Table 2 : Attitudes of respondents (practitioners) towards COVID-19

Attitudes of respondents (practitioners) towards COVID-19	**Average**
I take recommended measures at work to prevent Covid-19 infection.	4.21
I trust my colleagues takes similar measures to prevent Covid-19 infection	3.90
I have no worry going to work under various alert levels.	3.52
Vaccines are safe and with mass vaccination human will win over the virus.	3.93
I am pleased with how my company has reinforced the need for contact tracing with the Government Tracer App.	4.17
I am pleased that my company follows the protocols recommended by CHASNZ.	4.42
I am pleased that my company is committed to working alongside Government to control Covid-19.	4.38
I am satisfied with the preparedness of my company to counter the spread of the pandemic such as providing additional PPE.	4.48
I believe my company has effectively communicated and engaged with our workers to safely carry out works under Covid-19.	4.52
I am pleased with the Government's regular updating and briefing on Covid-19.	4.10
I believe the measures taken by the Government to manage Covid-19 are effective.	3.83

4.3 Practices of respondents towards COVID-19

Table 3 depicts Practices of respondents towards COVID-19. The average score was 3.72 (SD = 0.74), respectively, indicating an overall satisfactory result in implementing the protocols on the ground. It is also encouraging to see the majority of the surveyed industry practitioners can effectively continue their work during the COVID-19 outbreak. Overall, companies have played an active role in providing staff with training opportunity at 4.04. Tracking app is also installed in most companies at 4.46. However, there were still some practices that were not widely adopted by industry practitioners. Most people were not wearing mask at work nor use Covid-19 PPE at work. Both practices score the lowest among the others at 2.07 and 2.66 respectively.

Table 3: Practices of respondents towards COVID-19

Practices of respondents towards COVID-19	**Average**
I wear mask or face covering at work.	2.07
I practice physical distancing as required at work.	3.55
I attend Covid-19 briefing as arranged by my company.	4.04
I regularly update myself with latest Covid-19 information from publicly available information sources.	4.00
I use Covid-19 related PPE at work.	2.66

Our company has assigned a person to monitor and manage Covid-19 protocols.	3.52
Our company displays a government issued QR code for use with NZ COVID Tracer App.	4.28
Our company registers people entering and exiting workplace.	4.46
Our company has a process to evaluate employees are fit for duty as they enter workplace.,	3.93
Our company provides hand sanitizing facilities for workers before starting work.	4.39
Our company securely and safely dispose off waste and disposable PPE.	4.00

The survey produced results very similar to the Chinese study (Zheng, Chen and Ma, 2021). Both studies reported overwhelming percentage of participants having correct knowledge about the disease as well as optimistic attitude in defeating the pandemic. Practitioners in both New Zealand and China reported satisfactory level in practice of control measures in general, but it appears that there are shortcomings in practising basic preventive measures such as usage of face mask and PPE.

The COVID-19 pandemic has continued to ravage world economies and the lives of many people. New Zealand experienced a relatively very short period of lockdown in the first half of 2020 due to her early adoption of an aggressive strategy to contain the spread of the disease; the response in her construction industry included institution of control measures and protocols. For extended periods of time there has not been any COVID-19 cases in the community. Ironically due to the success in containment of the disease it appears that the general population (construction industry practitioners included) in NZ are quite relaxed in their behaviours towards the disease. With the border being slowly open-up to nearby countries, the risks of another wave of infection increase. The construction industry needs to assess its preparedness to face the challenges, for which understanding of her practitioners' KAP towards the disease is an integral part.

This research is likely the first to investigate the KAP of construction practitioners towards COVID-19 in NZ. There are significant limitations. Firstly, the sample is limited in representativeness due to the low rate of responses in the survey; it is risky in generalising the results. Secondly, the early success in eliminating community infection cases in NZ compared to other countries could have led to complacency among her population thus affecting their attitudes and practices towards the disease; and this in turn could have translated into the lacklustre interests in response to the survey. Further studies through qualitative methods using interviews and/or observation techniques would help to lessen the limitations and to assess any behaviour change among practitioners.

5 Conclusion

This study hopes to complement existing worldwide research efforts in understanding how the COVID-19 pandemic has affected the way health and safety management is conducted in the construction industry. Results from survey based on KAP theory would be the first step to explain behaviour change if any among the practitioners. Despite the limited sample the results of the survey indicated a) higher than average percentage in correctness of knowledge towards COVID-19 among practitioners b) overall positive attitude and satisfaction among practitioners towards the strategies and control measures implemented by the government and companies respectively and c) satisfactory level of practices of protocols among practitioners. The research has revealed an overall satisfactory state of practitioners' understanding of COVID-19 and its mitigations measures in New Zealand. Rooms for improvement are present and they heighten the need for WorkSafe and CHASNZ to review policy strategy and protocols development respectively and their implementations to improve effectiveness. Furthermore, the pandemic is evolving with new and more dangerous variants of the virus been discovered. Some countries are considering the need to co-exist with the virus, accepting COVID-19 as an endemic disease. The study may be repeated in the light of these development. In addition, NZ's early success in containing the spread of infection may likely have impact on local practitioners' attitudes and practices as compared to those of other countries; and this is an area worth further investigations.

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Standardisation of Information Input for Automated Compliance Checking Efficiency

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Abstract
Regulatory compliance checking in the Architecture, Engineering and Construction (AEC) sector is an essential process to ensure buildings perform to various standards and maintain its functions during the course of its life. However, this process is manual, laborious, and prone to human-error. The recent shift in the AEC sector towards Building Information Modelling (BIM) processes facilitate the automation of compliance checking processes, by interrogating digital models encompassing construction information in computer-readable data. There have been prototypes of automated compliance checking software developed and validated worldwide, but the process of preparing a BIM model to contain the necessary information has not been thoroughly established. Hence, this study identifies and assesses the information-input workflow necessary to prepare a data-enriched BIM model for automated compliance checking. An experiment research is designed using a sample BIM model exported to IFC format, automated compliance checking tool, ACABIM, and section 2.2.1 of the Acceptable Solution D1/AS1 to determine the information required and derive an information-input workflow. Results show that the sample BIM model in its original form is missing the IFC property 'HandicapAccessible' for all of its IfcSpace objects, which are required for automated compliance checking. A workflow was developed that data-enriches the original model with the missing property identified using BIM authoring software Autodesk Revit. Further testing on the data-enriched BIM model has proven the derived information-input workflow successfully enables automated compliance checking. While some errors leading to unpredicted results were observed, viable explanations for each error could be found. These findings were incorporated back into ACABIM tool and automated compliance check re-run, which eliminated majority of errors in the results. The implications drives policy formulation by local councils for building consenting process and experimental testing improvements for software developers.

Keywords
Building Information Modelling (BIM), Automated Compliance Code Checking, Standardization, Information Input, New Zealand

1 Introduction

Production information which forms an essential part of building information modelling (BIM) overlay requires the creation of production level parametric objects for pre-construction phase (Sinclair, 2012). This information requirements differs for various stages of use in the construction life cycle which further extends potential use in consent application. Compliance accreditation and certification initiatives have often been the focus of government initiatives, encouraging research and development in automated code checking (Harris et al., 2014). To achieve the required levels of automated coding checking, there needs to be exponential growth in construction industry wide BIM maturity. Several factors drive BIM maturity (BIMM) with two critical factors of process and technology management presenting a positive significant impact mediated by information management (Chen et al., 2016). From a strategic process management standpoint in the BIMM model, developing BIM model that can undergo advanced processes and retain product-oriented information is key to advancing maturity. Emphasis to increase collaboration among construction stakeholders from design development to end-of-life have been researched (Enegbuma et al., 2014; Ishak et al., 2017) including automated code checking requirements (Dimyadi & Amor, 2018; Ghannad et al., 2019; Eastman et al., 2009). However, the information requirements matching each building code presents opportunities for further study to enhance maturity and improve current code checking practices for design development completeness.

In New Zealand, section 14B and section 40 of the Building Act 2004 mandates building owners to obtain a building consent through the local Building Consent Authority (BCA) before they begin any building work (Building Act, 2004). The building consent process in section 3 involves compliance checking against the Building Code (NZBC) under the Act, whose purpose is to provide for the regulation of building work, to ensure people can use buildings safely and without endangering their health (Building Act, 2004). Section 49 specifies that checking of NZBC compliance is performed on the plans and specifications that accompany a building consent application (Building Act 2004), which is described as a manual, laborious and error-prone undertaking (Dimyadi & Amor, 2018; Ghannad et al., 2019). Recently in New Zealand, there are reported growth in the consent numbers (Martin, Collinge, & Fitzpatrick, 2018; Ng, 2020), suggesting more efficient code compliance checking process is beneficial for the construction sector. In shifting towards BIM processes, one of its outcomes including a virtual model of a building constructed digitally containing precise geometry and data (Eastman et al., 2011), saw prospect of computer-interpretable models and automated checking of these models (Eastman et al., 2009). Previous studies have since developed tools for automated compliance checking (Dimyadi & Amor, 2013; Greenwood et al., 2010; Nawari, 2017; Shih & Sher, 2014), with reports of successful demonstration of automated compliance checking tool in conjunction with a BCA in the city of Christchurch, New Zealand (Dimyadi & Amor, 2018). Given the slow pace of building consent, request for information (RFI) increase, rise in digital tools and need for productivity improvements, this study asks what is the right information input required by councils for building consent including a complimentary standardised workflow. Thus, this study aims to examine the information input requirements to improve automated compliance checking. This was achieved through identifying information requirements for automated compliance checking, examining the impact of information inputs for automated compliance checking and developing a standardised information input method for automated compliance checking.

2 BIM and Automated Code Checking

The task of checking to ensure a building design complies with the applicable rules/local codes, undertaken by designers and local authorities. Traditionally, this is a manual, time-consuming and error-prone process (Ismail et. Al., 2017). Standardised digital description (specification) of the built environment that is an open and international standard meant to be vendor-neutral and agnostic (BuildingSMART, 2019a). Contains within its specification IfcObjects (e.g. IfcSpace, IfcWall), and property sets that define properties of IfcObjects (e.g. Pset_WallCommon property set contains properties assignable to IfcWall, including FireRating, ThermalTransmittance etc.) (BuildingSMART, 2018). The earliest attempts include CORENET initiated by the Singapore's Ministry of National Development in 1995, involving code checking based on 2D drawings. This approach developed into E-Plan Check system via development of interoperable international standard for BIM model, the Industry Foundation Classes (IFC) by the International Alliance for Interoperability, and a platform named FORNAX, which is an object library with embedded rules for automated assessment (Eastman et al., 2009). The FORNAX objects were to enrich the compliance related data to the BIM model as the IFC schema alone was not sufficient to contain enough data for automated compliance checking (Nawari, 2017). However, hard coding the rules into the compliance checking system results in inflexibility and high cost to update when rules change, due to necessity of a programmer to re-code and implement back into the system to accommodate even a minor rule change (Dimyadi et al., 2016).

Solibri Model Checker (SMC) is a standalone platform that reads an IFC model and maps it to an internal modelling structure for the access to the model data and compliance processing (Nawari, 2017), utilised by HITOS project, DesignCheck and SMARTcodes initiatives internationally. SMC is at default provided with parametrised built-in rules for pre-checking basic geometries, space management, accessibility etc. (Ismail et al., 2017). One significant improvement from the FORNAX approach is the parametrisation of the rules, allowing the users to customise the rule by varying the table-set control parameters (Eastman et al., 2009; Nawari, 2017). In response to updates to local regulations, these parameters can be used towards adjustment to the existing rules without involving programmers. However, new rules can only be created via SMC programming interface, again having to involve programmers with Java expertise and a good understanding of SMC data structure (Greenwood et al., 2010; Nawari, 2017). A common aspect of the FORNAX system and SMC is that the rules are hard coded into the software. This is explained as the "black-box" approach, as the hard-coded routines are not transparent to the user (Preidel & Borrmann, 2015). Similarly, Nawari (2017) further analyses the approaches into black, grey and white-box methods with varying grades of customisation and user-interaction. The white-box methods are transparent in the processes executed to produce the results, hence granting more control to the end user.

Development of automated compliance audit tool (ACABIM) in New Zealand was focused on addressing the problems identified in the previous approaches. Firstly, the legal knowledge (rules, codes, standards) is separately represented in an open-standard legal data exchange format, instead of being hard-coded into the automated checking tool (Dimyadi & Amor, 2013). According to Dimyadi and Amor (2013), adopting an open-standard specification allows any revisions to be incorporated without the need to reconstruct it. ACABIM framework is dependent on the availability of computerised representation of the legal knowledge. A similar research by Dimyadi et al. (2016) discuss the approach of using LegalRuleML language. Secondly, the ACABIM approach acknowledges that designers may choose one of the many available paths to demonstrate compliance. This approach synchronises with the structure of NZBC, and its compliance paths discussed earlier. The authors introduce the Compliant Design Processes (CDP) concept, where the designer (or the person undertaking the compliance checking) chooses the compliance path based on the person's intimate knowledge of different design options most suitable for the specific case (Dimyadi & Amor, 2017). The CDP is represented using Business Process Model and Notation (BPMN), an open standard allowing embedding of computer scripts that convey and provide a graphical notation for the user-specified instructions (Simpson, 2005). ACABIM processing engine receives information from the BIM model (IFC format), takes it through the CDP as defined by the user, extract the legal requirement as per the instruction from CDP from the LKM.

3 Information Requirement

Predominantly, automated compliance checking studies develop a new approach, and attempt to validate their developed prototype and/or framework using sample regulation and BIM model. In each case, specific information required in the BIM model is identified (either implicitly or explicitly) in relation to the chosen sample of regulation to test. Ghannad et al. (2019) and Lee et al. (2016) allude to the required information in a worked example diagram but do not explicitly state that these are required in the model, and therefore no details provided on how this information is inserted into the BIM model. Preidel and Borrmann (2017) stated the required properties within the modelled building element and assumes that information is present in the BIM model. Though it is reasonable to expect the geometric information (length/width, area, volume quantities) is available in default of the BIM models, the information specific to the check being carried out are not normally included in the models created using common BIM authoring tools such as Revit or ArchiCAD (Nawari, 2017). Other researchers acknowledge that specific information for automated code checking need to be provided either manually, or by other means (Bloch & Sacks, 2018; Dimyadi & Amor, 2017; Dimyadi et al., 2016; Malsane et al., 2015; Shih & Sher, 2014), have taken various approaches to input the required information to the model. A framework developed by Cheng and Das (2014) includes a phase whereby missing parameters are identified in the model, and a respective template is created requiring the user to upload the missing values. In the application of prototype developed by Choi et al. (2014), information required in the form of Industry Foundation Classes (IFC) property within the modelled building element have been specified for evacuation regulations. Bloch and Sacks (2018) examined information-input through machine-learning process, testing automated room classification to each of the spaces in an apartment model and resulted with 82% accuracy, reporting potential to achieve 100%.

However, the machine-learning approach requires a 'pre-processed' training dataset, where its sample size is directly proportional to the quality of results. Dimyadi and Amor (2017) and Nawari (2017) suggest the development of specific Model View Definition (MVD) being a subset of the overall IFC schema (BuildingSMART, 2019b) by specifying the Exchange Requirements (ER) using the Information Delivery Manual (IDM). If a BIM model is developed in accordance with these steps, the model acquires necessary information for automated code checking (Nawari, 2017). However, a MVD being only a representation of the parent BIM model (in IFC format), it still requires some form of information-input into the BIM model. Dimyadi and Amor (2018) have listed the minimum data specification, following a proof-of-concept application to the developed ACABIM prototype.

Consequently, there is currently no available means to assess the impact of the information-input workflow. If the workflow itself proves to be a cumbersome, laborious and error-prone task with a heavy impact in the model preparation process, it defeats the purpose of the automation and minimise the potential benefits of the automated compliance checking itself, which is to make the existing process more efficient. The need of additional information-input into the BIM model, or data-enrichment, has been identified as necessary from the literature (Bus et al., 2018; Choi et al., 2014; Dimyadi et al., 2016; Malsane et al., 2015; Nawari, 2017; Preidel & Borrmann, 2017; Shih & Sher, 2014). This study focuses on reducing and documenting the workflow of the information-input procedures and observe methods to standardise this workflow, ultimately to improve the model preparation process for automated compliance checking.

4 Research Methodology

The research design involves observation of the workflow undertaken to 'data-enrich' a given model and observe if the information-input process successfully inputs the required data into the model. All of this involves collection and analyses of definite, quantifiable data, categorised into 'empirical' research from a positivist standpoint (Chen and Hirschheim, 2004). According to Green (2005), systematic review is a tool used to appraise, summarise and communicate unmanageable quantities of research. International databases of Scopus and Science Direct were searched, as these are commonly used and available databases. Searched publications include, in the title, abstract, or keywords, "Building Information Modelling" or "BIM", AND "automated", AND "code" or "compliance", AND "check" or "review" or "audit". As each of the terms induced several other similar meaning words (for example, "check", "review", and "audit") the 'or' conjunction was used to include the respective synonyms. From the result, publications within the last 6 years (2014 to 2020) were retrieved from the databases. These most recent papers have been used to identify the knowledge gap, presented in the research justification section. For more general and historical overview, all literature resulting from the above search have been reviewed and addressed in the literature review section.

In this study, a controlled environment is established by gathering a sample BIM model created by NZ construction industry design practitioner. This forms the basis information contained in the BIM model prior to the information-input workflow. The specialist treatment is the application of automated compliance checking on the model, and the information-input workflow applied to the same BIM model. The outcome variables measured following the treatment are the impact of the information-input workflow, from which methods to standardise the workflow are discussed (Chen and Hirschheim, 2004). According to Dudovskiy (2019), the sample data collected through this method is inevitably prone to selection bias and influences beyond the control of the researcher. The sample BIM model supplied for the purpose of this research was created using Autodesk Revit. In New Zealand, the major BIM authoring software in use are Autodesk Revit and Graphisoft ArchiCAD (Respond Architects, 2016; Thompson, 2012).

Access to ACABIM tool (Dimyadi & Amor, 2017) has been negotiated for the purpose of this study, similarly to the sample BIM model. The choice of the ACABIM tool can therefore be regarded as another convenience sampling method subject to bias. However, as discussed during review of other automated compliance checking tools (Corenet-FORENAX and Solibri Model Checker), the process to prepare a data-enriched BIM model to enable code compliance check is identical as shown in Figure 1. Additionally, ACABIM tool enables the users to choose different Compliance Audit Procedures (CAP) (Dimyadi & Amor, 2018), as opposed to other systems identified in the literature review. This correlates well with the structure of the New Zealand Building Code and different methods for designers to demonstrate compliance. Hence in order to automate code compliance checking in New Zealand AEC scene, ACABIM is a suitable tool.

NZBC Acceptable Solution D1/AS1 (Ministry of Business Innovation and Employment, 2016) is a set of prescriptive requirements which the design is 'deemed to comply' if the document is fully conformed to. NZBC D1 covers the access and circulation into and within a building, including access requirements for people with disabilities. Within D1/AS1, the prescriptive requirement is selected as the experiment proposed in this research [D1/AS1 section 2.2.1: "The clear width of an accessible route shall be no less than 1200 mm"]. An 'accessible route' is a term defined in D1/AS1. An 'access route' is also defined in D1/AS1. The corresponding instructions for the computer to execute for the above regulatory requirement are (1) Identify 'access route' space, (2) Identify 'accessible route' space, (3) Identify widths of the 'accessible route’ space (4) Check if width from 2) is >1200mm and, (5) Repeat above process for all ‘accessible route’ spaces identified across all floors identified in the building.

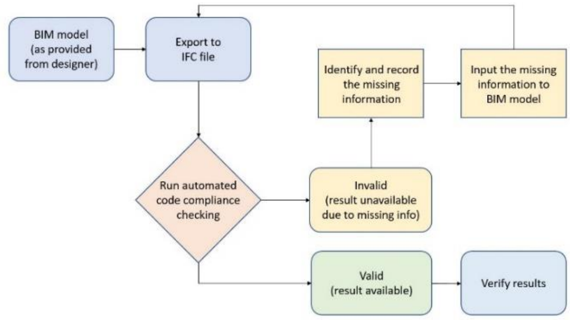

Figure 1. Information requirement process mapping

The original BIM model is first exported in to IFC file, and automated compliance checking is executed on ACABIM using the D1/AS1 section 2.2.1 sample check. *At this point, record if result is available (therefore the check is valid), or unavailable (due to missing information).* Missing information: When invalid results are observed, identify which information was missing from the original BIM model by analysing the ACABIM result script. *Then record the missing information*. Information-input process: *Record the step-by-step workflow undertaken to the original BIM model (in Revit environment) to input the missing information* (data-enrichment) as specified in the methodology. The step-by-step workflow for the data-enrichment will be recorded and appended to the report. Also *record the time taken to input the missing information*. Model status: Also *record the status of the sample model tested* – original model or data-enriched model. Automated compliance checking results for pass or fail are required to be verified to ensure the ACABIM tool has derived a correct answer from using a correct equation, for accuracy of the results. Previous studies have also taken the same approach (Bloch & Sacks, 2018; Zhang & El-Gohary, 2017) towards verifying their results. Key factors to verify are linked to the set of instructions for the computer stated previously. From this, the questions below for the verification process are derived are have all designated ‘accessible route’ spaces been identified? Are the identified ‘accessible route’ widths correct (compared to a manually derived answer)? Are the identified widths compared against the D1/AS1 section 2.2.1 requirement, ‘accessible route’ width > 1200mm? And has the check been repeated for all accessible routes in the building?

5 Results and Discussion

Original BIM model exported to IFC file – ACABIM results using the D1/AS1 section 2.2.1 sample check


```
"numberOfAllSpaces": "47"
      "numberOfAccessRoutes": "43"
      "numberOfAccessibleRoutes": "0"
      "nSpace": "0"
      "numberOfAccessRoutes": "59"
      "numberOfAccessibleRoutes": "0"
      "nSpace": "0"
```


The original model has not been identified with any accessible routes on the ground floor and first floor (indicated by “storeyIndex” “1” and “0”). ACABIM process therefore could not proceed to the next step, which is to identify the width of these spaces and check against D1/AS1 section 2.2.1. This result is deemed "Invalid" as per mapping flowchart (Figure 9). The included (present) information in the sample model observed are building storeys, spaces, and access routes. Common objects such as 'building storey', 'space', its names and geometric dimensions can reasonably be assumed they are contained in the model (Dimyadi & Amor, 2017; Nawari, 2017), as the case have been for this experiment. The missing information is that there are no spaces specified as 'accessible route'. In IFC specification, this means there are no 'IfcSpace' objects with the 'HandicapAccessible' property value set to 'True'. This type of missing information is consistent with previous findings (Bus et al., 2018; Cheng & Das, 2014; Choi et al., 2014; Nawari, 2017; Preidel & Borrmann, 2017), yet these studies do not explicitly state which properties are missing or present.

While 'accessible route' spaces are missing, the results do show 'access route' spaces are identified, meaning automated compliance checks involving 'access routes' are possible without undertaking the information-input workflow. This reinforces that information required for automated compliance checking is dependent on the compliance question to check. Also, the validity of the result depends on the information contained in the original BIM model, meaning the same experiment on a different BIM model is not guaranteed to give the same result. From this, two factors affecting the validity of automated compliance checking results are derived (Original BIM model and Compliance requirement to check).
The missing information and the corresponding information-input workflow can only be established once the above two factors are given. For the original BIM model, there is currently no New Zealand standard on the data requirement for a BIM model, hence the data in the model varies across the industry. The compliance requirements do exist in human interpretable format (standards, acceptable solutions etc.), but not in computer readable format – though there are New Zealand research in this area with promising results (Dimyadi et al., 2014). A standardised information-input workflow therefore must consist of minimum data requirement in a BIM model that is developed on the basis of the compliance requirements applicable to the proposed building, consistent to the findings from Dimyadi and Amor (2018) and Olsson et al. (2018).

A 'shared parameter' file is created to add the 'HandicapAccessible' property, and applied into the Revit model, then the value of the property is set to 'True' for spaces intended to be part of the accessible route as shown in Figure 2. These processes respectively took 45 seconds, 28 seconds, and 4 minutes 48 seconds, total of 6 minutes 1 second. It is worth noting that this time is purely for the information-input only and excludes the time that would take designers to determine which spaces are required to be accessible to meet NZBC performance requirement. The model, now data-enriched, is then exported to IFC format. The impact, in terms of additional time to prepare a data-enriched model, of information-input workflow can be extrapolated from this measurement. Time spent towards creating and applying the shared parameters have lesser impact as once created it can be used and pre-applied across multiple projects (Autodesk, 2018) using project templates – i.e. these are steps which do not need to be repeated every project.

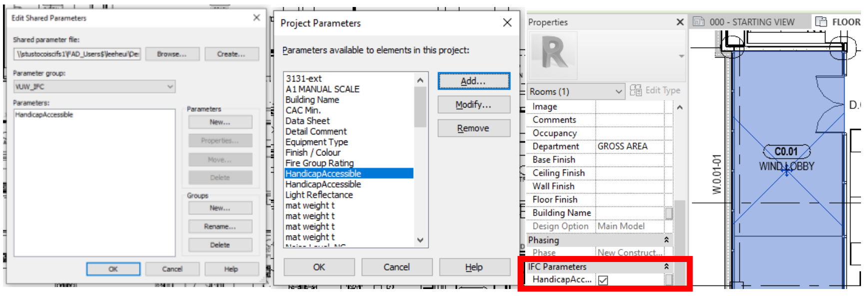

Figure 2. Shared parameter creation for access

The most time-consuming step, hence the biggest impact, within information-input workflow is setting value to the property. In this experiment, there were 16 spaces designated to be accessible routes on ground floor, and 11 spaces on first floor. The time taken to set the value to each of these spaces would be increased if there are more floors in the building, and more spaces are designated to be accessible routes (approximately 10 seconds per additional accessible route space). Also, identifying the accessible route is limited to demonstrating compliance with clause D1 only. Compliance checks other than D1/AS1 section 2.2.1 will require additional properties included to the BIM model, which consequently increases the time to set a value for each property. The developed information-input workflow is summarised, and how it fits in the overall experiment, in Figure 3.

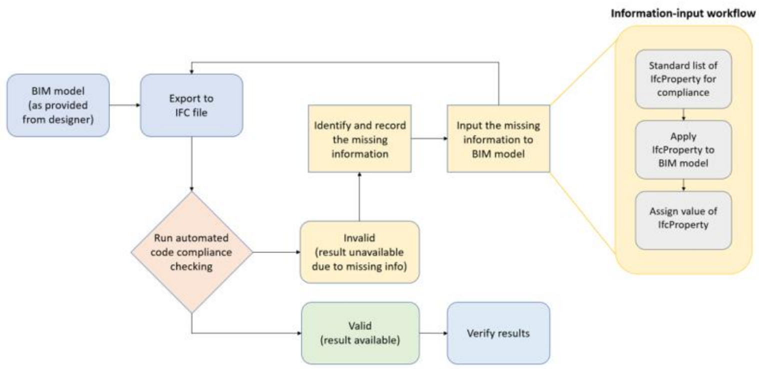

Figure 3. Information input workflow for automated code checking

The savings anticipated from this workflow is that by automating this compliance check, the need for Request for Information (RFI) is reduced. With consent applicant having the opportunity to run automated compliance check prior to submission for consent, non-compliances are rectified without the need of communication between Building Consent Authority (BCA) and applicant. Only one sample was used in this experiment, however, as the scope for automated compliance checking increases in the future, the amount of RFIs mitigated will also increase proportionally. Adding 'HandicapAccessible' property into the IfcSpace object demonstrated in the experiment provides opportunities for multiple compliance checks to be automatically performed from other sections of D1/AS1, for example sections 2.3.1, 7.0.1 to 7.0.6 etc., where requirements are applicable to 'accessible route' spaces only. Information-input workflow with an impact of 6 minute 1 second addition to BIM model preparation time in turn provides opportunities to eliminate numerous RFIs, which are the cause of consent delays and further building costs (Flaws, 2019). Quantifying this saving could be potential future research. It would seek to convert the information-input workflow impact and its savings into comparable figures – i.e. business' resourcing cost for additional modelling task (impact of information-input) versus the cost savings from eliminating the RFIs.

Data-enriched BIM model exported to IFC file – ACABIM results using the D1/AS1 section 2.2.1 sample check

```
"numberOfAllSpaces": "47"
  "numberOfAccessRoutes": "43"
  "numberOfAccessibleRoutes": "11"
  "nSpace": "11"
"numberOfAllSpaces": "66"
  "numberOfAccessRoutes": "59"
  "numberOfAccessibleRoutes": "16"
  "nSpace": "16"
```

The generated results table revealed that 11 and 16 accessible route spaces have been identified on the first floor and the ground floor respectively. The table showed for each of the identified accessible route spaces, the widths of the spaces are derived, then compared against the D1/AS1 2.2.1 requirement of minimum 1200mm and gave the result (message) of 'OK' as the derived width > 1200mm. This result is deemed "Valid" as per mapping diagram (Figure 2).

6 Conclusion and Recommendations

This study has developed an information-input workflow using sample BIM model created using Revit tool, NZBC acceptable solution D1/AS1 section 2.2.1, and the automated compliance checking tool ACABIM. Through a simulation, the type of information required in the BIM model depends on the compliance check being performed. As D1/AS1 section 2.2.1 is a requirement concerning access for people with disabilities, the missing information identified in the BIM model was the 'HandicapAccessible' property from 'IfcSpace' objects, using the IFC4 specifications. The information-input workflow was developed based on the missing information, applied to the sample BIM model, which had enabled the automated compliance check using ACABIM. Results from the check were verified, where unprecedented errors and outcome were discovered. Further study of the calculations performed by the tool determined viable explanations for the errors discovered, which were fed back to ACABIM developers. Re-run results showed the error had been eliminated. However, incorrect compliant/non-compliant outcome persisted due to a flawed computer instruction given in the first place. The experiment design did not provide adequate instructions for the computer to accurately execute the human thought processes. The verification step was crucial in ensuring the reliability of results produced from automated compliance checking, which was only made possible by use of a tool transparent in its processes.

Information requirement is dependent on the compliance check to perform. Hence, to establish a standardised information-input workflow, the scope of compliance check to be automatically performed must first be identified. Then, the 'standard' BIM data requirements corresponding to the automated compliance checks can be derived. Also, further research is necessary for developing and documenting accurate computer instructions that execute human thought processes for more reliable results from automated compliance checking. Therefore, professionals in the areas of compliance checking need training in information technology, specifically BIM modelling and data input. This is not limited to the building compliance officials (local authority employees), but also designers in the industry, as both are responsible under the Act (Building Act 2004. Section 8) when it comes to NZBC compliance. Future research identified are in the areas of quantifying the sacrifice and benefits of information-input workflow in terms of cost to data-enrich a BIM model to enable automated compliance check, versus the savings from mitigated Request for Information (RFI) during consent processing. Calculated, empirical evidence can reinforce the justifications for investment towards staff training for more informative, automated compliance checking-enabled BIM model.

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Barriers to Offsite Construction in Australian Low-rise Residential Buildings

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Abstract

Prefabricated housing has become a booming industry across the world. However, the uptake of offsite construction (OSC) approaches in Australian low-rise residential buildings is rather low compared with high-rise buildings and other countries. This research aims to identify the barriers to OSC in the Australian low-rise residential buildings. A mixed research method was conducted through a questionnaire survey and semi-structured interviews, which combined quantitative and qualitative analyses. Data from 35 questionnaires and 20 semi-structured interviews have been taken in this research. Four categories and 19 subcategories of barriers to the application of OSC in the Australian low-rise buildings were identified. Construction professionals provided their perceptions of each barrier. The results provide clear insights to adopt OSC in the Australian low-rise residential for buildings practitioners and researchers.

Keywords: Offsite construction, Australian low-rise buildings, barriers

1. Introduction

With continuous population growth in Australia, one challenge faced by the Australian construction industry is to meet the rising demands in dwellings. Most of the construction activities have been done using the conventional construction method. In the past few decades, offsite construction methods were introduced (Kamali & Hewage, 2016). The current off-site construction (OSC) market in Australia is still comparatively small, with only $4.5 billion of the total $150 billion construction industry (3%) (Quezada et al., 2016). Compared with conventional construction methods, many advantages of OSC have been found in extensive literature in the aspects of time and process (e.g., simplifying construction process and reducing construction time on site), quality (e.g., improving quality control and high levels of consistency), cost (e.g., reducing costs of the workforce in remote areas, reducing the costs where work is under resource pressure, and decreasing onsite damage), environmental sustainability (e.g., better environmental performance), and occupational safety and health (e.g., reducing onsite risks and better working conditions) (Arif & Egbu, 2010; Blismas, 2007; Jaillon & Poon, 2014; Kamali & Hewage, 2016). However, OSC for low-rise buildings has been not widely used in Australia. The barriers of OSC have not been identified by specific building practitioners. There is a lack of the comparison of different barriers to the application of OSC in Australian low-rise buildings.

This research aims to identify the barriers and provide professional perception for each barrier of OSC in the Australian low-rise residential buildings. A mixed research method was conducted through a questionnaire survey and semi-structured interviews, which combined quantitative analysis and qualitative analysis. This research provides clear insights to adopt OSC in the Australian low-rise residential for buildings practitioners and researchers.

2. Background

Traditionally, a building is constructed on site after proper designing and planning (Kamali & Hewage, 2016). This is called traditional onsite construction which is highly labor-intensive and often affected by weather, traffic, and neighboring properties (Boyd et al., 2012). However, the construction industry often evolves according to the development of technology and innovations (Molavi & Barral, 2016). Off-site construction is a manufacturing process, that generally takes place at a specialized facility where various materials are joined to form building components, elements, or modules of final installation (Sparksman et al., 1999). Similar terms and acronyms regarding off-site construction have been adopted in existing literature, such as prefabrication (Björnfot & Sardén, 2006; Senaratne & Ekanayake, 2011; Tatum et al., 1987), off-site prefabrication (Gibb, 1999), off-site manufacturing, off-site production (Emmitt, 2018), and pre-assembly (CIRIA, 1998). In this study, the term off-site construction is used consistently.

Comparing with conventional construction methods, various advantages of off-site construction have been found in previous studies. It provides several benefits such as reduced material wastage, high-quality production, fast onsite assembly, easy dismantling, and compatible reuse (Changd et al., 2018). In particular, significant cost reductions can be achieved through energy-efficient manufacturing, limited labor usage in assembling, limited time consumption for project completion, standardized design, and avoiding weather extremes during construction (Kamali & Hewage, 2016). Although there are many benefits to uptake OSC, the development of OSC remains slower. By comprehensively reviewing the literature, several aspects of major barriers to the uptake of OSC were summarized by (Lin et al., 2021). Table 1 shown 19 barriers which be categorized into design and quality, cost and finance, skill and knowledge of stakeholders, and supply chain. Lin has explored the feasibility of applying different OSC approaches in Australian low-rise residential buildings. However, these theoretical shortcomings have not been recognized by specific professionals. Thus, this study aimed to verify the theoretical barriers that can provide knowledge of interest for both researchers and practitioners.

Table 1. Barriers of OSC (Lin et al., 2021)

Categories	**Barriers**
Design and quality	Monotone in aesthetics
	Decreased flexibility for design changes
	Interface problems on site due to low tolerances
	Impair quality of buildings
Cost and finance	High upfront investment of OSC buildings
	Slightly expensive compared with traditional methods
	Difficulty in obtaining finance
Skill and knowledge of stakeholders and supply chain	Poor manufacturing capability
	Lack of skilled labour in OSC

	Lack of skills by professionals in OSC
	Lack of management experience
	Lack of knowledge repository and portal
	Difficulty in certification of overseas precast products
	Transportation is difficult and expensive
Industry culture and market	Current business model may not satisfy OSC
	Dependence on traditional construction methods
	Lack of government incentives and promotion
	Lack of market demand for OSC building or elements
	The potential of job losses onsite due to OSC

3. Research Methodology

A mixed research method was conducted through a questionnaire survey and semi-structured interviews, which combined quantitative analysis and qualitative analysis. The questionnaire survey was firstly conducted to obtain the rate of barriers to the OSC uptake in the Australian low-rise buildings. The questionnaire survey consists of two parts. The respondents' background has been collected from section A, such as professional area, company type, and years of experience in the construction industry. Section B asked respondents to rate the listed barriers from the literature review. A five-point Likert scale was conducted to show the level of agreement. The online questionnaire survey has been distributed to 140 architectural firms, construction contractors, and consultancies across the country. 35 companies completed the survey which is sufficient to conduct statistical tests, as it is larger than 32 usable data which is the minimum needed for the questionnaire survey (Fellows & Liu, 2015). The questionnaire data were analyzed through statistical software SPSS.

Following the questionnaire survey, semi-structured interviews, as a qualitative method, were conducted to solicit experts' perceptions on the barriers of OSC in the Australian low-rise residential buildings. The diversity of interviewees are various roles such as architects, builders, subcontractors, and manufacturers. Eventually, there are 20 participants took apart in the interviews which is a fair representation of stakeholders regarding a range of offsite construction activities including design (Interviewees A, B, and C), prefabrication manufacturing (Interviewees N, O, P, Q, R, S, and T), building (Interviewees D, E, F, and G), monitoring and regulations (Interviewee K). It is believed that such a pool of experts would provide the breadth of knowledge and necessary expertise as recommended by Ochieng and Price (2010). Semi-structured interview guided by the pre-determined questions and supplemented by follow-up questions. The interview dialogues were audio-recorded and transcribed. All the transcripts were analyzed by the constant comparative analysis method (CCAM) in NVivo version12.0. The interview helps to identify the barriers of OSC in the Australian low-rise residential buildings. It is significant to obtain rich information from experienced professionals in the construction industry.

4. Findings and Discussion

4.1 Findings of Questionnaire Survey

Respondents were asked to rate the barriers to the OSC uptake in the Australian low-rise buildings identified from previous studies. Table 2 shows the frequency of response, mean, and rank of these 19 barriers. The mean scores of barriers to OSC uptake ranged from 2.94 to 3.89. The standard Deviation reflects the dispersion of the results. The normalized values of mean scores were also calculated to determine the critical barriers, which has been adopted by Xu et al. (2010) where normalized values equal to or larger than 0.50 were critical factors. There were seven barriers with normalized values greater than 0.50. This indicated that respondents perceived that those seven factors were critical barriers to OSC uptake. The top four critical barriers were "Current business model may not satisfy OSC" (S15), "Interface problems on-site due to low tolerances" (S2), and "Lack of market demand for prefabricated building or elements" (S18), and "Slightly expensive when compared to traditional methods" (S6). (1) Lack of skilled labor in OSC, (2) High upfront investment of OSC buildings, (3) The potential of job losses onsite due to OSC were less considered as barriers to using prefabrication.

Table 2. Ranking of barriers to the OSC uptake in the Australian low-rise buildings

No.	Barriers	Frequency of response					Total frequency	Mean	Standard Deviation	Normalised value	Rank
		1	2	3	4	5					
S1	Monotone in aesthetics	3	3	8	16	5	35	3.49	1.121	**0.58**	6
S2	Decreased flexibility for design changes	3	3	8	16	5	35	3.49	1.121	**0.58**	7
S3	Interface problems on site due to low tolerances	2	3	4	17	9	35	3.80	1.106	**0.91**	**2**
S4	Impair quality of buildings	3	5	7	16	4	35	3.37	1.140	0.45	9
S5	High upfront investment of OSC buildings	7	6	6	14	2	35	2.94	1.282	0.00	18
S6	Slightly expensive when compared to traditional methods	2	4	10	11	8	35	3.54	1.146	**0.63**	**4**
S7	Difficulty obtaining finance	3	9	10	8	5	35	3.09	1.197	0.16	15
S8	Poor manufacturing capability	3	5	12	9	6	35	3.29	1.178	0.37	13
S.9	Lack of skilled labour in OSC	3	11	9	9	3	35	2.94	1.136	0.00	19
S10	Lack of skills by professionals in OSC	3	9	7	10	6	35	3.20	1.256	0.27	14
S11	Lack of management experience	2	7	7	15	4	35	3.34	1.110	0.42	11
S12	Lack of knowledge repository, portal	1	9	6	14	5	35	3.37	1.114	0.45	10
S13	Difficulty in certification of imported precast products	1	5	12	13	4	35	3.40	0.976	0.48	8
S14	Transportation is difficult and expensive for long distance and large, heavy loads	2	5	7	15	6	35	3.51	1.121	0.60	5

S15	Current business model may not satisfy OSC	1	3	5	16	10	35	3.89	1.022	**1.00**	**1**
S16	Dependence on traditional construction methods	1	8	10	11	5	35	3.31	1.078	0.39	12
S17	Lack of government incentives, directives and promotion	1	11	10	11	2	35	3.06	0.998	0.13	16
S18	Lack of market demand for prefabricated building or elements	0	7	7	14	7	35	3.60	1.035	**0.69**	**3**
S19	The potential of job losses onsite due to OSC	2	12	7	12	2	35	3.00	1.085	0.06	17

Note: Normalised value = (mean – minimum mean)/(maximum mean – minimum mean). The critical barriers are highlighted in bold.

According to Fig. 1, architects provided a higher rating on the hindrances that reflect their higher concern in adopting prefabrication. It shows the ranking of the barriers by different building professionals. Consultancy and Contractors considered the "Current business model may not satisfy OSC" as the most significant hindrance to adopting OSC, while Architect regarded "Monotone in aesthetics" as the most significant barrier. The ranking of the barriers greatly differs between the different professionals. To investigate the differences in rankings of barriers to OSC uptake perceived by Architect, Consultancy, and Contractor, Spearman rank correlation test was applied to examine the correlation on the rankings among Architect, Consultancy, and Contractor (see Table 3). The value of r_S of rankings between Architect group and Consultancy group on barriers to OSC uptake was -0.002, with a p-value of 0.994 higher than 0.05. The value of r_S of rankings between Architect group and Contractor group on barriers to OSC uptake was -0.132, with a p-value of 0.591 higher than 0.05. The value of r_S of rankings between Consultancy group and Contractor group on barriers to OSC uptake was 0.040, with a p-value of 0.870 higher than 0.05. Thus, the null hypothesis was not rejected, indicating that no significant correlation existed between any two groups of Architect group, Consultancy group, and Contractor group on the rankings of barriers to OSC uptake.

Table 3. Spearman rank correlation test between Architect, Consultancy, and Contractor on OSC barriers

Comparison	r_s	p	Conclusion
Architect vs Consultancy	-0.002	0.994	Accept H_0
Architect vs Contractor	-0.132	0.591	Accept H_0
Consultancy vs Contractor	0.040	0.870	Accept H_0

H_0 = There is no significant correlation on the rankings of barriers between the two groups.

Ha = There is a significant correlation in the rankings of SC factors between the two groups.

Note: Two-tailed test.

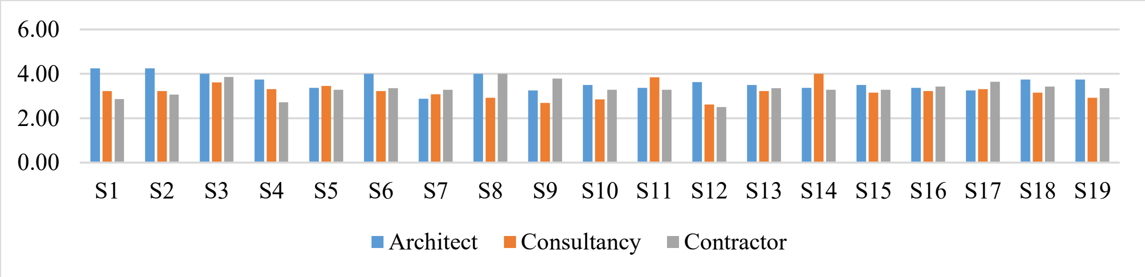

Figure 1. OSC uptake barriers from different professions' viewpoint

4.2 Findings of Semi-structure Interviews

Refer to Table 1, four categories and 19 subcategories of barriers to the application of OSC in the Australian low-rise buildings were discussed by interviewees. All the interviewees have been coded to protect their privacy. They have been categorized by design (Interviewees A, B, and C), prefabrication manufacturing (Interviewees N, O, P, Q, R, S, and T), building (Interviewees D, E, F, and G), monitoring and regulations (Interviewee K).

Category 1: Design and quality

S.1 Monotone in aesthetics

The architect expressed his concerns about the appearance of OSC buildings as that "You cannot have beautiful façade. If you look at prefabricated construction, there are no beautiful curves. They are generally square and rectangle. It is very hard to make organic shapes. Most of the prefabricated designs are very boxy. You don't have lots of shapes. It is just because it is cheaper to manufacture the same shape again and again. Furthermore, the precast will make the houses look similar in this suburb."

S.2 Decreased flexibility for design changes

One architect mentioned that the main problem of applying offsite construction is less flexibility. They cited an example "We have designed an apartment building project, in which the top two levels are luxurious apartments. After we have prepared the drawing and started to sell apartments, customers would like to change the apartment layout. Although all designs have been done, they still need to change the design to sell these apartments. But for offsite construction, it is not easy to change the design at this stage and increases the cost." This depends on the market situation. If the real estate market is very good, the design is not a big problem, and the customers will be willing to purchase them no matter how the design is. But in the current poor market, we could not make the contract very strict. If we include many conditions in the contract, the customers may not choose and buy it. For instance, there is an apartment building in Southbank which is on hold, as they could not sell another 20 apartments. Only when 80% of apartments have been sold, the bank can provide a loan to the developer.

S.3 Interface problems on site due to low tolerances

The interviewed builders expressed their concerns about the interface problems during installation. One builder mentioned that 80% of the problems can be addressed, but the remaining 20% cannot be fixed and need to be re-ordered. One builder mentioned that "The main concern is the size matching problem. We have attempted prefabricated wall, cabinet, and kitchen, but the size did not match during installation on site." The interface problem may lead to the delay of the project, especially when prefabricated components are imported from overseas, as revealed by one builder "The thing is you bring something from overseas, what happens if something is not working. From the fixing side, someone needs to come to install it.

We need to find someone to install it. If they say it is not the problem I bring in, then we have construction delay."

S.4 Impair quality of buildings

The high quality is considered as one advantage of adopting OSC, while negative perception from failure or low-quality products has been regarded as prominent factors hindering its wider adoption. There may be some quality problems with prefabricated buildings. For instance, one architect was worried about the waterproofing problem of prefabricated buildings. If one prefabricated block is placed on top of another prefabricated block, how to deal with waterproofing of the gaps between the two blocks? It is going to fail all the time. For builders, they are more worried about whether the prefabrication has any negative effects because the builder needs to provide ten years warranty.

Category 2: Cost and finance

S.5 High upfront investment of OSC buildings

According to the current contract of a residential project, the deposit is only 5%. The developer or owner needs to support the application offsite.

S.6 Slightly expensive when compared to traditional methods

The high cost of OSC is another barrier to using OSC. Some builders found that the cost of OSC is slightly higher than conventional construction methods. The interviewed builder stated that "We love to go prefabricated, as it is easy, clean, and low wastage, but there is a cost involved. For volume construction, we are trying to bring the cost down, but prefabrication is too expensive. When the prefabrication's cost comes down, more builders will go toward the prefabrication." The interviewed consultancy mentioned that "it may have no market as it has no advantages of cost. If the volume of low-rise buildings is not large, there will be no price advantage." One architect also highlighted that the cost is not competitive and the lower price of OSC buildings is 1500/m^2 and the higher price is 1800/m^2. The builder mentioned that if the OSC manufacturer would like the builder to try a new construction method, but the cost cannot be reduced, the builder is not competitive in the market.

S.7 Difficulty in obtaining finance

For OSC project, it is difficult to obtain finance from the bank. In the case of the modular building method, most banks will not release progress payments until the home is permanently fixed onsite or until the final completion of the project. One more thing is that if projects are prefabricated overseas, the bank will not provide loans to them. The architect mentioned that some other offsite construction projects, which are new to the bank. It is difficult for the bank to accept this kind of project. The bank will make progress payment to the builder, but most of the prefabricated project work is done in the factory.

Category 3: Skill and knowledge of stakeholders and supply chain

S.8 Poor manufacturing capability

OSC practices are closely associated with the design and manufacturing capacity of manufactures. There is a lack of building manufacturers which satisfy the customized demands. Housing developers have to produce the building blocks as well as buy it, which stretches the production chain and increases the overall cost.

S.9 Lack of skilled labour in OSC

One reason is that the whole process of OSC project, from the initial production of prefabricated components to their installation, is very complicated. This is because all the components involved are manufactured in advance and need to be assembled and installed precisely in accordance with the manufacturer's instructions. It is often very difficult to remedy mistakes and therefore necessary for construction companies to establish sound organizational and quality assurance systems to ensure that workers complete the process accurately and according to schedule.

S.10 Lack of skills by professionals in OSC

Most professionals in Australia lack skills in OSC houses and apartments, including architects, builders, suppliers, electricians, and plumbers. The local builder highlighted that "Australia is very inexperienced in prefabricated houses and apartments. For the moment, which is most difficult for us is all claddings are bricks. You cannot bring in the prefabricated wall in bricks. Let us get rid of bricks. If we can have a prefabricated wall with other claddings, it can absolutely work." In addition, the manufacturer needs to train some technicians or laborers for promoting these products to market, and thus the construction market will be willing to accept this. They need to offer one-stop service to meet different customer needs from manufacturing, installation to technology. Like the light steel structure, they also offer the service of installation.

S.11 Lack of management experience

The OSC adoption requires a high level of management. The OSC adoption involves multi-parties, and a high level of integration is required (Luo et al., 2015). However, poor collaboration has been observed as a result of the fragmented nature of the construction industry. It is difficult to develop a collaborative relationship between stakeholders in a project-based industry, where each party works individually as an independent organizational entity chasing its interests. The unfavorable organizational mechanism was one of the barriers to adopting OSC. Similarly, the competency of subcontractors is crucial for the OSC adoption.

S.12 Lack of knowledge repository, portal

The builder mentioned that the timing is very important, and currently Australia is very inexperienced in prefabricated low-rise buildings. For the moment, which is most difficult for us is all claddings are bricks. The wall cannot be prefabricated in bricks and can have a prefabricated wall with other claddings.

S.13 Difficulty in certification of imported precast products

The first concern for builders is that overseas companies may not understand and meet Australian standards and regulations. If these materials are exported to Australia but do not meet the standards, these builders and overseas companies may lose money. The architect also expressed that for the product imported from overseas, they need to go through all regulations and processes and get the right certificate, as Australia does some material testing. All the materials need to meet the fire-resisting, waterproofing, and adhesive connections. The building surveyor will check all certificates of the materials. For instance, overseas steels need to be certified to ensure they meet Australian standards. Many overseas steel manufacturers have obtained Australian standard certificates. The second is that the building surveyor needs to approve the steel framing. If the steel framing did not follow the building code, they need to have a performance solution. Sometimes the ability of building surveyors is insufficient, and they will employ an engineer to do some inspection.

S.14 Transportation is difficult and expensive for long distance and large, heavy loads

The storage space on-site, especially in a dense urban environment, is limited to store building materials and prefabricated components, which influences the application of OSC. In dense urban areas, narrow roads, and heavy traffic flow affect the transportation of large volume prefabricated components. Furthermore, the transportation cost is high, especially for the prefabricated components imported from overseas. For example, Prebuilt has completed many prefabricated single houses. Their problem is that each module of a house is very large. Transportation is a problem. During design, the architect gave a briefing to manufacturers that the modules could not be larger than 4.5m. Thus, the size of a room needs to be designed within these limitations. The thickness of the prefabricated ceiling and walls is greater. The story height of a normal apartment is 3.1m, but the story height of a precast apartment is normally 3.6m. The builder also mentioned that many precast elements need to be assembled and the truck is so large. In the areas close to CBD, such as within 15 km, many streets are too narrow to pass these trucks. There are also difficulties in lifting and assembling these large elements.

Category 4: Industry culture and market

S.15 Current business model may not satisfy OSC

The current business model of the construction industry is featured with a cycle of "land acquisition, development, and outright sale" (Pan et al., 2012). Such a business model may not satisfy the growing challenges of new technologies (Liu et al., 2016). House building is often decoupled from contracting but focusing on land acquisition and gaining profit from that process. This is mainly because land prices have a major effect on the final out-turn costs, representing up to 50% of total cost in some regions.

S.16 Dependence on traditional construction methods

The traditional project process is not suitable for adopting OSC (Nadim & Goulding, 2010). OSC adoption requires more time in pre-project planning to deal with issues of architectural design, labor and prefabricated components, transportation, technological solutions. However, the majority of residential developers are reluctant to invest in the preparatory phase as excessive time might induce higher capital costs. Meanwhile, being unable to finalize the design early on has been regarded as a significant barrier to adopting prefabrication construction.

S.17 Lack of government incentives, directives and promotion

Currently, there is a lack of necessary Australian codes and standards for OSC buildings. Without a nationwide standardization, most construction components are not standardized, which in turn makes it hard to design OSC buildings. Building surveyors are unable to certify the installation process of OSC buildings if the used installation methods are not included in current Australian standards.

S.18 Lack of market demand for prefabricated building or elements

The market for prefabricated buildings or elements is relatively small. There are many precast walls in Australia, which include external walls and internal walls. These precast walls are mostly used in the apartment. But they are seldom used in low-rise buildings. The architect considered that there is no massive market of prefabricated buildings in Australia because Australians prefer to have something customized and they do not like standard stuff. They like something unique. For some countries which have a large population, like China and India, precast buildings are cheap, and the people have no high requirement about the building.

S.19 The potential of job losses onsite due to OSC

The interviewed plumber mentioned that the wide application of OSC will reduce the work opportunities of plumbers significantly. Similarly, the electrician had concerns about decreasing the jobs of electricians. The reduction in jobs opportunities of workers will lead to the union's resistance to the application of OSC. The plumber is worried that in the long run, the work opportunities of the plumbers will be reduced significantly. If this business model is used, the work hours of plumbers will decrease, which means their payment will also decrease. The degree of their acceptance is a big problem.

5. Conclusion

This study verified the barriers of OSC in the Australian low-rise buildings. The result from the questionnaire survey shown the ranking of barriers to the OSC uptake in the Australian low-rise buildings. The critical barriers were "current business model may not satisfy OSC", "Interface problems on-site due to low tolerances", and "lack of market demand for prefabricated building or elements". The professionals' viewpoint has also been explored. Architects present a more serious concern in adopting prefabrication. The semi-structured interviews have further analyzed the results of the questionnaire survey. Four categories and 19 subcategories of barriers to OSC application in the Australian low-rise buildings were identified from interviews. Since most of the interviewees were came from Melbourne, their perspectives may not be enough to represent the thinking of the entire construction industry in Australia. The future study needs to explore the issue widely in the extent literature and practical construction industry. Although the barriers have been discussed and ranked, the majority of respondents present a positive willingness to adopt OSC and expect a towards OSC uptake in the Australian low-rise residential buildings.

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Adaptation of supply chain management theories to Australia-China construction supply chain

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Abstract
Along with the development of international trade and the increasing benefits of global sourcing, global supply chains are increasingly linking production across countries. Since joining the World Trade Organization in 2001, China is now acknowledged as the manufacturing centre of the world. Over the last decade, the Australian construction sector has sourced more building products from overseas, especially from China. However, construction enterprises involved in global sourcing are facing difficulties such as disruptions to shipping and logistics, issues with communication, differences in standards and regulations and more recently, changes in trade policy. This research is primarily a literature review of supply chain management theories with a particular focus on global construction supply chains to find out the global construction supply chain characteristics. The second objective is to identify the key challenges of the Australia-China building product supply network and to examine how current global construction supply chain management theories apply to the main challenges. The findings are expected to provide construction industry professionals and key policy makers with the necessary knowledge to understand the impact of the current trade tensions between Australia and China, and to manage this international supply chain into the future.

Keywords
Australia, China, global construction supply chain, supply chain management theories, systematic literature review.

1 Introduction

The construction industry represents a significant part of many national economies. However, the construction industry is often characterised as contributing significantly to greenhouse gas emissions, low productivity, significant material wastage, safety issues, and problems with project quality control (Moussaoui et al., 2021). Therefore, it is important to consider innovative supply chain management systems to improve value add and achieve customer satisfaction in the construction industry. Construction supply chain management (SCM) is defined as the application of manufacturing supply chain management techniques to mitigate the construction project risks, reduce construction cost, shorten project duration, and improve quality (O'brien, 1999).

In the last three decades, the global trade flows have accelerated dramatically and created enormous economic value. According to Woetzel et al. (2019), China has become the largest exporter of goods in the world since 2009 and earned the moniker "Global Factory". In 2013, China became the largest trading nation in the world, surpassing the United States' position (The World Bank, 2020). The Australian construction industry has been sourcing construction materials from overseas, especially from China since the last decade because of its significant manufacturing capacity and lower labour cost. Many economic sectors in Australia are similarly integrated into the global economy.

However, global supply chains are exposed to issues such as market volatility, different regulations, delays in transportation, differences in culture and language, concerns over product quality, and protection of intellectual property rights (Jiang and Tian, 2010). Moreover, recently global supply chain disruptions and vulnerabilities have been intensified because of export disruptions following the outbreak of COVID-19. Therefore, it is urgent to improve the global construction management efficiency by mitigating the global supply chain disruptions and addressing these problems.

Since the 1990s, researchers started concentrating on adopting SCM theories to identify the construction supply chain's characteristics and deficiencies and to find methods to improve the construction supply chain efficiency (Segerstedt and Olofsson, 2010). Therefore, this research adopted the global construction SCM theories to improve the construction supply chain efficiency and applied the theories in the Australia-China construction supply chain to cope with these two countries' supply chain challenges.

The research objectives are to firstly conduct a systematic literature review to determine applicable SCM theories. The second objective is to identify the characteristics of the Australia-China construction supply chain and to apply relevant SCM theories to investigate supply chain challenges. This research aims to contribute to the SCM body knowledge and propose measures to mitigate global supply issues in the construction sector.

2 Literature Review

2.1 Supply chain management theories

Supply chain includes all activities associated with the flow of goods from upstream raw materials to downstream final products and to the bidirectional flow of information between upstream and downstream agents. SCM is the integration of all the activities from procurement of materials or services then converted into final products and transfer to customers. SCM is a physical network consisting of different companies involved in the extraction of raw materials, creating products, and delivering them to customers through managing information flows, product flows and material flows between different parties by using SCM. (Nawangsari & Sutawijaya, 2019).

There are two main streams of thought within supply chain theory in the construction sector. The first one is related to logistics theory to minimise waste by adopting efficient supply chain management of material supply flows to construction sites. The second one is associated with lean construction to create value throughout the entire supply chain network to minimise project cost and time.

SCM theories were combined with lean management concepts to develop lean supply chain management principles (Manzouri and Rahman, 2013). Lean SCM theories may be categorised as follows:

- Inter-organisational theories: Emphasise the organisations should count on their internal resources to achieve customer or client orders by managing their internal activities such as inventory adjustment, production planning, solve disruption issues or reduce total cost.
- External theories: Emphasise the organisations rely on the outdoor resources to manage supply chains. The organisation has to use its supply chain partner's capacities to manage its activities, processes then solve problems and attain higher performance.
- Relational theories: Emphasise the power of relationship among supply chain participants to manage their internal activities and combining with supply chain management.

Organisations need to adopt reward system to attract supply chain partners' attention to achieve supply chain benefits, for example, mutual relationship.

2.2 Global construction supply chain management

Despite its origins in the manufacturing industry, SCM can also be useful and effective in the construction industry even though construction processes are different from manufacturing. SCM can achieve the integration and collaboration for both internal and external project stakeholders. The construction supply chain has been through a lot of problems because different interfaces exist in the supply chain (O'brien, 1999). It is estimated around 49.6% of the work in construction sites are non-value-added activities. There are plenty of reasons such as labour mistakes, construction wastage, decision-making delays, lack of communication in each stage of the supply chain, unpredictable weather conditions, lack of skilled labours, material and equipment wastage (Memon et al., 2011) that can reduce supply chain efficiency.

Since many construction products or materials are sourced from overseas in a complex global supply chain network, it is essential to manage the inter-organisational and external organisational relationships by managing different project stakeholders (Sarkis, 2012). Global supply chain organisations distribute across countries, outsource or offshore materials or processes. These global supply chains are constantly challenged to achieve environmental, social, or economic performance by integrating different project stages and project stakeholders together (Van et al., 2010). Other challenges include differences in economies, cultures, politics, infrastructure, and competitive environment. Global supply chains are relatively more exposed to potential delay interface connections, more uncertainties, therefore, it requires more complicated coordination, communication, and management (Manuj and Mentzer, 2008). While there is substantial research activity in the SCM area, there is clearly a lack of research extending SCM into global sourcing by the construction industry.

This research will conduct a systematic literature review to investigate global construction SCM theories, therefore, can improve the efficiency of global sourcing by construction companies.

2.3 Australia-China construction supply chain management

Following this trend of global trade and the increasing ease of logistics and information communication technologies, many organisations have moved some or all their operation and manufacturing factories to locations with lower wages, reduced taxes and abundant labour. The potential of sourcing from China has been recognised since the mid-1980s and trade between China and Australia has increased significantly totalling AUD 215 billion in 2018. China has become the manufacturing centre of many products required by the construction industry, namely ceramics, steel and aluminium, timber flooring, electrical goods, glazing, and furniture. This leads to China experiencing a rapid economic growth in the recent decades (Xue et al., 2012a) The low-cost labour and materials in China is a competitive advantage for global sourcing or offshoring. Even with labour costs increasing significantly from the late 1970s in China in tandem with increases in the cost of other factors of production, its competitive advantage in the global supply chain is clear. China's manufacturing capacity is often attributed to China's indigenous industrial clustering approach (Cuñat, 2013).

There are numerous benefits and risks in global sourcing. According to Hung Lau and Zhang (2006), there are three main motivations to source from China, including economic, strategic, and environmental. The most important motivation is economic benefits, which dramatically reduce the capital investment for offshoring companies since China has lower labour, production, monitoring and logistics costs.

2.3.1 Australia-China construction supply chain challenges

However, based on the survey conducted by Crossley and Tomson (2013), 92% of the study cohort found problems with product quality from overseas that cannot comply with Australian standards. For example, the Chinese suppliers may offer products at lower prices but compromise on quality since there is a lower chance for purchasers to return the defective products (normally around 30% of the ordered products). Additionally, purchasers do not have quality control inspection data when they are sourcing from China, as sourcing based on price which will lead to quality issues. Another main problem is the lack of intellectual property rights protection. As overseas procurement laws are inadequate, some Australian companies find that it is hard to protect their designs and other intellectual property rights when sourcing from China. Chinese institutions are normally weak, and the situation is worsened with the aggravating corrupt practices and other unethical behaviour. In addition, other issues also increase the difficulties of sourcing from China, such as language barriers, custom differences, transportation delays, fluctuations in currency exchange rates, the lack of supply chain management systems and longer inventory management (Jiang & Tian, 2010).

In addition, a recent study by Liu et al. (2021) observed that Australia has a high strategic dependency on China for many construction products, namely ceramic and furniture products. Strategic dependency was defined as (i) more than 50% of the imported commodity is from China, (ii) Australia is a net importer of that commodity, and (iii) China has greater than 30% market share of that commodity in global trade. Notably, Australia will find it hard to seek substitute suppliers from other locations if there is a supply chain disruption between Australia and China. Therefore, it is important to adopt the global construction supply chain management theories in the construction supply chain to improve the supply chain efficiency.

3 Research Methodology

As Scopus is the largest abstract and citation database of peer-reviewed literatures including scientific journals, books and conference proceedings. To identify global construction SCM characteristics, a systematic literature review of the relevant articles from Scopus search engine is conducted by using the following search string: "TITLE-ABS-KEY (global AND construction AND supply AND chain AND management) AND (EXCLUDE (SUBJAREA , "MATH") OR EXCLUDE (SUBJAREA , "AGRI") OR EXCLUDE (SUBJAREA , "EART") OR EXCLUDE (SUBJAREA , "CHEM") OR EXCLUDE (SUBJAREA , "CENG") OR EXCLUDE (SUBJAREA , "MEDI") OR EXCLUDE (SUBJAREA , "PHYS") OR EXCLUDE (SUBJAREA , "BIOC") OR EXCLUDE (SUBJAREA , "IMMU") OR EXCLUDE (SUBJAREA , "PHAR") OR EXCLUDE (SUBJAREA , "VETE")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j"))". A total of 95 papers were obtained and after filtering for relevance, availability, duplication, and completeness 47 papers were selected. All the reviewed papers are journals which can meet the accepted high standards in this discipline.

Ten main global construction SCM characteristics were categorised from these papers. After these characteristics were identified, they were then compared to general SCM theories to distinguish characteristics that were unique to global construction supply chains. These global construction SCM theories will then be applied to the Australia-China construction supply chain to detect and classify the supply chain challenges.

4 Findings and Discussion

4.1 Findings

Ten main characteristics were identified for global construction SCM:

a. **Inventory management [IM]:** This is the process of planning, organizing, and controlling inventory to reduce the cost of inventory. IM helps to provide adequate supply but not excessive supply (Singh & Verma, 2018).

b. **Logistics management [LM]:** Logistics is a relatively important part in construction SCM to provide efficient approaches for project scheduling and budget. logistics including procurement, processing operations, and customer relationship management. Accurate flow of information is very important in construction logistics as different project stakeholders are involved (Moussaoui et al., 2021)

c. **Environment management [EM]**: Considering sustainable development, the global construction projects should cope with environmental problems which can play an important role in the decision-making process such as politics, economics, industry, and individuals. The current main environmental problem is climate change or global warming (Mohammadnazari and Ghannadpour, 2020). Therefore, the global construction supply chain should develop a Life cycle Assessment to reduce energy consumption and reduce CO2 emission (Sutawidjaya et al., 2021). Thinking from a life cycle perspective to reduce the post construction maintenance and achieve the global environmental advantages through the project lifetime.

d. **Design management [DM]:** Optimise the design for prefabrication or offsite construction to achieve value for money and comply with the concept with lean construction to maximise value and minimise waste (Lu et al., 2021).

e. **Risk management [RM]:** Construction risks could lead to cost overruns and delays. Therefore, identifying risk categories and risk response strategies are critical for global construction SCM (Wang et al., 2020). As for the external risks, country risks and multi-culture risks are the main reasons for global supply chain emergencies, while financial risks and decision risks are the main internal risks.

f. **Collaboration Project Management [CPM]:** All project stakeholders should consider collaborating from environmental, economic, and social aspects to achieve sustainable project outcomes (Larsson and Larsson, 2020). All project stakeholders in the global construction supply chain need to adopt an efficient knowledge sharing system to effectively collaborate. (Hao et al., 2019)

g. **Supplier/Subcontractor/Supply chain evaluation [SE]**: Especially in the global supply chain, the supplier selection involves plenty of risks. Therefore, a supplier evaluation model is developed to help the contractors to select suppliers (Cheng et al, 2020). Shan and Li (2014) adopted the particle swarm optimization model to evaluate the supply chain performance since the construction supply chain is complicated with inter-organisational structures, therefore contributing to a comprehensive construction enterprise supply chain performance evaluation system. Tserng and Lin (2002) adopted the portfolio theory in financial management by using the Accelerated Subcontracting and Procuring (ASAP) model to select subcontractors.

h. **Cluster Strategy [CS]:** Industrial clustering not only contributes to new business formation but also accelerates innovation (Ikram et al., 2018). Clustered supply chains can help small and medium sized enterprises (SMEs) to cope with the competitive global supply chain through different ways of collaboration. A clustering strategy can help SMEs to achieve higher global share (Xue et al., 2012a).

i. **Information Technology [IT]:** Integrating both Building Information Modelling (BIM) and Geographic Information Systems (GIS) to monitor material flow and resource availability in the construction supply chain (Irizarry et al., 2013).

j. **Resource planning [RP]**: Resource planning systems help the construction supply chain reduce waste by addressing material shortage issue that may delay the project or increase inventory cost (Tserng et al., 2006).

These ten characteristics of SCM specifically concerned with global construction supply chains were then compared with the SCM categories and theories and listed in *Table 1.* The reviewed papers are coded based on the global construction SCM characteristic categories in the ***Reference Section.***

Table 1. Applying SCM theories on GCSCM

	Code	**Characteristics**	**Freq.**	**SCM Category**	**Global construction SCM Theory to cope with SCM Theory**
1	IM	Inventory Management	1	Inter-organisational; Relational	**Inventory Management Theory:** the continuing process of planning, organizing, and controlling inventory that aims at minimizing the investment in inventory while balancing supply and demand.
2	LM	Logistics Management	3	Relational	**Logistics Theory:** Build up construction logistics centres (CLC) to set up a Kitting by packing up different materials ans products then deliver them as one package and combine with just-in-time delivery to deliver the right quantity at the right time and in the right condition.
3	EM	Environment Management	21	External	**Life Cycle Assessment Theory:** Quantify the project lifecycle energy consumption, greenhouse gas emission to cope with global warming issue and achieve green supply chain. **Activity Based Life Cycle Assessment:** Concentrating on critical activities in the global construction supply chain to minimise the environmental impacts.
4	DM	Design Management	3	Relational	**Choosing by Advantages (CBA):** Creating transparent and collaborative environments by identifying sustainability factors, organising location-dependent factors, incorporating supply chain issues at the design stage to choose globally sustainable materials. **Design for Manufacture and Assembly (DFMA):** Design products as prefabrication and other offsite construction methods to improve construction productivity with advanced construction materials. Also consider the assembly technologies for logistics and supply chain management.
5	RM	Risk Management	2	Inter-organisational; External; Relational	**International Capacity Cooperation Theory:** conducting cross country risk assessment to identify if there is any structural failure, such as market failure caused by tariff barriers, excessive transaction costs or excessive trading risks.
6	CPM	Collaboration Project Management	5	Relational	**Game Theory (Equilibrium Strategy):** Achieve knowledge sharing in between the construction supply chain enterprises to improve the supply chain sustainability. **Lean Construction Theory:** Lean construction research has been widely pursed as for global collaboration to reduce construction period and save budget. **Supply Chain Integration Theory:** Integrate and associate with the inter-organisational collaboration to achieve mutual benefits.
7	SE	Supplier/Sub-contractor/Supply chain evaluation	5	Relational	**Portfolio Theory:** From the financial management by listing all the possible subcontractor or supplier combination and analyse to find out the most ideal combination in the portfolio.
8	CS	Cluster Strategy	4	Relational	**Industrial Cluster Theory:** Considering from both vertical and horizontal integration of supply clusters to promote a competitive supply chain network and accelerate a sustainable cluster development.
9	IT	Information Technology	1	Inter-organisational; Relational	**Information Theory:** Adopting shared information by using BIM and Geographic Information Systems (GIS) to track supply chain status and ensure the delivery on time. All the supply chain

					partners are cooperating together to improve supply chain efficiency.
10	RP	Resource Planning	4	Inter-organisational; Relational	**Resource Planning Theory:** Global optimization of inventory cost can benefit for the entire supply chain. Planning the resource inventory and organisation the in early stage of supply chains to prepare for resource shortage issue and over inventory issue.

4.2 Discussion

4.2.1 Global construction SCM theories

From the systematic literature review, ten global construction SCM characteristics were identified. It is notable that almost half of the reviewed papers belong to the "External" category in SCM, which indicates that researchers have focused more on life cycle assessment and tried to achieve green SCM, which is a competitive advantage for an organisation that providing project stakeholders with value added activities and enhancing the sustainability of supply chain (Mohammadnazari and Ghannadpour, 2020). Whereas general SCM is more focused on inter-organisational and relational categories to reduce the construction period, save project budget and improve the project quality according to the research conducted by Manzouri and Rahman (2013).

Both global construction SCM and general SCM have focused on "Relational" category, which indicates the importance of collaboration of different project stakeholders to achieve mutual benefits. Global construction SCM concentrated on wider relational conditions, such as managing global logistics (Moussaoui et al., 2021), considering about inventory management (Mohammadnazari and Ghannadpour, 2020) from the project planning stage to balance supply and demand globally, evaluating supplier risks from overseas (Liu et al., 2017), and developing clustering strategies to accelerate the supplier innovation system and improve the supply chain efficiency (Xue et al., 2012a).

4.2.2 Applying global construction SCM theories on Australia-China construction supply chain

According to ***Section 2.3.1***, some challenges existing in the Australian-China construction supply chain can be explained by global construction SCM theories, such as the offshoring quality issue can be illustrated by Design for Manufacture and Assembly (DFMA) theory, International Capacity Cooperation Theory, and Information Theory. Therefore, when Australia sourcing from China, they should provide detailed product description and share sufficient information considering about construction efficiency to ensure the suppliers can provide the relevant products that suitable for the project, then save construction cost. As for the intellectual property rights protection challenge, Portfolio Theory can be applied when choosing the supplier and avoid future disputes. In addition, the transportation challenge can easily adopt Logistics Theory, longer inventory management issue can be easily explained by Inventory Management Theory. As for the problem that Australia is strategically dependent on materials from China, Australia can adopt Game Theory and Resource Planning Theory to achieve mutual benefits with China and planning resource from a lifecycle perspective to increase the construction supply chain resilience, therefore, to seek for mutual benefits

4.2.3 Limitations and further research

This systematic literature review was conducted based on a very limited set of key words. Further research will include on additional key words such as "SCM", "global SCM", "construction SCM" to identify associated global construction SCM theories. Further research will utilise in-depth interviews with construction companies in the supply chain to identify more recent issues relating to the pandemic and trade tensions, subsequently, seek solutions to improve the supply chain.

5 Conclusion

This research has identified ten global construction SCM concepts based on conventional SCM theory. Global construction SCM concepts are more concerned with lifecyle assessment and project stakeholder collaborations, while conventional SCM theories are concentrated on inter-organisational management. These identified global construction SCM concepts can be adapted to illustrate and resolve current and future challenges in the Australia-China construction supply chain. Relevant policy makers can also develop more effective policies based on these global construction SCM theories. This research helps scholars to better understand the global construction SCM concepts and intents to solve the relevant challenges.

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Barriers and Benefits of Self-Organised Housing: A Systematic Review of Literature

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Abstract

Australia's housing prices are continuing to rise at a rate faster than household income rates, causing an affordability issue. Previous studies revealed that the existing policies in Australia could not lower housing prices in Australia, and the policies merely benefit the majority of Australians who currently own a home. Hence, this research identifies an alternative solution to reduce housing development costs, where policy reform is not crucial. The self-organised housing model can be used as an alternative strategy for providing affordable housing solutions to low-income earners. This research aims to identify the barriers and benefits of self-organised housing. A systematic review of literature was conducted, and secondary data was extracted from peer-reviewed journal articles and grey literature. A total of 73 articles from different journal articles and industry reports were identified and reviewed thoroughly. The findings of the research showed that the main barriers include financing, planning approval, collaboration, and recognition and familiarity. On the other hand, the key benefits comprise suitability, sustainable implementation and cost savings. This study concluded that self-organised housing not only demonstrated the ability to lower initial housing costs, but also reduce the lifecycle costs through the encouragement of sustainability.

Keywords: Self-organised Housing, Affordability, Deliberate-Development, Policies, Residential, Sustainability

1 Introduction

The Australian Government defines affordable housing as 'one that is appropriate for the needs of a range of low to moderate-income households' (Abelson, 2009). Housing affordability problems are the direct result of increased property market prices, which outweigh the typical combined income of potential homeowners. In Australia's case, this directly affects low-income earners and first home buyers (FHB). Housing Affordability has been a concern in the 21st century in major Australian cities such as Melbourne and Sydney, where the market prices are continually increasing at a faster pace than the national income rate (Demographia, 2020). According to Abelson (2009), housing affordability can be negated via policy implementation to subsidise low-income households and enable greater purchasing power. Such monetary policy measures have previously and continuously been implemented by the Australian Government, which has proven to be a further inhibitor to low-income earners as housing prices have continued to steadily increase. Morris et al. (2019) demonstrated that government tax policies promote home financialization via "negative gearing" and a favourable capital gains tax for investors. As a result, low-income earners cannot depend on Federal Government initiatives to ensure housing affordability. Subsequently, it is considered that individual action is required to help create affordable housing opportunities. Implementation of Self-Organised housing is a method that has been internationally proven to reduce the cost of housing and is controlled by the occupier (Lang et al., 2017). The collective housing method involves the participation and remuneration of multiple parties, grouping together to develop several homes fit for use without the intention to on-sell. Through negating developer's fees and obtaining their dream home at cost price rather than market price, individuals were able to achieve up to 25-30% cost savings (Lloyd et al. 2015). Crabtree (2018) identified that Self-Organised Housing is relatively unfamiliar in the context of the Australian Domestic Housing industry; therefore, evidence is inadequate to determine the barriers that Australians would likely face when participating in Self-Organised Housing. Consequently, International experience and case studies have been relied upon to identify such barriers. In Australia, it is well established that housing prices are continually rising at a rate, which is unsustainable for younger generations to afford. The necessity for new housing development techniques is understood to be critical, to enable low-income earners the ability to purchase their first home without the financial stresses currently associated with the 'Australian Dream' (Daley et al., 2018). Therefore, the primary aim of this research is to educate readers about the benefits of Self-organised Housing and to evaluate how such development methods can be effectively implemented in Australia, mitigating housing affordability problems for Australians. To meet the aim of the study, the following objectives are formulated: (a) To explore the benefits of Self-Organised Housing from international experience; (b) To identify barriers experienced internationally when Self-Organised Housing was implemented; and (c) To propose actions which may be implemented in Australia to prevent barriers previously experienced internationally related to Self-Organised Housing.

2 Literature Review

2.1 Housing Affordability in Australia

In the early 1990s, it took an average household around six years to accumulate a 20% deposit on a standard property. It takes around 9 to 10 years presently. Additionally, the typical deposit for first-time home purchasers climbed from around $42,000 in 2008 to over $70,000 in 2014 (Simon et al., 2017). Many young households are having difficulty saving for a deposit because their HELP loan debts have increased and they are now required to invest a greater percentage of their income into superannuation than their parents did 25 years ago. (Daley, 2018). In Victoria, the average full-time working adult weekly earnings in May 2007 were $1,100.10, rising to $1,562.60 in May 2017. This indicates a 42% rise in wages; however, such figures do not account for factors such as inflation, underemployment, or reduced working hours for younger generations due to increased years of study (Raynor et al., 2017). However, the growth in house prices has exceeded the growth in wages across the same period. Using Metropolitan Melbourne as an example, the median sale price jumped from $522,000 to $822,000, representing an increase of over 57% (Raynor et al., 2017). The Australian Government has implemented various policies and has spent billions of dollars on initiatives to help combat housing affordability in Australia to assist low-income earners and first homeowners to make their way into the housing market. Although, regardless of the policies implemented the housing prices have continued to increase at a steady rate. Through critical analysis of such policies, it may help identify which measures have been ineffective. Furthermore, it is understood that the term affordability is a relative measure on the economic state of households to determine what is 'perceived' as affordable. Abelson (2009) identifies that housing costs are not simply a figure put forward from the real-time purchasing cost of the home/land but should be calculated on overall lifetime costs, as those overall costs include loan repayments/interest. Abelson correctly de-credits the statistics of housing costs as they do not accurately reflect the ‘financial stress’ imposed on the homeowner. In saying that, Abelson does not consider the costs of the services that the new age homeowner has to pay such as gas, electricity and water which further contributes to the overall lifecycle cost to the home.

2.2 Government Policies

Abelson (2009) argues that the increase in the housing market was an occurrence of loan interest rates reducing over time, allowing the purchaser to obtain greater loans without increasing the overall interest accrued. The author identifies this as the true cause of the initial spike in housing costs. Policies which the Australian Federal Government have implemented to help combat housing affordability for FHB are related to monetary concessions and grants. The two most notable policies are ‘First Home-Owner Grants’ (FHOG) and Stamp Duty Concessions. Both policies have been introduced in an attempt to increase the buying power of FHB. In Australia, each State & Territory charges their own specific stamp duty rate on home purchases dependent on the expenditure on the property and whether it is being used as an investment or for occupation. The majority of State Governments have implemented some form of stamp duty concessions for FHB. In Victoria, homes up to $600k were not subject to stamp duty and homes valued up to $750k were provided with a discount, permitting net savings up to $30,000 for FHB (State Revenue Office Victoria, 2017). Stamp duty concessions cost the state budgets millions of dollars per year. These policies have only resulted in spikes of FHB purchases, allowing younger Australians to purchase properties earlier and at a higher expenditure rather than lowering housing prices. Such spikes in activity have also demonstrated a down period soon after. Blight et al. (2012) identified that an immediate influx of FHB purchases in 2002 was caused by the implementation of grants being doubled in size. The 6-month influx was then followed by a downturn period from 2003-2006. Such phenomenon also occurred via the implementation of first home buyer packages in 2009 creating an inconsistency in the demand for housing, which subsequently impacts developers’ risk and housing prices.

The Australian Government has a long history of providing FHOG dating way back to 1964 implemented by the Menzies Government. FHOG policies have continued to be an ongoing affair of Federal Governments over the years, being subject to abolishment and re-introduction as new cabinets were elected to parliament. Further to the Federal Government grants provided over the past 70 years, State and Territory Governments have also provided further ‘top-up’ cash grants to FHB. The Victorian Government was the first to do so, introducing the ‘First Home Bonus’ in 2004 providing an additional $5,000 for new and established homes purchased by FHB (Dungey et al. 2011). Cash grants provided by Federal and State Governments have only instilled false hope to FHB’s, providing the notion that they have an additional $10-$20k to spend on their first home at auction. A report published by Daley et al (2018) considered that all FHOG only inflated the demand for housing, allowing some individuals to outbid an investor, thus further increasing average house prices. Previous research has shown that present policies in Australia cannot reduce housing costs, and that the measures only benefit the majority of Australians who already own a house. As a result, this research identifies an alternative strategy to reduce housing development costs, where policy reform is not crucial. The self-organised housing model can be used as an alternative strategy for providing affordable housing solutions to low-income earners. Therefore, it is important to explore the barriers and benefits of self-organised housing in Australian context.

3 Methodology

The systematic literature review in conjunction with critical analysis was adopted, to enable a comprehensive understanding of development methods implemented internationally. The Scopus database was utilised to conduct a search of relevant academic journals initially on keywords such as "Australia" "Baugruppen" "Deliberative Development" "Development Finance" "Home ownership" "Housing Affordability" "multi-residential Development". This keyword search was unsuccessful as 'Deliberate Development' is consistent with various titles around the world, therefore it was difficult to limit research to a singular title reference. An alternative search was conducted based on journal articles which shared references with the research of Sharam (2020). Sharam's research was chosen as the key journal article as it was well recognised within deliberate development research, which included keywords similar to those originally identified.

Database Search:

- Identification of relevant research journal article, conduct main search based on documents with shared references~~.~~ (3,919 Documents Identified)
- Refinement of database search based on 'subject', 'publish year' & keyword search 'Housing' (334 Documents extracted)
- Exclusion Criteria: 'Medicine' 'Nursing' 'Biochemistry, genetics & Molecular Biology' 'Neuroscience' 'Pharmacology, Toxicology & Pharmaceutics' 'Dentistry' 'Chemistry' 'Immunology & microbiology'

Study Eligibility (Screen 1):

- Review of journal articles relevance based on keywords and abstract
- Articles Screened (334), Articles Included for further review (73)

Study Eligibility and Data Extraction (Screen 2):

- Further review of relevant articles to check the relevancy of the full paper
- Articles screened and retained (33)

Data Analysis:

- Themes Identified (5): Affordability in Australia, Finance, International Experience, Policies, Self-Organised Housing

Figure 1. Systematic Review Process

Upon identification of articles sharing references with Sharam's research, 3919 documents were included in the search result. To further refine the search result on the Scopus database, all documents were required to be in the 'final' publishing stage to ensure validity of research, a 20-year timeline from 2001-2020 was input and exclusion criteria was applied to remove inapplicable research relating to: 'Medicine' 'Nursing' 'Biochemistry, genetics & Molecular Biology' 'Neuroscience' 'Pharmacology, Toxicology & Pharmaceutics' 'Dentistry' 'Chemistry' 'Immunology & microbiology', the final refinement method was the additional keyword search of 'Housing'. This refinement provided the systematic review with a total of 334 documents for further screening via excel spreadsheet review. All research journal data was exported into a spreadsheet containing the following information: ‘author/title/year/abstract/author keywords/document type’. The screening method involved review of ‘author keywords’ which provided a brief subject criterion of each journal article. Upon review of the keyword search, the number of relevant journals were shortlisted to 73. Upon further screening, 33 articles are used for further analysis. The processes involved in the systematic literature review are illustrated in the Figure 1.

To further justify qualitative data extracted from Scopus, grey literature review was undertaken to extrapolate the numerical data provided in the research journals. The numerical data provided insight into the benefits to CSO housing, justifying the possibilities of such development methods. Further review involved critical analysis of case studies from international implementation, the research journals identified the major pitfalls/barriers associated with CSO housing developments. Furthermore, grey literature review of qualitative & quantitative data was utilised to further support key findings and themes identified in the systematic review. Relevant data were obtained from research providers such as CoreLogic & the Australian Bureau of Statistics (ABS). Quantifiable data of housing prices enabled accurate representation of policy efficiency. The critical analysis provided insight into the results and the effectiveness of such policies.

4 Findings

Systematic review enabled the identification of key findings within published literature. It was important to establish consistency of findings throughout international case studies as requirements and policies can vary between countries. Using critical review and analysis of international implementation, barriers and benefits were identified to provide an overall assessment and recommendation of how CSO housing can help young Victorians in the current housing climate.

4.1 Existing Policies Efficacy

To mitigate increasing housing prices, the Australian Government was pressured to implement policies to help combat the continual rise. Since the beginning of the 21st century various State and Federal policies were implemented (Dungey et al. 2011), including: (1) *First Homeowner Grant:* (FHOG) in 2000 providing First Home Buyers (FHB) $7,000. (2) *First Homeowner Boost*: Following the global economic crisis, FHB purchases between October 2008 & July 2009 were provided additional funds up to $14,000 and $21,000 for those building a new home. (3) *First Home Bonus*: The Victorian Government provided assistance to FHB building a new home with up to an additional $13,000 towards their new home construction, while also being eligible for stamp duty concessions. (4) *Stamp Duty Concessions*: In 2017 the Victorian Government implemented concessions on Stamp Duty taxes, where homes up to $750k were provided reduction on stamp duty costs. The policies identified above present a sample of some of the monetary incentives implemented by the Federal and Victorian State government for FHB. Based on the key statistic identified by CoreLogic, it is considered that such incentives have only further increased housing prices in Victoria.

4.1.1 Stamp Duty Savings

The implementation of stamp duty concessions was envisaged to assist FHB, enabling greater purchasing power against potential investors. The investor, although bidding the same amount for the home would be subject to greater stamp duty expenses. Effectively paying upwards of $20,000 more than the FHB on a property purchase valued at $650k.Although stamp duty concessions are provided to FHB to serve as a competitive edge against other purchasers, stamp duty concessions act in a similar way to cash grants for first home buyers. As buyers do not have to pay as much stamp duty, they are instead prepared to pay more for a property, therefore increasing demand and not decreasing overall housing costs (Davidoff et al., 2013). Further to Davidoff's view, when FHB are bidding against each other, the stamp duty savings become irrelevant, as each FHB would likely have the same purchasing power and would bid the additional money saved through stamp duty concessions. Consequently, spending an additional $20-$30k on a house bid, raises the average house prices by up to 3%. Furthermore, the additional money is likely to be added to the overall mortgage loan (subject to finance rates), where an additional $20k to a mortgage (subject to 2.64% finance rate over 25 years where payments are made monthly) would be valued at $27,342. Cao et al. (2015) estimated that stamp duty concessions equate to $17 Billion of taxes per year, where such Federal and State budgets could be better utilised elsewhere.

4.1.2 First Homeowner grants (FHOG)

In the past 20 years, it has been demonstrated that such grants offer little to no assistance to first home buyers as prices have continued to inflate at a rate which younger Victorians cannot afford. This has been reflected in the Federal Government's decision to reduce grants to those purchasing established dwellings and further incentivising new builds. It is yet to be determined if such grants only contribute to developers/builder's net profits, although importantly it does encourage the supply of new homes contributing to the economy and employment rates. Eslake (2013) estimates that the State and Territory Governments have spent a total of $22.5 billion (in 2010-11-dollar values) from 1964-2011. The Federal Government insists that such grants are in place to assist FHB's. However median house prices over the past 20 years indicate that the expenditure of $1.3 billion per year (Daley et al. 2013, p. 49) is likely better off spent elsewhere.

4.2 Benefits of Self Organised Housing

4.2.1 Suitability

Palmer (2016) described that speculative, supply-led housing produces conservative and risk-averse dwellings to purchasers, creating a lack of diversity amongst dwellings in apartment buildings. It is argued that the purchaser should be involved in the design of each property to ensure that the housing market suits the buyer, guaranteeing supply meets demand. Sharam (2017) explains that the housing market is unstable due to either undersupply or oversupply throughout the housing market. When oversupply of the housing market is apparent, it creates greater risk for the developer as they are not able to sell the property but are exposed to ongoing loan repayments. This in turn drives the market price up to combat the financial liabilities of the development. Housing suitability compares the number of bedrooms within a dwelling against the number of occupants utilising the bedrooms, identifying whether the dwelling is under or over utilised. From 1911 to 2011 the average number of people per dwelling has decreased from 4.5 to 2.61 (Australian Bureau of Statistics, 2017) where the ABS Census of Population and Housing (2016), identified that 69% of houses and 47% of apartments had 1 or more spare bedrooms**Error! Reference source not found.**. In a world where occupiers are seemingly purchasing homes with more bedrooms than required, deliberate development allows the purchaser to facilitate design based on essentials, ensuring that the occupier is only paying for what they need, thus reducing overall purchasing costs.

4.2.2 Sustainable Implementation

Troy et al. (2015) identified that developers and builders carry all financial and development risk, where dwellings are built for profit without consideration to value, life-cycle management, and maintenance. Development decisions relating to lifecycle benefits do not decrease the purchasing value of a home but instead drive construction costs up. Abelson (2009) confirmed that financial stress and affordability should be considered as the overall lifecycle cost with utility and loan repayments as the main contributing factors. Therefore, sustainable implementations to developments considerably contribute to affordable housing without requirement for government policy. Self-Organised Housing allows the occupier to be at the head of the decision-making process allowing sustainable implementation, which may increase initial construction costs but save on lifecycle costs in the future, outweighing the initial investment. Not only does a sustainable home reduce the lifestyle costs for occupiers, but the Nightingdale Housing model created by Breathe Architects identified by Smith (2007) also revealed that a sustainable design does not have to reflect a premium price tag. Piaia's study (2017) on the 'PROFICIENT' CSO business model identified that stakeholders invested in CSO housing, were guided by professionals with the use of decision supporting tools made available. Tools such as the 'Total Cost of Ownership tool' (TCO) were utilised to present an estimate of mortgage, maintenance, and energy costs over a 30-year period. This tool helped investors identify the lifetime benefits of sustainable inputs in the project.

4.2.3 Cost Savings

Without doubt, the main attraction to the self-organised development method is the reduced overall purchasing cost to those involved. Szemzo et al. (2019) identified that residents of CSO housing can reduce overall costs by as much as 10-20% compared to market pricing. This allows the purchasers to severely decrease the overall loan capacity required and contribute to less financial stress associated with loan repayments. An additional benefit to the CSO housing method is that it does not directly require government policy or reform to implement. Through the removal of developer profit margins, marketing & agent fees typically associated with speculative development. CSO housing immediately presents a viable solution to Victorians looking to purchase their first home. The reduced immediate costs in conjunction with high-quality design implementation & sustainable features serves as multi-stage cost-benefit to occupiers: (1) Reduced Overall purchasing costs reduces the deposit capacity requirement for lending authorities; (2) Decreased overall project costs generating a high-quality project in conjunction with sustainability benefits increase overall development value. Increasing profitability index ratio, decreasing lending authority risk; (3) Reduced overall mortgage for purchasers: Reducing the on-going mortgage repayments, therefore, reducing financial stress; (4) High quality design implementation & sustainable features lead to reduced financial requirements relating to maintenance and services costs.

4.3 Barriers Experienced Internationally

4.3.1 Financing

One of the major barriers experienced by CSO housing is that stakeholders involved are required to bear the risk of the development. They must demonstrate enough financial equity to enable the lending authorities to approve the loan to be able to purchase the land and procure the construction process. Typically, this is not an issue for an experienced developer as they can demonstrate prior experience and capital, based on previous developments. Unfortunately, self-organised developments are considered as a high-risk liability to lending authorities regardless of the development value index. Sharam (2020) identified one example of an owner/occupier syndicate in Australia that participated in the development of four townhouses. Members were required to provide 30% of the total development cost upfront and demonstrate the capacity to share the development risk. Essentially, each party was required to demonstrate that they were able to service the loan in the event of one party became insolvent. In Finland Laine et al. (2018) identified that resident-driven developments were required to finance 50% of the development cost themselves, in Germany equity of 30-40% is required for (Baugruppen) CSO developments to obtain debt financing (Ring, 2016). Daley (2018) calculated that in Australia it takes on average nine to ten years for a household to save enough money to achieve a 20% deposit. Whereas saving enough to fund a collaborative development would seem unattainable given the current lending authority requirements.

4.3.2 Planning Approval

Financial risk and liability are inhibited by the planning approval process, incurring extended overall project timelines. When inexperienced developers are provided with loan approvals, it typically results in higher interest rates. Sharam (2020) demonstrated experience with one set of members experiencing a long delay in the planning approval process. This delay caused considerable additional project costs where the majority of members were required to sell their properties as the debt was larger than anticipated. Smith (2007) identified that planning requirements in relation to land use were identified as a substantial constraint for occupier led sustainable developments, this was mainly due to onsite planning requirements and local planning schemes. Planning restrictions create difficulty and delays to CSO housing developments resulting in financial stress to investors and insolvency.

4.3.3 Collaboration

Hamiduddin et al. (2015) explained that such developments are not appropriate for low-income earners as higher tier income earners have more budget flexibility and contingency funding. This would negate anxiety related to increased development costs related to delays and overruns. In addition to cost restraints associated with group developments, Laine et al (2018) reviewed a case study of a collaborative project in Malta. It was demonstrated that participation from all parties involved long meetings and heated discussions mostly related to the division of costs. The collaborative decision-making process can lead to prolonged design decisions and delays in overall timelines. Piaia et al. (2017) addressed the implementation of such developments throughout Europe, namely Germany, UK & Italy. One of the greater challenges identified was collective decision making. Due to an increased number of stakeholders, it resulted in an elongated decision-making process where designs took up to 10 years in the making. It was demonstrated that the recruitment of a group leader needs to be reviewed before commencement, as members are typically inexperienced and can cause delays and issues when it comes to decision making. A male resident involved in a collaborative development in Hamiduddin's study identified the removal of an external resource resulted in tension at weekly meetings during the build phase. This was due to conflicting opinions without mediation from an external resource, it was identified that an effective project manager was considered essential to the success of the scheme.

4.3.4 Recognition and Familiarity

Palmer's (2018) reviews the collective self-organised housing movement, demonstrating support of 'promoting urban consolidation' and identifies it as being un-unique to the Australian and worldwide market. This method of collective development is described in various terms worldwide, resulting in a lack of universal reference. Lang et al. (2018) demonstrated the lack of familiarity and usage of variable terms amongst published literature for similar development methods worldwide. The Collaborative Housing model or similar methods were referenced in 16 different terms amongst 35 published papers. The lack of consistency with respect to terminology establishes unfamiliarity and scepticism throughout the housing industry, hindering the ability to openly discuss and educate the benefits of actions.

5 Discussion

5.1 Government Policies (Federal & State)

Qualified research has been provided by Abelson believing that housing affordability can be negated through policy implementation to subsidise low-income households, enabling greater purchasing power. Although, this policy measure has effectively been implemented via current FHB grants, which only increased all lower tier income earners to a higher level for property purchases, increasing property bids as a result. Daley (2018) recognised that first home buyer grants may help some individuals to outbid an investor to purchase their first home, although these policies majoritively result in greater housing prices through inflation of demand. Policies relating to cash grants mostly benefit existing homeowners further increasing sale prices. Based on calculations provided by Daley in the Grattan Institute review of Housing Affordability, it was estimated Policies related to housing affordability contributed by both Federal and State Governments equate to the following amounts: Exemption from capital gains tax - $35 Billion per year; Exemption from state land taxes (75% of residential land exempt) - $7 Billion per year; and First home buyers grant $22.5 Billion per year. Approximately $64 Billion spent on grants are argued to only increase housing prices further, making it more difficult for first homeowners. In the UK the Homes and Communities Agency (HCA) launched a $30M fund to help facilitate custom-built homes in July 2012, the objective was to "bring forward sufficient numbers of successful schemes to demonstrate to commercial finances that the lending model is a viable and sustainable business which can be taken forward by the industry" (HCA 2012, p. 7). The loan was provided to help facilitate initial project costs pertaining to land purchase, site preparation and professional fees. Lang. et al (2017) identifies that (Baugruppen) CSO housing projects are challenging to attract enough potential residents due to the initial outlay required for high land prices. If policy funds were re-directed to help encourage self-organised developments, where interest-free or low-interest loans would be paid back similar to HELP debt, this would help reduce the risk and liability associated with self-organised housing. A shortfall to the HCA fund implemented in the UK was the $45 million in applications received, where demand was higher than originally allowed for, making it difficult to differentiate between applicants. Hamiduddin et al. (2015) identified the benefit of Germany's use of design-based competitive bidding for public land, on-sold for collective developments only. As groups were required to provide proof of project finance and viability as part of their submission, this filtered out weaker groups who were unable to prove commitment to the project. If an application is required similar to a tender bid, this is likely to reduce the risk associated with creation of a government policy fund for CSO housing.

5.2 De-risking approval Process (Local)

Interviewees in Morris' (2019) study suggested that in lieu of implementing policies, barriers experience at the local and state government level should be removed. Barriers experienced was the requirement for facilitation of finance and the capacity required to initiate a CSO housing development. In addition, 'interviewees called for preferential treatment in local council planning approval to reduce risk and avoid time delays' as reported by Palmer (2020). It is understood that government approvals are a timely process during CSO housing developments due to local council concern, this delays the ability to commence construction and increases loan repayments. As the development timeline extends, investor expenditure increases without tangible outcomes, causing build-up of pressure and anxiety within the development group. This is duly demonstrated by Sharam (2020), where 5 out of 9 case studies experienced increased costs due to planning approval delays, in which some instances caused excessive financial debt and insolvency. Grattan Institute's (2011) report, recommended a new 'Small Redevelopment Housing Code' which would protect neighbours, reduce planning uncertainty, and improve the quality of new developments. Such local government policy reform would provide guidance for CSO Housing developers to ensure rapid approvals, reducing construction delays and financial liabilities. This may further encourage CSO housing as a recognised development technique within local municipalities, where participants would believe that council approval is not a barrier. Hamiduddin et al. (2015) identified countries where there is a dependency and reliance of volume build projects (in this case Australia), supportive planning and government recognition was vital to promote self-build as an alternative method to purchasing an affordable apartment in a volume build development. Although based on the research of existing policies in this report, it is understood that Government policy is not something low-income earners can rely on when it comes to housing affordability and individual implementation is required to help create affordable housing opportunities from the onset.

5.3 Recognition

Currently, there is little to no recognition of Self-Organised Housing in Australia, this is reflected in political processes and acknowledgement at a local level. Bossuyt et al. (2018) recognised the necessity for social commitment, to achieve political commitment from authorities. Promoting the requirement for public recognition and the understanding that alternative options are available in lieu of purchasing affordable apartments from volume builders. Interviewees from Palmer's study (2020) predominately suggested soft interventions, the most common being a state-level agency to fill the knowledge deficit, build trust and to "show it as an option" (future resident). In Berlin 'Baugruppen' (otherwise known as collective housing) has become more professionalised, where Architects initially identify the purchasable land and creates a proposal for collectives to take part. In the context of Australia, it is suggested that architects create instrumental action in encouraging and educating the possibilities for CSO Housing. Acting as the central point, finding viable land and a collective of potential owner-occupiers to finance and partake in a CSO Housing development. The Architect can then be appointed by the collective group and play a central role to provide an alternative to speculative development, which Australians are familiar with.

6 Conclusion

This research endeavours to identify the barriers associated with Self Organised Housing and develop recommendations, demonstrating how such development techniques can be effectively implemented in Australia. Notably, three of the main barriers faced related to financing, approval and collaboration. The necessary actions proposed to local governments include creation of a framework for collaborative developments, to follow and rely upon when partaking in such methods. The framework would present hope and confidence to agents, as it would remove the stigma that is currently associated with CSO Housing methods. At the Organisational level, recognition and leadership was recognised as the forefront of the movement. Architects and Designers are recommended to advertise potential sites to aspiring first homeowners and demonstrate the possibility of developing their first home, with a group of individuals at lower than market costs. Encouragement and participation from industry experts would facilitate consistent work for companies, as they would act as a superintendent to provide moral support to investors and mediate any possible dispute amongst parties. It has been extensively demonstrated that Self-Organised Housing is predominantly utilised in European countries and is relatively unobserved in Australia. This investigation predominantly relied upon research papers which provided International context on case studies. Such barriers that were experienced and reviewed as part of this research may not be applicable when implemented in Australia. Countries such as Germany are subject to different regulatory building requirements and Government Policies, which are likely to vary from those in Australia. Such variability may influence findings and recommendations as part of this research. The study did not include any research about the current understanding of Self Organised Housing in Australia amongst residents. Future research regarding the knowledge and perception of collaborative techniques would be beneficial in identifying whether Australians would be interested in engaging in CSO Housing. Questionnaires may identify whether scepticism is apparent in Australian behaviours due to possible traditionalistic behaviours, such research would further identify how barriers can be broken down and mitigated to bring confidence to CSO Housing in Australia.

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A collaborative approach for Risk Management in the design phase of construction projects in South Africa

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Abstract
Construction projects are often described as complex, integrated systems that create high levels of risks requiring complex decision-making processes involving many stakeholders to manage, particularly in their design phase. While collaboration is critical for detailed understanding of design processes, it is often very difficult in practice, since risk is interpreted differently by different stakeholders. The risk management (RM) approach adopted on South African construction projects takes no cognisance of the shift towards an interdisciplinary approach. This research examined, how a change in RM practice can accommodate the use of collaborative risk management (CRM) in developing interdisciplinary strategies for interdependency challenges on South African construction projects. A multiple case study approach was used, with empirical data from semi-structured interviews of experienced practitioners. Data was analyzed abductively to interrogate the interplay between theory and real-life examples of practice in order to evaluated the collaborative climate. It was identified that more decentralized processes of CRM can foster a co-operative culture, and that contract negotiation and communication are key to ensuring that stakeholders are able to perform their respective design tasks adequately. The results further suggested that CRM can be a tool to transform risk management into be a proactive, continuous and process-driven practice.

Keywords
Collaboration; collaborative risk management; design phase; interdependence.

1 Introduction

The majority of contemporary design processes in construction are still carried out in accordance with traditional methods and norms, and there is a tendency to try and fit existing RM techniques rather than modifying practices to accommodate the needs of collaboration. RM solutions are still impacted by stakeholders concentration on risks associated with their own design tasks instead of a collaborative approach (Osipova, 2014). A collaborative approach to risk management integrates individual perspectives into a coherent and rounded risk management strategy, ultimately benefiting the design process and all those concerned with it (Davies et al, 2016). However, different stakeholders continue to pursue competing interests, these interests being; a combination of perceptions, concerns and needs of stakeholders (Gomes et al., 2016), and these are linked with decision making and collaboration efforts. The dynamic, interwoven nature of collaborative design has created complexities and uncertainties between diverse stakeholders. These complexities and uncertainties are the main sources of risk, and they impact on the overall design process if not addressed early on in the project process (Floricel et al., 2016). However, RM practice has not adapted to these new collaborative design approaches to better cope with the resulting increase in complexity. This study intends to explore how the need for collaboration between stakeholder and RM can provide an improved way to managing risks during the design phase.

Despite the wide variety of available tools and techniques, in South Africa (RSA) RM is still criticized as being ineffective, and of not achieving its main objective of bringing more certainty to projects (Osipova and Eriksson, 2013). This is because risk, and approaches to its management are heavily influenced by traditional practice that have conceive of risks as disparate and compartmentalized (Thamhain, 2013). These approaches have not only affected the communication among the stakeholders, but have resulted into delays in information exchange, slow decision-making and contractual disputes. Furthermore, these approaches are inadequate at identifying, evaluating and managing collaborative risks, which mostly arise from non-linear design processes. Traditional risk management approaches do not provide a holistic framework that these non-linear collaborative design processes need, to redefine the risk management value. For more efficient and effective risk management, it is essential to have a systematic methodology that recognises the importance of the experience and knowledge that exists among collaborated stakeholders.

Any transition from the current 'silo-ed' discipline-based model to a collaborative model is associated with the dynamics of change. The increasing size and complexity of construction projects demands a resultant increased ability to manage disparate stakeholders and risks throughout the design process to prevent unwanted consequences within their different tasks (Du et al., 2016). These tasks often proceed in parallel, relying on preliminary information from other tasks; information that has not yet been finalized. Handling such incomplete design information requires knowledge about the variety of tasks that few stakeholders have, adding further complexity. Whilst complexity and uncertainty are distinct concepts, collectively they introduce difficulties and 'messiness' to projects (Gidado, 1996). The increased complexity in collaborative design processes has meant that despite improved methods, many projects still fail to meet expectations (Bryde et al., 2013). Thus combating the failures of traditional RM to collaborative risk management requires a transitional culture.

Collaborative risk management (CRM) is a system that can continuously adapt and influence the process of change. It is defined as an approach that highlights the importance of collaboration between stakeholders in managing risks that cannot be identified at the outset of the project (Osipova & Eriksson, 2013). It is fundamentally a decision making approach to accommodate all stakeholders, finding compromise zones, and narrowing differences between adversaries (Williams, 1999). CRM is an approach that can better cope with the challenges of increased complexity in which different interests of contrasting stakeholders need to be considered, balanced and negotiated. The transition within a collaborative framework will have the potential to overcome traditional dispersion of responsibilities (Jaafari, 2001), as it includes risk management processes and contracting strategies to avoid contractual rivalry (Tang et al., 2007). The objective of CRM is to have a transparent, adjustable and participative processe, particularly at the design phase when non-linear design tasks are predominant. It will identify ways of promoting collaborative arrangements between all stakeholders in RSA. Yet, even though CRM is regarded as an effective solution to managing these kinds of risks, its use is limited and still presents challenges.

2 The Need for Collaboration

In light of collaboration, stakeholders are increasingly looking for alternative ways of working with each other. The result has been the development of formal collaborative working arrangements known as partnering and alliancing, both of which are intended to align project objectives with common business goals to create a more cooperative and productive working atmosphere (Rahman & Kumaraswamy, 2005; Xue et al., 2010). However, despite the increasing ways of working with each other, several case studies show that even though formal collaboration arrangements had been adopted, stakeholders often encounter practical problems, such as a lack of collaborative mind-set and insufficient initial efforts to establish a shared culture.

Although a significant adoption of collaborative working arrangements has been observed in South Africa, a strong traditional focus on control hampers a collaborative design environment and, therefore, does not create suitable conditions for CRM. A collaborative design environment fosters the development of innovative options and adaptive solutions in risk management. But, the emphasis on formal mechanisms (such as contracts, procedures, and techniques) has further impeded collaborative processes because, many stakeholders involved have an inadequate understanding of their different roles and responsibilities, resulting in conflict when contractual arrangements are not resolved (Turner et al., 2016). Formalization also often underplays the important social dimension of collaboration in practice, and the dynamics of relationships among different people within and between different organizations (Knoll & Golkar, 2017). Thus, this state of lock-in therefore, hampers the development and adoption of new and innovative measures of risk management.

In seeking the essence that makes collaboration work, this paper focused on the amplified complexity by the interdependencies of stakeholders and their tasks, which necessitate a collaborative approach to ensure consistent and efficient RM decisions, enabling stakeholders to apportion their responsibility to manage risk fairly. The collaborative interdependencies have resulted in highly intertwined tasks which in turn result in risks that are difficult to uncouple.

2.1 Adoption of Collaborative Risk Management

The construction industry has long managed to identify and analyze known risks and has recognized that dealing with the hidden, less obvious aspects of uncertainty is complicated and requires practitioners to be more proactive in their approach (Smith and Merritt 2002). The emphasis of effective RM in dealing with the broad spectrum of risks is to move beyond the traditional RM mechanics, and examine the sources of unknown risks (Jarkas and Haupt 2015).

In practice, a typical approach to risks is trying to identify them as early as possible and respond to them as quickly as possible once identified (Peckiene et al., 2013). However, with collaboration, stakeholders have realized that, while there may be good RM methods which provide a critically important toolset for risk management, it takes collective thinking and collaboration of all the stakeholders to identify and deal with the complexity of interwoven risks (Thamain, 2013). Managing risk collaboratively appears to be a relevant problem currently explored by many researchers from all over the world. This predetermines unfavourable risk allocation outcomes which results in cost and time overrun and, undoubtedly, in legal disputes. Therefore, it is necessary to consider CRM as a solution that emphasizes equitable and balanced risk sharing among design stakeholders.

Collaborative risk managed designs intend to promote equitable risk sharing procedures that aim to assign responsibility and accountability of risks to various stakeholders involved in the design phase. A risk sharing problem concerns both qualitative issues (what type of risk is allocated and to whom), as well as quantitative issues (how much of the risk is allocated). These risks can arise out of a stakeholder's engagement with the design processes, which need to be identified and the perceptions of stakeholders should be considered when establishing the context and dealing with risks. Inappropriate risk allocation has led to adversarial relationships between stakeholders (Lehtiranta, 2014) and how risk sharing should be organized under a systematic, collaborative risk management scope is the focus of this research.

3 Research Methodology

The research methodology is abductive, in that it allows the researcher to provide a better explanation of the continuous interplay between theory and various real-life examples (Ridenour et al., 2008). In order to execute this research, a multiple case study approach was adopted. The cases were 2 projects during the preliminary design to preconstruction phase (an academic pathology facility development and retirement apartment development). In both projects, the project teams are still engaging with risks and experiences, and collaboration among stakeholders was intensifying as the data was being collected. The other 2 projects were already complete (residential apartment development and a commercial development); where the design teams reflected on the problems they faced during the deisgn phases. The aim was to provide a detailed holistic description that illuminates the respondents' understanding of the CRM phenomena.

The primary data was collected using semi-structured interviews containing a mixture of open and closed-ended questions. 29 practitioners were interviewed about their risk perceptions and how that affects or influence collaborative efforts, as well as their options and suggestions on promoting collaborative arrangements between all stakeholders. This provided a flexible method producing rich data on the case studies, so to acquire comprehensive knowledge for strong theory building (Zainal, 2007). Participants were selected based on their role in the design process and familiarity with collaborative efforts and the use of CRM in these projects. A non-probabilistic, snowballing sampling technique was used (Saunders et al., 2016); the chain started from architects in each of the different case studies.

CRM is an unfamiliar concept in South African design practice and, in the different case studies, it was important to obtain a detailed and comprehensive view of it by investigating the practices intended to establish actual collaboration. The data was transcribed and then the main themes related to collaboration, RM and CRM practices were coded in Nvivo, to facilitate a coherent theme across each respondent.

4 Findings and Discussion

The interview questions were categorized to make it possible to determine and understand the participants' level of experience, knowledge and awareness of CRM. The respondents' perceptions on current RM practices and impediments was queried; and their involvement in collaboration and how CRM can support a transitional process towards equitable risk allocation practices, was explored.

Table 1. Profile of Respondents showing positions in projects

Professions	**Project 1** *Forensic Pathology*	**Project 2** *Retirement Apartments*	**Project 3** *Apartments and Museum*	**Project 4** *Commercial Development*	**Referral Participants**
Structural Engineer	1	1	1	1	
Quantity Surveyor	1	1	1	1	1
Architect	1	1	1	1	2
Project Manager	1		1		1
Risk Manager				1	1
Client	1			1	
Development Manager		1			
Construction Manager				1	1
Portfolio Programme Manager					1
Client Project Manager				1	
Contractor	1				1
Number of Interviews	**6**	**4**	**4**	**7**	**8**

4.1 Connecting Risk Management with Collaboration

Current risk practices are influenced by design management practices and in real life, practitioners deal simultaneously with risks in multiple dimensions. These risks include: How to manage collaborative processes among stakeholders in different simultaneous design processes? What are the implications of CRM during the design phase? How can stakeholders forecast design problems that can only be dealt with collaboratively? And lastly; how do stakeholders deal with their opportunistic behaviour of self-interest seeking?

Most stakeholders suggested flexibility in managing collaboration, as it allows design teams to collaboratively change the course of action in managing risks and uncertainty. The risks related to collaboration listed by different practitioners included, inconsistencies associated with design planning, poor information management, risk attitudes characterized by poor communication and construction contracts which result into unfair risk sharing because of erratic decision making, as shown in Figure 1.

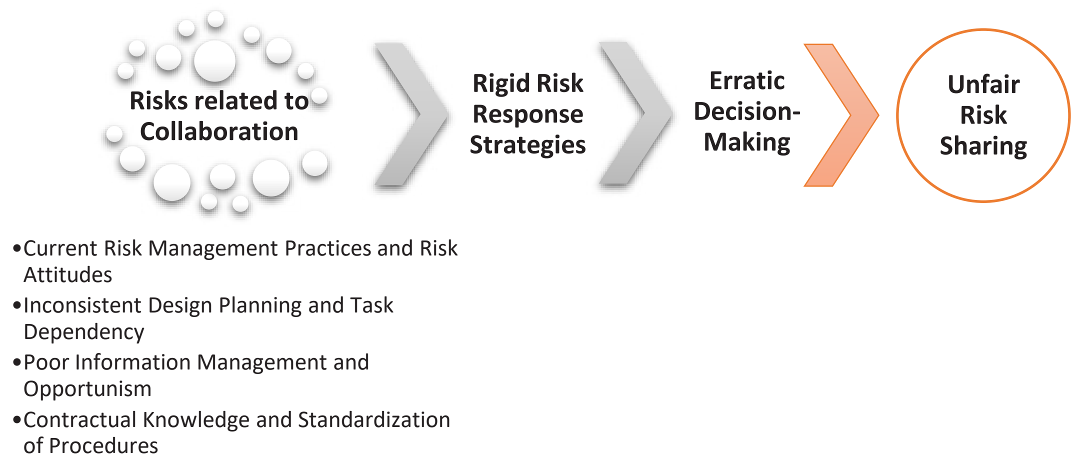

Figure 1. Collaborative risks that can result in unfair risk sharing

To gather practical information regarding the current situation of collaboration in the RM process, practitioners were asked about the extent in which they used selfless flexibility in managing collaboration practices, so to suggest resolutions to the related risks:

Design planning: design planning can prompt changes to collaborative problem-solving. Currently, little effort is given to planning the design in detail in the belief that it is time-consuming for such a creative and iterative process "*…this is a situation perpetuated by a lack of understanding in the co-ordination of cross-disciplinary information, task dependencies and availability of fully integrated design techniques*" (Architect 3).

Suggestion: Collaborative design planning needs to transcend the fragmentation of construction projects. Effective collaboration in risk management requires clear communications and the ability to pass thoughts, ideas, information and instructions quickly and effectively between stakeholders or design teams. By establishing communication flows, involvement patterns and other behavioral responses to unexpected design changes, the nature of any professional and cultural interfaces can be established.

Information management: the timing of information transfer is not properly controlled: "*…designers do not have the right information at the right time and are overloaded with unnecessary information*" (Project Manager 2). This creates the risk of failure of design tasks, deficient analysis and wrong decisions with a potential for waste due to reworking. Information management is vital to design success, and it needs to improve because it has led to the manifestation of errors, omissions and information redundancy which has, in turn, led to claims and disputes.

Suggestion: The transparent flow of information is crucial for effective collaboration and informed decision-making. It is also important that the design data and multidiscipline models be shared on a regular basis for design coordination, design review, and analysis. In addition, the design data needs to be organized and accessible; secure yet available to the right people, in the right context.

Risk attitudes: "…Design stakeholders have differing risk attitudes not only because they come from different disciplines but their attitudes are influenced by their ethics, beliefs and anticipations which consequently define how they calculate the probability of occurrence and impact of a given risk on a project" (Risk Manager 1). To control these differing risk attitudes, stakeholders should be brought together at the beginning of the project to discuss risks that are likely to occur during a design phase, and to have all views and perceptions brought together in the preparation of the risk management plan.

Suggestion: The practice of proactive risk management improves the ability to manage the existing and emerging risks and helps adapt quickly to unwanted changes. The defining characteristics of proactive risk management are risk mitigation and risk impact reduction.

Construction contracts: "…Construction contracts form the behavior of the design stakeholders and, have a significant impact on the successful completion of the project" (Contractor 1). Respondents largely acknowledge the need to account for the dynamic and flexible nature of complex projects by periodically reviewing and changing the contractual specifications where needed, as part of the ongoing contracting process. "…What we want is a clean contract; allowing for people who want to work collaboratively, to do that without the noise" (Contractor 2). Another source of a problem is that, because complex projects have so many uncertainties: "…it is in fact impossible to draft a contract to accommodate these uncertainties" (Project Manager 1), the end result being an incomplete contract.

Suggestion: The clarity of contracts, the quality of documentation, and the method of payment have significant impacts on performance. A fairly drafted contract should contain proper contractual arrangements which identify and allocate risks equitably, provide realistic obligations and clear objectives and targets, provide for formal dispute resolution processes, and also include motivation and incentives to the contracting stakeholders.

Risk management practices: "…Contractors have to deal with most risks; we are forced to be active in risk management" (Contractor 2). The respondent felt that: "…this is due to current practices where risk management is not a major part of consultants' assignments". Early involvement of the contractor in the design process is considered to be the main advantage. Besides: "…contractors' risk management is more thorough if they are part of a design" (Architect 4). Cooperative work between architects and contractors is argued to result in better technical solutions and help in avoiding many design and technical risks. Tee et al., (2019) also maintained that integrating practices help stakeholders address problems related to both coordination (by emphasizing information transparency) and cooperation (by aligning incentives).

Suggestion: For effective collaboration in managing risks, it is important to appreciate principles of equity and fairness in distribution of responsibilities as fairly described in the contracts. The need for project participants to identify and understand all potential risks associated with a design process cannot be over-emphasized. One critical factor to achieving successful implementation of collaboration is the optimal sharing of risks and distribution of responsibilities between stakeholders, as shown in Figure 2.

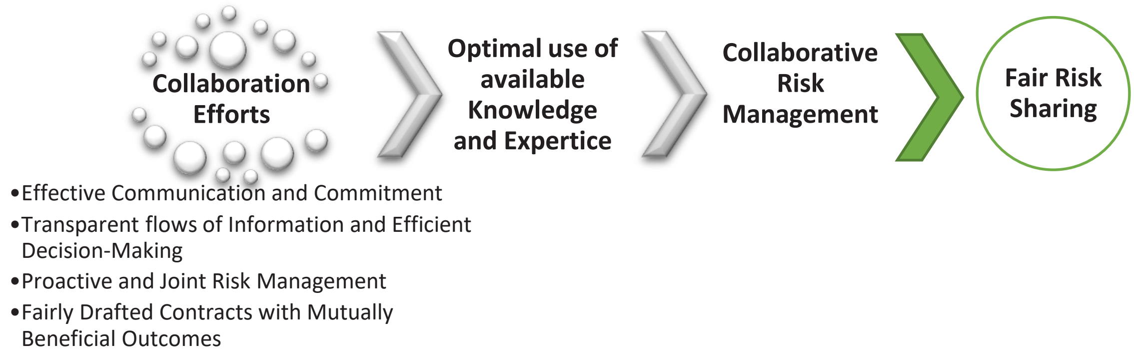

Figure 2. Collaboration efforts that result into fair risk sharing

4.2 A Collaborative Risk Management Process

Traditional RM practices that promote opportunism motivate for the use of CRM and confirm an absence of collaborative values and an understanding of risk sharing. Effective RM requires a collaboration-oriented mentality that encourages stakeholders to respect each other, to share knowledge and to have an open dialogue regarding risks, sharing amd collective management of risks. The CRM approach further underlines the need for identification of responsibility and accountability, with mutual trust.

Respondents identified risk sharing as an optimum way of managing risk as it helps to allocate resources more efficiently and improves design efficiencies. It enabled design teams to not only fulfil their functional roles; supplying the requisite technical skills and operational knowledge, but also to facilitate commitment, the development of an unambiguous decision-making process and to establish optimal, transparent collaboration. It is important that the mechanism for risk sharing is aligned with incentivizing stakeholders to achieve the primary goal of the project, whilst allowing each party to realize their secondary objectives, as shown in Figure 3.

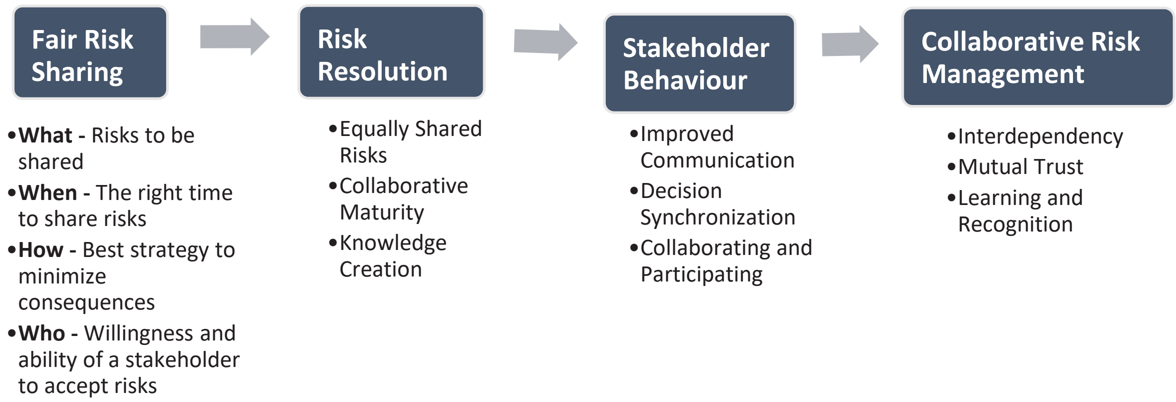

Figure 3. Fair risk sharing that leads to successful collaborative risk management

4.3 Constructive Collaboration

Collaboration is a process of shared creation that involves mutual engagement of stakeholders to solve problems together (Davies et al., 2016). Effective collaboration is claimed to lead to fewer disputes, lower design task iterations and a better quality building (Ayegba et al., 2018). Effective RM needs to adapt to diverse situations, whilst maintaining an open dialogue to enhance multi-stakeholder participation and risk sharing to produce an atmosphere of mutual trust (Msomba et al., 2018). Implementation of these interlocking pieces takes place through participative, flexible and iterative processes and activities. To achieve CRM, a co-operative culture which promotes a shared understanding before it can perform a joint sense-and-decision-making process, which collectively can resolve any design problems, is necessary.

Real collaboration cannot happen without a collaborative mindset and behavior which promotes trust at its core. Trust is a collaborative aptitude that impacts decision-making because decisions are made in light of the level of trust and the perceived risk (Jin and Ling, 2005; Kamminga, 2012). The practitioners viewed trust as a valuable component as it can also reduce risks associated with collaboration, relationship development and increasing commitment to such relationships. This trust will eventually result in a jointly designed CRM process, with the emphasis of shifting from an individualistic to a collective approach. This will further enable collaborative knowledge creation to result into collective efficacy.

Initiating, developing and implementing collaborative practices requires a creation and utilization of new knowledge. This knowledge needs to be explored continuously, both internally and externally, by all stakeholders and should be used not only to the enhanced risk mitigation effectiveness but also to increase information sharing, conflict reduction and share risks equitably. Respondents from all cases reflected on the time required to create a shared understanding of both project goals and the need for a common concept of collaboaration in their projects.

5 Conclusion

The increasing amount and diversity of task interactions have resulted in design processes becoming unmanageable due to the sole use of traditional RM tools. Existing project management practices fail to incorporate complexity-based thinking and collaborative practices into RM. This has led to poor risk management outcomes because different stakeholders continue to conduct separated risk management processes.

Collaboration has several benefits, which is the key reason why construction projects have introduced the concept. It is, however, difficult to form CRM processes if stakeholders lack a feeling of joint responsibility.

In the interviews, different practitioners set the scene of current RM practice as individualistic whereas the combine efforts of all stakeholders are required to make collaborative adjustments due to the changing circumstances. As a consequence, stakeholders currently do not utilize the most effective ways of managing risks and should move towards a CRM process. This room for improvement creates an opportunity for optimising collaboration.

The benefits of CRM were acknowledged with references made not only to the enhanced risk mitigation effectiveness but also to increased information sharing, conflict reduction as well as to share risks fairly. CRM encourages people to have a collaboration-oriented mentality that encourages people to have an open dialogue regarding risks and have an understanding of responsibility and accountability.

However, this change of paradigm does not take place naturally or without resistance as the findings show that some professionals see CRM as an extreme alternative to current practice as it involves risk sharing. Future developments in collaboration will lead to the widespread use of CRM principles in project management. This field of study is rather new in South Africa, so there is a need for further research explicitly linking the practices of a relationship-based approach applied to the risk management process. Also considering negative elements that come with collaboration.

6 Acknowledgement

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The Value of Price Indices to Construction Decision-makers

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Abstract
One of the factors causing cost overrun in construction projects is the inaccurate estimation of the costs of projects. The accuracy of cost estimates, in turn, is influenced by the availability of data including price indices. This study aimed at developing knowledge about the impact of economic information on decision-making in the construction market. The objective of this research was to explore the nature and type of price indices produced for the construction industry of Australia. The research data was collected from the quarterly publications of two organizations that are involved in preparing construction price indices in Australia. The annual changes in price indices by these organisations were analysed and compared with the Australian Bureau of Statistics (ABS) annual change in the price index. The study indicated that the organisations' indices tended to overestimate price increases, and display similar trends. The paper offers practical help to those involved in developing and improving economic understanding of building price. This research also provides insights into the interplay between price movement information produced by industry-based economic forecasters, and the price data published by the official government statistical office. Thus, this study was undertaken to provide information to users about the quality and nature of economic forecasts of construction prices in Australia.

Keywords
Building economics, decision-making, demand and supply, price indices.

1 Introduction

Forecasting is an integral part of all business planning (Mills 2003). Likewise, forecasting the outlook for building prices is of interest to many firms in the construction sector. Specifically, accurate short-term construction price forecasting is important for the success of decision-makers in the construction industry (Jiang et al. 2014). On the other hand, there has been a general assumption that the indices used for forecasting were accurate measures of general inflation of relevant output prices of the construction industry. This paper measures the performance of two widely used Australian construction industry price indices that are commonly used for estimating purposes. This is done to provide users with an indicator of the margin for error of building price forecast undertaken in Australia.

This research assesses the accuracy of the building price indices prepared by two Australian quantity surveying organisations. To the authors' knowledge, no study has been conducted to compare the accuracy of the building price indices in the context of the Australian construction industry. The analyses were carried out by examining the building price indices which were published and updated every quarter by the organisations. Because each organisation used different base year for its price indices, the error was measured as a percentage change over separate one-year period from 2000 to 2018. Forecasting performance was determined by comparing the Producer Price Index (building construction) published by the Australian Bureau of Statistics (ABS) on an ex-post basis (ABS 2021). ABS is the official government agency that collects economic data for the Australian Government, and the data obtained from the agency can be considered accurate since they are frequently updated and are based on actual price information. The agency collects and maintains high-quality data which is also used to determine the national accounts. Hence, this research used ABS data as a benchmark for the analysis.

2 Literature Review

2.1 Construction Demand and Supply

Understanding the construction prices index is essential for managing resource usage since the movement of the construction price could affect the decisions of construction developers, clients, property investors and financial institutions. Fluctuation of construction price indices is mainly caused by changes in market conditions in terms of the demand and supply of construction works (Wong and Ng 2010). However, construction demand and supply can fluctuate dramatically depending on economic and market factors (Meikle 2001). Additionally, Akintoye et al. (1998) found that the construction market fluctuates due to changes in external economic conditions and global economic events. According to Skitmore et al. (2006), prices rise as demand increases and fall when demand declines. The authors also mentioned that increases in the supply levels (the availability of contractors) cause decreases in price levels. Besides the level of demand and supply, construction prices can be influenced by market characteristics such as building type, procurement options and geographical location (Skitmore et al. 2006, Best and Meikle 2015). Therefore, the construction price index fluctuates based on demand, supply and market characteristics.

2.2 Measuring Construction Price

There are various indicators of construction supply and demand. The value of construction approvals has been used to represent the demand in the construction market because it is an indicator of changes in the future level of construction output (Goh 2005). The value of construction completions is another indicator which represents the level of supply in construction because it is the total amount of products in the construction market (Malpezzi and Maclennan 2001). However, both indicators may not represent construction price.

Construction price can be measured in three ways: (i) the output price, (ii) the input price, and (iii) the intermediate prices (Best and Meikle 2015). The collection of the output price focuses on the actual or out-turn final prices paid by clients for building work. In Australia, ABS adopted the first approach to develop the Producer Price Index (PPI) (ABS 2021). PPI is widely applied by government departments as the measures of prices changes in the goods and services in the construction sector.

Second, is the input prices approach. In this method, a selected set or 'basket' of inputs resources is priced (Best 2011). Inputs include typical construction materials (including some components, such as windows, that are typically manufactured offsite), various types or classes of labour and possibly some items of construction plant and equipment. Basket costs are adjusted to include estimates of site-specific and general overheads and builders' profit including other adjustments including local taxes and consultant' fees (Best and Meikle 2015).

Third, is using the intermediate prices which are composite rates or prices for items of work (Pieper 2008) and, as such, combine the cost of all required inputs (materials, labour and so on). Such prices are available from price books and successful tenders, but the way they are used depends on the pricing approach of particular contractors and the circumstances of particular projects. They need to be used consistently; for example, if prices from successful tenders are used, all prices need to come from the same tenders, and even then, there is no guarantee that margins have been evenly distributed across the items in the tender, as tenderers may weight some items to enhance their cash flow. The premise for this method is that by pricing composite yet discrete items of construction output, not only does the data represent purchaser prices, but these prices inherently reflect differences in productivity and labour/equipment ratios between locations. This component cost method is similar to the BQ approach; however, rather than pricing every part of a project, a standardized set of components is taken to represent whole projects or even a whole sector; this greatly reduces and potentially simplifies the price collection process (Best and Meikle 2015). This research used ABS data which was developed using the first approach (the output price).

2.3 Construction Price Indicators in Australia

Indicative costs and price indices are routinely collected, analysed, and published by several international firms, with some data freely available on websites and other data only provided to paying clients. Australian firms that are active in this area include; Rawlinsons quantity surveyors and construction cost consultants (Rawlinsons), the Australian Institute of Quantity Surveyor (AIQS), and the Australian Bureau Statistic (ABS).

One of the ABS indices is the "price indices of the output of the building industry" which is available in ABS Cat 6427.0. This price index measures changes in the prices of the output of building construction in various states and territories in Australia. This index is also used as: (i) input into the national accounts by providing a deflator for current price expenditure on building construction to calculate chain volume estimates and (ii) input into broader measures of price change, such as the economy-wide stage of production indices.

3 Research Methodology

The building price indices produced by two quantity surveying organisations were collected to analyse their accuracy by comparing with the actual price movement recorded in ABS's PPI (Cat 6427.0) for the period ranging from 2000 to 2018. These organisations comprised:

i. Rawlinsons Building Price Index (Rawlinsons 2019): Rawlinsons Quantity Surveyors and Construction Cost Consultants is a private-sector firm that publishes building price data of a variety of building types. Rawlinsons indices are independent and widely used indices prepared specifically to provide data on construction costs and variations in those costs (Nicholas, 2014). Indices for several Australian cities are published in Rawlinsons.

ii. Australian Institute of Quantity Surveyors (AIQS) building price index (AIQS 2019): AIQS is a standards body for built environment cost professionals. The institute provides information that is relevant for quantity surveying, cost management, construction professionals and other stakeholders. Every quarter, the institute publishes Building Economist, which comprises building price indices and construction costs of buildings in various Australian cities. Although the institute used the term Building

Cost Index (BCI) in its publication, since the cost data available in the Building Economist includes overheads and profit, it is considered as building price index (BPI) in this research context.

Data (price indices) obtained from each of the above organisations were collected and examined for suitability in determining the level of accuracy and bias. These indices were then compared with the building price indicator published by the ABS for each period on an ex-post basis (ABS 2021).

The following steps were used in analysing the data:

Step 1: Collecting price indices (2000 to 2018) which were prepared by the Construction Cost Consultant (Rawlinsons), professional association (AIQS) and government body (ABS) from the websites and published cost books.

Step 2: Calculating the annual change in price indices for ABS, AIQS and Rawlinsons.

Step 3: Computing Mean Error (ME), Mean Absolute Error (MAE), Mean Squared Error (MSE) and Theil's U:

$$\text{ME} = \frac{1}{n}\sum_{i=1}^{n}(CIA_i - CIO_i) \tag{1}$$

$$\text{MAE} = \frac{1}{n}\sum_{i=1}^{n}\left|CIA_i - CIO_i\right| \tag{2}$$

$$\text{MSE} = \frac{\sum_{i=1}^{n}(CIA_i - CIO_i)^2}{n} \tag{3}$$

$$U = \sqrt{\frac{\sum_{i=1}^{n-1}\frac{(CIA_{i+1} - CIO_{i+1})^2}{CIO_i}}{\sum_{i=1}^{n-1}\frac{(CIO_{i+1} - CIA_i)^2}{CIO_i}}} \tag{4}$$

Where CIA_i is the annual change in price index by ABS and CIO_i is the annual changes in price indices by AIQS and Rawlinsons.

This study analysed the movement of the building price indices for one location, that is, Melbourne. This was done for the sake of brevity, but similar analysis can be conducted for all capital cities in Australia. Moreover, Melbourne could be considered a reasonable proxy of price movement in other locations.

4 Findings

The objective is to analyse the movement of the building price indices for one location, in this case, Melbourne. All the annual data series contained in this study is adapted from the Australian Bureau of Statistics (ABS), Rawlinsons, and AIQS period of June 2000 to June 2018. The annual change in the price indices, as well as the errors, were computed and presented in Table 1. The Error (e) = per cent change per annum of ABS - per cent change per annum of Rawlinsons/AIQS. Accordingly, the mean annual per cent change for ABS, Rawlinsons and AIQS were found to be 2.86%, 3.84% and 3.70% respectively.

In Figure 1, the annual increment in construction price predicted by Rawlinsons and ABS as well as the deviations (errors) are presented. Accordingly, a maximum error of 7.60% is observed in 2009. This could be due to the Global Financial Crisis (GFC) in 2008/2009 in which the turbulence in the global market affected the accuracy of the forecasts.

Table 1. Building price movement for Melbourne (% change pa)

Year	ABS	Rawlinsons	Error (RAW)	AIQS	Error (AIQS)
2000	6.12%	7.08%	-0.96%	8.61%	-2.49%
2001	2.02%	3.98%	-1.97%	2.44%	-0.42%
2002	3.25%	5.43%	-2.18%	2.38%	0.87%
2003	5.47%	6.01%	-0.54%	8.72%	-3.25%
2004	4.80%	3.71%	1.09%	5.35%	-0.55%
2005	3.59%	6.14%	-2.55%	5.58%	-1.99%
2006	1.08%	4.99%	-3.91%	4.33%	-3.25%
2007	5.08%	4.80%	0.28%	5.07%	0.01%
2008	6.64%	5.63%	1.01%	4.82%	1.81%
2009	-4.64%	2.96%	-7.60%	1.26%	-5.90%
2010	4.87%	1.50%	3.37%	1.65%	3.21%
2011	6.12%	4.02%	2.10%	3.25%	2.87%
2012	-1.09%	2.49%	-3.58%	1.97%	-3.06%
2013	1.71%	2.00%	-0.29%	0.77%	0.94%
2014	1.48%	2.00%	-0.52%	1.92%	-0.43%
2015	2.04%	2.26%	-0.21%	3.01%	-0.96%
2016	0.67%	1.90%	-1.23%	3.28%	-2.62%
2017	1.23%	3.00%	-1.77%	3.18%	-1.95%
2018	3.93%	3.00%	0.94%	2.74%	1.19%
Mean	2.86%	3.84%		3.70%	

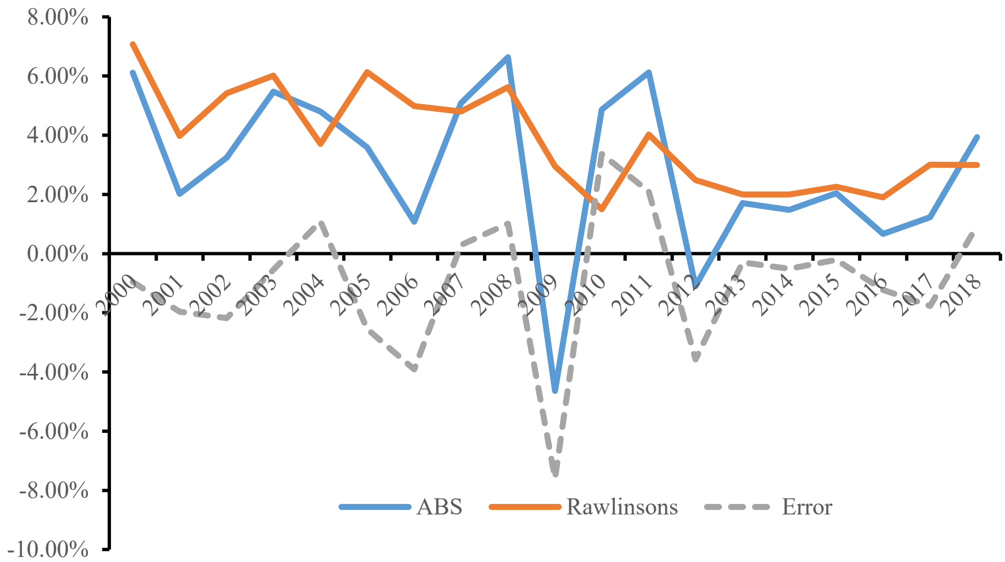

Figure 1. Annual changes in the price index for Melbourne by ABS and Rawlinsons

Figure 2 depicts the annual per cent change of the price computed based on ABS and AIQS price indices for Melbourne. Similarly, the maximum deviation of 5.9% is obtained in 2009, which could also be due to GFC. From the figure, in 2007, ABS and AIQS forecasted a similar percentage change.

The Mean Error (ME), Mean Absolute Error (MAE), Mean Square Error (MSE), are the statistical methods applied on the eighteen data points (2000 – 2018) to evaluate the accuracy of the construction price index. The MSE is one of the methods to quantify the difference between the values estimated by an estimator (i.e., parameter estimates) and the population parameter (Lohr 2019). Theil's U is a relative measure of performance compared to the simplest form of forecasting, namely the last piece of known data. If Theil's U is close to one (1) the forecast is no better than using the last piece of known data as the forecast for the next period, also known as a Random Walk.

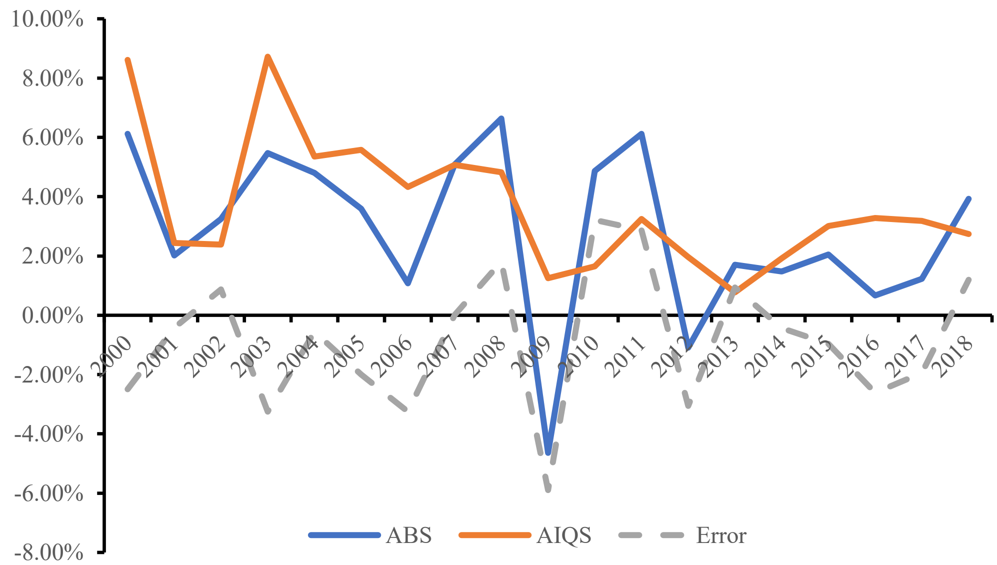

Figure 2. Annual changes in the price index for Melbourne by ABS and AIQS

MAE for Rawlinsons and AIQS was computed first and the result showed that the MAE for AIQS is 1.99 whereas MAE for Rawlinsons is 1.90 (Table 2); this implies that, based on the data from 2000 to 2018, the annual percentage price change for Rawlinsons is more accurate. Further, it can be concluded that since Theil's U for both organisations indices is not very close to 1, the prices indices can be considered as good indicators of the changes in the construction price.

Table 2. 1-year price movements for Melbourne compared to ABS building price indicator

Measure	**Rawlinsons**	**AIQS**
Mean Error (ME)	-0.97%	-0.84
Mean Absolute Error (MAE)	1.90%	1.99%
Mean Squared Error (MSE)	0.07%	0.06%
Thiel's U Statistic	0.62	0.65

5 Discussion

As mentioned above, the assessments of the predictive performance of two price indices were conducted by using data published from June quarter of 2000 to June quarter of 2018. When comparing the ABS's data with the other two data sets, the price movements are very close and display similar trends. For instance, both forecasts slightly overestimate increases in the index. The ABS index was underestimated by both forecasts as shown by the Mean Error (ME) (Rawlinsons = - 0.97%, and AIQS = - 0.84%). When the Mean Absolute Error is considered, both forecasts are within 2% of the ABS price movement (Rawlinsons = 1.90%, AIQS= 1.99%).

The outcome of this study showed that both forecasts are bullish, and tend to overestimate the true increase in building prices. ABS data was revised quite frequently as compared to Rawlinson's and AIQS price indices; hence, the ABS data could be considered more accurate to assess the price movements. Past research by Mills et al. (2003) has shown that the ABS makes several revisions to the data; thus, ABS PPI data can be considered as a good benchmark for reference or comparison.

In addition, both indices failed to predict the downturn in price (negative price changes) in 2009 and 2012. This could be considered as optimism bias. It is also worth mentioning that in 2009, the errors in both indices are significantly different (Rawlinsons= 7.6%, AIQS= 5.9 %), and failed to predict the price correction that occurred due to the Global Financial Crisis. However, it is fair to say that many forecasters during that same period also did not predict the GFC either (Bernanke 2018). However, the questions remain about whether the price movements for the previous years, as recorded by Rawlinson and AIQS, should have been revised after the GFC had occurred.

The final issue examined was whether the two forecasts provide any value to the users compared with other measures of general inflation eg. the Consumer Price Index (CPI). However, if Thiel's U is considered, both price indicators perform well (Rawlinsons= 0.62%, AIQS= 0.65 %). Thiel's U is below one (1) (Karasu et al. 2020, Sackey et al. 2020) and this suggests that the price movements measured by both QS organisations are useful. Finally, the analyses confirmed that there is only a slight difference between each of the price indexes produced by different construction analysts; thus, both organisations' indexes do add value and accurately measure building price movement, albeit with some error.

6 Conclusion

This research has considered the nature and quality of two indicators of building price, namely the Rawlinson's and AIQS building price indices. The results showed that both display similar trends. The indices tended to overestimate price increases, and over time this could be expected to continue. However, because both price indicators displayed similar trends and both were consistently too high, this could be corrected. Also, both indicators had good Thiel's U statistics, suggesting that they did better than the simplest form of forecast, namely a random walk. As a result, the indices could be considered to add some value to users about the future direction of construction prices.

The largest error occurred when both indices missed the impact of the GFC, which was not uncommon at the time. However, the biggest criticism of the price models was their inability to revise their forecasts after the influences were known. Past research conducted by Briscoe (2006) has called for industry stakeholders to become more engaged in the process of statistical revision and use. The author went on to suggest the creation of a user forum to monitor the quality of statistics and deal with the more technical aspects of comparisons.

This study has both practical and theoretical implications. Firstly, it can assist the users such as QS firms, contractors, sub-contractors and suppliers to evaluate the existing construction price indices and make appropriate decisions regarding which index to adopt. Secondly, it can help the organization that developed the price indices to assess their methods of developing the indices. Thirdly, the findings of this study can be used as a basis to build more robust models which can be implemented to forecast more accurate price indices. One of the limitations of this research is that it did not explore why variations in price indices occur in a similar environment. Future studies could be carried out to understand the reason for variations.

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The use of social media platforms for business branding in the South African construction industry

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Abstract
In the contemporary era of digital migration, social media (SM) has altered how people, societies and organizations produce, distribute and use communication amongst themselves. Global SM users are likely to intensify around the world as user accounts increase. Previously, SM has been exploited by individuals as a personal tool in their private capacities. Nowadays, there has been a gradual change to this approach and the use of SM expanded past personal usage and it has become a normality to see dynamic interest on SM. SM execution in a business-setting is distinctly unique in relation to individual use. Beyond a recreational medium, SM can help acquire business benefits when it is actualized viably, which can exceptionally impact the success of the firm, especially the monetary and social manageability aspects. In this study we investigate how the South African construction industry uses social media platforms for business benefit. Interviews were conducted using open ended questions to obtain in depth information from construction businesses. The study pursued an in depth understanding of how SM is used for business benefit. Thematic analysis of data was adopted to synthesize and interpret data. Findings revealed that LinkedIn, Twitter and Facebook were the most used platforms in the SA construction industry. Industry lags behind in adoption of SM and the benefits of using these platforms are yet to be fully recognized. Potential risks associated with use of SM identified and a deficiency of strategies and policies to mitigate these risks exists.

Keywords
business communication, branding, client networking, social media, social media platforms.

1 Introduction

The construction industry is repeatedly criticized for being technology disinclined. The industry remains largely traditional in many respects, and there are efforts worldwide to quell this discernment as the industry is implied to rely largely on manual labour and traditional construction methods to execute its projects. There are many reasons argued to comprehend the slow adoption of technology in construction and some strides towards innovation are being made. However, these are still untransformatory, while the technology revolution continues to advance leaving unhurried adopters behind.

Social media gained prominence in most business markets like marketing, technology, fashion and others. Some businesses caught on quickly and benefited from its gains whilst others remained behind. Perera *et al.,* (2017) referred to social media in the construction industry as not considered a natural fit. The construction industry is perhaps not considered as one of the tech savvy industries due to its traditional approach to business. The construction industry is not known for fancy branding and marketing of its business. Historically they have relied on traditional forms of marketing and branding their businesses some of which largely included word of mouth through past customers, phone calls and street advertising.

2 Social media and the construction industry

Baruah (2012) conceptualised the idea of social media (SM) as multiple varieties of web-based communication utilised by the general public to fabricate systems, virtual-communities, and collectives to pass around particulars, views, messages, and media files (such as images and videos). SM enhances how information flows in communities across the globe through the expeditious stretch of social-networking sites and media sharing advancements, the widespread of mobile technology use has provided the extra support of access to such sites anywhere and at any-time. This combination creates highly interactive platforms with which the general public and societies circulate, come up with, scrutinize, and reshape user-created content (Wilkinson, 2017).

Romania *et al.,* (2019) suggested that the prevalent use of SM suggests a democratisation of information. There is a recognisable gradual move away from reliance on marketing people to the general public taking control of advertising generating content to circulate, view posts, trends and videos on multiple SM platforms. Even with the emergent popularity of SM platforms, the business to business (B2B) sectors like construction industry was left behind from this growth (Perera, *et al.,* 2017; Wilkinson, 2017), making minute strides. This resulting in the industry lingering behind other industries in the day-to-day adoption of SM platforms to enhance their business operations. According to Perera *et al.,* (2017), the use of SM in engineering, architecture and construction industry has developed the internet prolongs improvement and streamlines an assortment of business operations. To support this, Azhar and Abeln (2014) cited a study conducted in Australia by infolink.com.au (Australia's Architecture, Building, Construction and Design Directory) that showed that a third of businesses in Australia had not adopted social media and similarly displayed in a survey of more than 1,126 that 36 percent of businesses are not sure how to use social media to engage their market. Additionally, they reported that 72 percent of businesses were aware that devising a social media approach was significant but were unable to produce this strategy to involve their followers (*ibid*), suggesting that these businesses were not fully recognizing the benefits of social media platforms.

2.1 Social exchange theory, purchase funnel and social media branding

Traditionally construction businesses relied on word of mouth, street advertising, phone calls and past customers for repeat business or to be refered to new customers inorder to gain new business. SM has drastically disrupted the traditional approach. It has presented a multitude of wide-ranging communication platforms that businesses can utilise to communicate their brand intentions with customers within a click of a button. This presents a new opportunity for connecting with larger volumes of potential customers anywhere in the world in an instant and building or growing a positive business brand. Pan and Crotts (2012) explored many theories to explain how people form networks and used social exchange theory among other theories to aid in this. The age old theory coming from sociology studies explores exchange between individuals or groups (Emerson, 1976)

Businesses brand themselves so that customers can identify with them and ultimately choose their brand among others. This choice lies primarily on the offering of the brand, but the customer needs to first be aware of the product or service, formulate an opinion, consideres it and prefers it over other alternatives because of the benefit/reward received and then purchses it. Customers will generally assess the options and will choose a brand/product/service that will offer them a reward/benefit. The social exchange theory postulates that human relationships are formed by the use of a subjective cost-benefit analysis and the comparison of alternatives. It suggests that people form relationships if it is rewarding/beneficial. Inorder for any transaction to take place (incuding a business transaction), a relationship has to be created (with a person, brand, or need matched). Multiple forms of relationships can be created through social media and communication broadened to reach multiple customers to communicate a message to. It is suggested that we attempt to maximise our benefits/rewards and minimise our costs. We commit to the relationship if the outcome is profitable. Further, it is implied that when deciding to commit to a relationship, parties will apply the three analysis to value whether there is benefit in them partaking in the relationship: 1) cost-benefit analysis; 2) comparison level; 3) comparison level for alternatives (Pan and Crotts, 2012). These analysis may be utilised by construction businesses to aid in creating a social media brand for their business that will speak to customers. This entails the business understanding its positioning in the market and its competitors, and leveraging its advantages.

2.1.1 Conceptual Framework

The construction businesses (B2B) can improve their business brands and access a broader market share through maximising the use of SM platforms. Utilising a brand positioning strategy in the market that offers a mutually beneficial partnership with customers. The customers are looking for a reward/benefit from brands and a brand that can succeed in articulating the benefits/rewards to customers as they also undertake a a cost-benefit analysis inorder to commit to a relationship or even a transaction. In this study we adopt an exploratory approach to investigate how South African construction industry use social media for business benefit.

We hypothesise that adopting SM platforms will benefit/profit construction businesses and enhance their brands?

3 Research Methodology

The study adopted a qualitative approach to investigate the adoption of SM platforms in the construction industry. This approach was condidered the appropriate approach as this was an exploratory study that was looking to understand how and why construction businesses were utilizing SM platforms. Interviews were chosen as the appropriate form to aid in gathering data and answer the questions. The section below outlines the process implemented inorder to answer the research question.

3.1 Research Process

The purpose of the study was to assess the South African construction organizations' use of SM for effective business branding. The study consisted of the firm level research examining the different platforms used, what these platforms are utilized for and potential benefits associated with this use by construction businesses. A qualitative exploratory approach was adopted for the study in order to gain the understanding from businesses on their viewpoints on effectiveness of business branding through social media usage. The research design was selected due to the qualitative nature of the data required from participants on the emergent use of SM for business related purposes and also because of very little or no research conducted relating to the construction industry in South Africa. The literature review was beneficial in identifying the constructs and themes used in the research instrument. A quick pilot study was carried out to validate the constructs/themes in the research instrument. After the pilot study, some adjustments were made, and a final semi-structured questionnaire was adopted for use in the study. The study was conducted in Johannesburg (Province of Gauteng), South Africa because of the high number of consulting firms available in the Gauteng province.

3.2 Sample and Sampling Technique

From a desktop search conducted, the sample of respondents was from a population of construction companies considered as the top companies in Architecture, Engineering, Project and Construction Management, and Quantity Surveying who were also active on SM. For the purpose of the research study, companies who had used at least one SM platform (being interactive) in the past 30 days were classified as a being active on SM. Previous studies on SM platforms in Nigeria revealed that the widely used SM platforms in construction industry were LinkedIn, Twitter and Facebook (Azhar and Abeln 2014). On the same basis, the accounts that were first checked for participants presence were LinkedIn, Twitter and Facebook accounts, since participants had more than one SM account. Furthermore, only construction companies that were registered with professional bodies were selected for the study in order to ensure the validity and reliability of the sampling frame and ensures the organizations selected conduct business within the constraints of their professions as guided by their professional and statutory bodies. After a quick desktop of selected companies, the findings revealed these construction companies were active on three platforms and also research studies found that the most popular SM platforms used within construction organisations are LinkedIn, Twitter and Facebook (Azhar, *et al.,* 2019; Perera, *et al.,* 2017; Perera, *et al.,* 2015). The activeness (last post) was categorised into hours and weeks for easy documentation. Companies that had posted hours ago range from 1-23 hours ago, and those that had posted weeks ago range from 1 day ago – 4 weeks ago. Table 1 illustrates profile of the interviews in respect of profession, job level, activeness on SM of the company, and the schedule of the interviews. Table 1 reveals a list of 16 semi-structured interviews that were conducted with participants working within marketing/communication departments focusing on business branding to attain in-depth information regarding the use of SM for business branding in the construction industry.

Table 1: Profile of participants

Interviewee	**Type of Firm**	**Position of interviewee**	**Gender**	**Activeness LinkedIn/ Twitter/Facebook (Last post)**
1	Architecture	Head of Marketing and Communication	Female	Hours ago
2	Project Construction Management	Head of Marketing and Communication	Male	Hours ago
3	Architecture	Business Development Manager	Male	Weeks ago

4	Project and Construction Management	Marketing and Communications coordinator	Male	Weeks ago
5	Quantity Surveying	Head of Marketing and Communication	Male	Hours ago
6	Architecture	Marketing and Communications Manager	Male	Over 30 days
7	Quantity Surveying	Business Development coordinator	Male	Weeks ago
8	Project and Construction Management	Business Development Manager	Female	Weeks ago
9	Quantity Surveying	Marketing Manager	Female	Hours ago
10	Engineering	Business Development Executive	Male	Weeks ago
11	Architecture	Public Relations and Social Media Assistant	Female	Weeks ago
12	Project and Construction Management	Head of Marketing and Communication	Male	Weeks ago
13	Engineering	Communications and Marketing Officer	Male	Weeks ago
14	Engineering	Business Development Manager	Male	Weeks ago
15	Engineering	Head of Marketing and Communication	Male	Hours ago
16	Quantity Surveying	Head of Marketing and Business Development	Female	Hours ago

3.3 Research Instrument

The study examined the effectiveness of branding using SM in the construction sector. The research set out to investigate the various platforms utilized by construction sector and how these A qualitative approach was adopted using semi-structured interviews to collect data.

To achieve the objective of investigating the social presence of the respondents, fifteen social media platforms were identified from literature: LinkedIn, Facebook, Twitter, WordPress, Instagram, YouTube, social bookmarking sites, Blogger, Snapchat, Google+, Flickr, the company's own website, Vimeo, Yammer, and Pinterest. Similarly, with respect to the second objective of assessing the challenges of the adoption of CRM 2.0, ten challenges were identified from literature: management's negative perception, lack of business strategy, lack of control over social media use, external pressure, organization's size and their lack of investment, management's unwillingness to adopt new technology, and fear of clients' information by social media platform managers.

4 Findings and Discussion

The findings of the study showed that participants from companies in the fields of Quantity Surveying, Construction Project Management, Engineering and Architecture formed a total of 16 interviews conducted where 62,5% of participants were males and 37,5% were females. The result obtained from the analysis form the basis upon which 4 themes were drawn for the study. All the participants interviewed occupied positions in the marketing and communications, new business development, public relations or social media specialties within the business which suggested that they would be more cognizant of the dynamics of SM within their businesses.

a) Type of SM platform used in construction industry

The results of the study revealed that the most common SM platform utilized by construction companies was primarily LinkedIn and Twitter. Only six of the participants added the use of Facebook in addition to LinkedIn and Twitter as one participant was quoted saying “We are active on LinkedIn, Twitter and Facebook, but we use LinkedIn the most”. LinkedIn was found to be the most used and preferred SM platform in construction followed by Twitter. Facebook was chosen as a third option.

Table 2: Social media platforms used in construction

	LinkedIn	**Twitter**	**Facebook**
Participants	100%	100%	38%

Despite the use of LinkedIn, Twitter and Facebook being the only 3 SM platforms mentioned by participants, a desktop analysis of their companies revealed that they also have presence in other platforms such as YouTube, Instagram and Google+. 50% of these companies had presence in additional platforms not mentioned in the interviews. They cited reasons for not mentioning other platforms as “it’s not our main platform” or “we are not very active on it” or “it’s not very user-friendly for our purpose”.

b) Frequency of use of SM platform

The frequency of use of the additional platforms (YouTube, Instagram and Google+) was found to be low. Some pages were inactive for longer than 30 days which supported the response that the company does not consider them as their primary SM platform utilized to communicate with users. Whereas the three LinkedIn, Twitter and Facebook were identified as the primary SM platforms utilized by construction companies. The results of a desktop search showed an improved frequency of activity on the SM platform for the three primary platforms. Below is an indication of the frequency of use in categorized in hours, weekly and monthly on the date of conducting a desktop search of these companies.

Table 3: Frequency of activity on social media

Posting Frequency (LinkedIn/Twitter/ Facebook)	**Number of participants**	**Interviewee number**
Daily/ Hours	6	1,2,5,9,15,16
Weekly	9	3,4,7,8,10,11,12,13,14
Monthly	1	6

The above table indicates that 56% of participants post weekly on their SM platforms, while 37% post on a daily basis on their SM platforms suggesting a reasonable level of activity of construction companies on their SM platforms.

c) Rationale for the choice of SM platform

The study also identified the rationale for construction companies' selection of SM platforms. The results showed that these platforms are primarily selected based on their potential to perform business related activities of the construction companies. These include tasks such as: brand awareness, human resource and recruitment, marketing and public relations, dissemination of company news, corporate social investment, construction knowledge management and sharing, client networking and though leadership. Some of the respondents were quoted as saying,

"We use social media to broadcast company news, make announcements, recruitment, marketing, sharing our successful project completion and building brand awareness".

Another respondent indicated that *"We use social media for recruitment, showcasing projects completed, corporate social responsibility, announcements of the projects won, awards received, events we are hosting and brand awareness"*

d) Benefits and value derived from SM platforms in construction

The study also revealed there were potential benefits for using SM in construction industry. Some of the benefits indicated by participants included: increased brand awareness, improved brand image, recruitment opportunities, increased traffic to company websites, ability to reach global audience, increased engagement with target audience, improved corporate social responsibility communication, increased online visibility, ability to monitor industry competition among others. Brand awareness and recruitment were the most dominant responses that came through from 100% participants in the construction industry. One participant was quoted saying "Brand awareness and recruitment are the two big reasons we use SM platforms in our company" signifying their importance for their company.

Whilst assessing the kind of value construction companies derive from the use of SM platforms, there was a strong indication that most participants were not convinced that they derived a huge amount of value from the SM platforms and hence they did not put a lot of effort, investment and emphasis into it.

About 50% of participants in the study indicated that they derive value from the use of SM platforms. They also acknowledged the use of different social media management tools like Sprout Social, Agorapulse and Hootsuite to allow their organisations to attain SM analytics in order to (1) track the success of posted content (e.g. the number of likes for a post, retweets, shares etc.), (2) analysing the effectiveness of their social efforts, and; (3) measuring the value or return on investment (ROI) of SM. The other 50% participants indicated that the value of using SM for a construction company cannot be measured. One participant was quotes saying

"I personally do not think that the value of using social media can be measured in the context of construction industry. We as Quantity Surveyors provide a business to business service. The way we get employed as consultants on project, specifically public sector projects, has nothing to do with whether we posted on Twitter of Facebook. Yes, bad posts can hinder our reputation,

but good posts will not bring in profit, we are not judged like that when submitting proposals or tenders in the public sector".

Another participant indicated in support saying

"That's a bit tricky (measuring value of SM). I wouldn't say that we measure the value of the social media in terms of our profits or bottom line. I think that would be hard because we operate a business to business market. But, by using Sprout we are able to quantify the success of our (companies) social media initiatives. We use the number of views, likes, reposts, shares and comments to see how social media is effective for creating brand awareness".

Determining the success of using SM for business branding in the construction industry is a factor that B2B construction companies still struggle with.

Respondents agree that it is rather easier to measure SM traffic through using the statistics generated using SM management tools, however measuring value or influence of SM is more challenging. It is therefore difficult to directly attribute increased profit in a construction organisation to the use of SM.

e) Effectiveness of SM as a business branding tool in the construction industry

Two respondents argued that SM platforms were effective in other industries but were not seen as effective in construction. This was argued based on the nature of B2B that targets other businesses. Moreover, the level of adoption of technology in South African construction is very low coupled with limited research on the use of SM in SA construction, suggesting a lower utilization of SM in SA construction compared to other developed countries like the United States and United Kingdom. The SA landscape is more focused on using SM for personal use and career development than for business related purposes. This suggests the full benefits of using SM for business branding in SA construction are still to be fully recognized and appreciated by construction companies. Some respondents further elaborated and said:

"Not many business-to-business companies use social media in South Africa. Actually, not many businesses use social media at all. You do find companies have links to social media sites on their websites but when you check the sites, there isn't much posted. Maybe its because SA in not as technologically advanced as other countries. At this stage I do not think that SM is effective in SA"

While another participant indicated *"I can't really say how effective or beneficial social media is for us (South African construction industry) because there isn't any research on it".*

Most participants indicated that the effectiveness of SM for business branding is greatly reliant on the content that organizations use on their platforms. One participant indicated that

"the content that the company generates for their SM platform creates a brand perception among the audience in the SM landscape", suggesting that the content should be intentional and specific for the targeted audience to build the perception of the business brand. The effectiveness of SM platforms seems to rely on the content utilized and the targeted audience receiving this content and formulating a perception on the business brand.

f) Risks and challenges concerning SM platforms

The use of SM platforms in business presents additional challenges and risks. All participants in the study cited damage to business brand and reputation as the key risk associated with using SM platforms. This risk may emanate from various factors including human error, hackers, false information or malicious acts of other users, inappropriate behaviour of employees among others. Other participants highlighted that SM is meant to be a platform where a virtual community interact beyond, geographical and political constraints to achieve a common benefit. The bad behaviour of others that hide behind impostor accounts to spread fake news, degrading brand and reputation of businesses, came up as a serious risk to construction companies in SA. Most participants highlighted other risks but were also aware of ways they needed to adopt to mitigate risks. Most companies had SM policies in place whilst others were developing these policies for their businesses.

5 Conclusion

The qualitative data reavealed an awareness and utilisation of multiple SM platforms in the construction industry. There are potential benefits derived from using SM platforms in the SA construction industry. The benefits are minimal as the users have not fully exploited the platforms for maximum benefits. Users believe these platforms are not as effective in the construction industry due to the B2B nature of the business. However, there is a common inclination towards the choice of platforms like LinkedIn, Twitter and Facebook as the platforms that better serve the needs of B2B in the construction industry. The companies are however selecting the platforms that they believe bring value and serve their businesses better and focus on these platforms to market and position their brands. However, there is also hesitancy and complexity around how B2B businesses in construction derive value/ profits from the use of SM platforms. Risks of using SM platforms was also highlighted by construction industry as one of the disincentives in fully engaging with SM platforms. These risks were identified as varying from human error, hacking, false information and inappropriate use by employees among others.

Despite all the challenges, the construction industry in South Africa is cognizant of SM platforms and the benefits they can derive from these platforms. The platforms aids construction industry in recruitment, brand awareness, disseminating company information, sharing corporate social responsibility initiatives and showcasing completed projects and innovation among others. However, the industry has not yet reached a stage of full utilisation especially for B2B sector in construction.

We recommend that a further investigation of how B2B companies in construction can derive value/profits from the use of SM platforms be explored. This may offer more insights and education to construction companies and enhance their presence and business brand on SM platforms thereby deriving value for their businesses. Additionally, this may aid in educating construction businesses on how to mitigate risks relted to the utilisation of SM platforms.

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Construction & Demolition waste management practices in Australia and the UK: A comparison of organizational factors

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Abstract

Construction waste management remains in its infancy compared to other industrial sectors. In Australia as well as in the UK, Construction and Demolition Waste (C&DW) represents a significant proportion of solid waste going to landfill. In both countries, 44% of the C&DW is directed to landfill, which is higher than the worldwide average of 35%. Even though there is increasing interest from governments, industry and researchers on the topic, waste management practices still need to be improved. A purposive sample of stakeholders involved in the C&DW stream in Australia and the UK participated in the study. Semi-structured interviews were organised to discuss best practices in both countries. This paper presents organisational factors and reveals the key aspects identified by the industry specialists in both countries. These include identifying the economic values of waste materials, and maximizing waste management plans. The research also identifies external policies that would affect waste management practices in construction companies. A comparison of best practices in both countries is suggested as beneficial to managers and environmental stakeholders concerned with C&DW management.

Keywords

Australia, Construction, Demolition, United Kingdom, Waste Management

1 Introduction

The construction industry accounts for about 13% of the global economy and serves as a key driver for other industries due to infrastructure and facilities development (H.M. Government, 2008). In Australia, the construction and demolition (C&D) sector generated 16.9 million tonnes of waste in 2007 and 20.4 million tonnes of waste in 2017 representing a 3.5 million tonne increase in 10 years (Pickin, Randell, Trinh, & Grant, 2018). Amongst this waste, 10.1 million tonnes were recycled in 2007, and 13.6 million tonnes were recycled in 2017. Despite an increase in recycling, the amount of waste sent to landfill appeared to remain relatively high (Pickin et al., 2018). In the UK and in Australia, the amount of waste generated by the construction industry is increasing. The UK generated 221.0 million tonnes of waste in 2016, an increase of 3.3% from the 214 million tonnes generated in 2014. C&DW represented 29% of this waste (66.2 million tonnes), and 60.2 million tonnes was recovered, indicating a recovery rate was 91% (DEFRA, 2020). Construction company processes/procedures and public policies have been evolving to increase recovery and improve C&DW management. Lendlease, an international property and infrastructure group in Australia, Asia and Europe publicly reported that between the financial years 2010 – 2015, their diverted and disposed waste in Europe increased from 68% to 95%, whilst in Australia for the same period, change was from 57% to 74% (Davis et al., 2018). In Australia, according to NSW Environment Protection Authority (2019b) recycling rates in the C&D industry in NSW were 75% in 2010-11, 77% in 2017-18 with an aim of reaching 80% by 2020. The recovery rate from non-hazardous construction and demolition waste is significantly higher in the UK reaching 92,3%, (Department for Environment Food & Rural Affairs, 2021), compared to Australia where is doesn't reach 80%: only masonry materials are recovered at 81% (Australian Bureau of Statistics, 2020).

This research conducted a comparative analysis of waste management practices in Australia and the UK. Utilising both theoretical and empirically evaluated models the research identified practical operational policy and management interventions to integrate and enhance C&DW management in both domains. To facilitate this, the research investigated organisational, process and people perspectives of C&DW management following Van Tiem et al. (2012) who explained that optimising these three perspectives in an integrated way produces sustainable performance improvement and provides a medium for changing behaviour with respect to waste (Pongrácz and Pohjola, 2004). Newaz et al. (2020) and Davis et al. (2019) utilised a similar methodology and theoretical lens to identify factors affecting construction waste management in Australia. This paper focuses on an organisational perspective. A discussion of the organisational factors identified in the study identify convergence and divergence between the UK and Australia. Finally, conclusions and limitations associated with the research are set out.

2 C&DW Legislation and Organisation

All stakeholders involved in developing building projects need to make a profit and perceive the costs of recycling / reusing C&DW as a burden (Won and Cheng, 2017). To counter this and deliver efficacy, legislation and fiscal policies are a key driver to assist in construction waste minimization (Ajayi and Oyedele, 2017, Tam and Hao, 2016, Osmani, 2012). Typically, there is a desire to provide a benefit and enhance sustainable practices (Pitt et al., 2009, Al-Hajj and Hamani, 2011). Despite this Pitt et al. (2009), suggest there is little research that supports Governments' formulation or improvement of waste management strategies. These strategies are seemingly designed, promulgated and sometimes repealed with little or no construction professional engagement, which should be a prerequisite to good governance (Tam, 2008b, Bingham et al., 2005, Ajayi and Oyedele, 2017). An overview of pertinent legislation and its effect in each of the research domains follows.

2.1 Australia

There are eight States and Territories in Australia and each one has initiated independent C&DW reduction processes and strategies associated with reuse and recycling in response to federal policies (Park and Tucker, 2016). For instance, the Government of the Australian Capital Territory (ACT) promotes reuse of C&DW on site. In Western Australia, the Waste Authority provides members of the Master Builders Association (MBA) with information and tools to reduce waste and increase reuse and recycling (Li and Du, 2014). And finally, the Australian Building Codes Board enforces the National Construction Code with the authority to implement sustainable building practices (Park and Tucker, 2016). At an Australian Federal Government level, largely due to the undesirable impact of C&DW, the legislation of several policies focused on waste management and the environment in general have been promulgated

(Maund et al., 2018). For example, The Australian National Strategy for Ecologically Sustainable Development, the Environmental Protection and Biodiversity Conservation Act, the Intergovernmental Agreement on the Environment and the Commonwealth State of The Environment Reporting are representative examples of current Australian policies (Davis et al., 2019). To discourage disposal of waste in landfill, some states have imposed a levy. It is a source of funding for the government and can be invested in waste management (Commonwealth of Australia, 2018). Inconsistencies in legislation can lead to suboptimal outcomes. For example, around the time of writing some industries are transporting their waste to adjoining states with lower fees for waste disposal. Subsequently, the Environment and Communication References Committee has recommended “best-practice landfill standards” to overcome this practice (Commonwealth of Australia, 2018) (p. xi).

In 2014, the State of NSW published the NSW Waste Avoidance and Resource Recovery Strategy 2014-21. At the time, a 2021 target was set, in as much as 80% of waste generated by the C&D sector should be recycled (NSW Environment Protection Authority, 2014). More recently, they requested feedback from the community, the industry and other stakeholders and issued the Environmental Planning and Assessment Amendment Act 2017 (New South Wales Government, 2018), in order to clarify the EPA Act (p.5). Concerning waste management, the NSW Environment Protection Authority (2018) published The Better Regulation Statement - Protection of the Environment Operations Legislation Amendment (Waste) Regulation and the Standards for managing construction waste in NSW (2019a). Despite these well-developed strategies, Pickin and Randell (2017) suggested implementation was far from optimal, leading to the Australian Government reporting that C&DW represented 31% of the total waste sent to landfill (Pickin et al., 2018). Despite a gap between the policy intent and policy outcome, the construction industry has made some headway to reach good environmental policy outcomes (Maund et al., 2018).

2.2 UK

Cognizant of Brexit, at the time of writing the UK derives waste legislation from the EU regulatory framework (Adjei et al., 2015). The aims of EU waste legislation are promoted by the EU waste management principles (prevention principle, precautionary principle, polluter pays responsibility, and principles of proximity and self-sufficiency) and the EU waste hierarchy (Strange 2002 in (Adjei et al., 2015). The EU waste legislation and policy set the goal of ensuring that 70% of all CD&W is reused, recycled or recovered by 2020. The Site Waste Management Plan 2008 (SWMP) legislation that commenced in UK in April 2008 was repealed in December 2013 as part of a DEFRA red tape legislation challenge (Legislation Update Service (LUS), 2013). The legislation required a SWMP on every project with a value more than £300,000. Despite being repealed, industry professionals are still expected to voluntarily produce SWMP for effective waste management or as a means of ensuring compliance with green certifications such as BREEAM (Building Research Establishment Environmental Assessment Method). This fact is consequence of limited consultation associated with UK SWMPs, where 83% of respondents suggested they would continue to use some form of tool to record and manage waste on site (DEFRA, 2013). Noteworthy, from a government perspective, policing and enforcement of the legislation was stated as a key issue, together with a lack of capability to enforce the legislation. The legislation seemingly had little effect on ‘fly tipping’ (a process of illegal tipping).

Other UK legislation included a landfill tax that was introduced in 1996, to ensure that landfill waste disposal was priced to reflect its environmental cost and to help promote a more sustainable approach to waste management in which less waste was produced, reused or recycled (Morris et al., 1998). The landfill tax rate has increased over time. This has been pronounced as a highly effective tax (Ajayi and Oyedele, 2017). The overall goal of the landfill tax was to ensure that polluters pay for the cost of waste management in line with then current EU directives. Contrary to this, in earlier research, the premise of the legislation was debunked (Morris et al., 1998). Morris et al (1998) cite Government Ministers announcing contrary uses of the tax in a general way to reduce wages, as opposed to its regulated objects, that included inter-alia; reclamation, reduction of pollution, R&D and environmental protection. Other significant UK legislation that affected C&DW activities according to Ajayi and Oyedele (2017) was the European Union Waste Framework Directive (2008/98/EC) which required waste to be managed without risk to health or the environment including air, water, soil, animal and plants. It established the polluter-payers principle that stipulated that the cost of waste management should be paid by the current or previous waste holders i.e., the polluter. The Waste Framework Directive, which favours preventive measures over re-use, recycling, and other recovery, was the best approach to tackling waste, having been implemented in the UK through Waste Regulations (England and Wales) 2011. In both UK and Australia, policies were useful to encourage construction companies to increase waste management. However, there was often a gap between the policy intent and the policy outcome (Maund et al., 2018). The following section introduces the methodology used to undertake a comparative analysis of waste management practices in Australia and the UK respectively.

3 Methodology

This is the first study to compare Australia and UK waste management practices based on a construction industry stratified sample. Three perspectives being; organization, process and people were identified as suitable points of view to investigate following Van Tiem et al., (2012) explained a focus on these three perspectives is required to attain sustainable improvements in a project setting. Love et al. (2012) and Simon et al. (2020) also used this method to study error management in construction projects and the tendering phase of Public and Private Partnerships respectively. Data collected through interviews were analysed from an organisational perspective, to meet the aim of the research. The research strategy employed primary data from interviews exploring the narrative of events in construction and waste stream organisations (Jamshed, 2014). Following the methods used in previous studies and to collect and examine the in-depth perspectives of the participants, interviews were conducted to collect data from construction and demolition experts. The sample was purposive, designed to capture in-depth experience and expertise. It comprised 35 experts from within the construction sector. Selection was based on participants satisfying at the following criteria (Krueger and Casey 2000):

1. Minimum 5 years of experience of construction project delivery in Australia and UK and;

2. Sound knowledge of C&DW management, policies and procedures and;

3. Part of the current waste stream supply chain.

All the interviews were semi structured (Kallio et al., 2016). Open-ended questions were posed to the participants following the perspectives of organisation. The participants were encouraged to contribute as much as they could using their knowledge and experience. An interview protocol framed the semi-structured interviews. A simplified version of the protocol is set out in Table 1.

Table 1: Simplified Interview Protocol

Comparison of Australia and UK Construction Waste Management Practices - Interview Protocol	**Category**
Please identify internal policy/ governance (i.e., policy, strategic plans, company reports, etc.) that potentially affect waste stream management. Please identify external policy/ governance (i.e., legislation – state or federal, policy, best practice or code of practice document) that potentially affect waste stream management.	Organisation
Overall, what are the key challenges for waste steam management? What forward thinking solutions do you anticipate will change waste steam management within the next 5 years?	General
Ethics approval reference: H-2017-0053	

Interviews were digitally recorded and transcribed. The researchers used the software Nvivo to help with the data analysis because the software works well with most research designs and analytical approaches (Zamawe, 2015). The three steps of data analysis of grounded theory were followed. First the data was coded line by line with ideas and key sentences moved into categories. Second, relationships and connections are identified between the categories. Third, these relationships and connections were refined (Noble and Mitchell, 2016, Corbin and Strauss, 2008). These three steps allow the research to distance from the data and analyse it (Bonello and Meehan, 2019).

The evidence was based on discussions with 35 participants (19 in Australia and 16 in the UK). Table 2 provides a summary of the interviewees. The interviewees and their respective organisations have been made anonymous to comply with university research ethics.

Table 2: List of the interviewees

Interviewee	**Type of organization**	**Country**
Interviewee AUS-1	Tier 2 construction company (A)	Australia
Interviewee AUS-2	Tier 2 construction company (A)	Australia
Interviewee AUS-3	Tier 2 construction company (A)	Australia
Interviewee AUS-4	Tier 2 construction company (B)	Australia
Interviewee AUS-5	Tier 2 construction company (B)	Australia
Interviewee AUS-6	C & D recycling company (C)	Australia
Interviewee AUS-7	C & D recycling company (C)	Australia
Interviewee AUS-8	Tier 2 construction company (D)	Australia
Interviewee AUS-9	C & D recycling company (I)	Australia
Interviewee AUS-10	Tier 1 construction company (F)	Australia
Interviewee AUS-11	Tier 1 construction company (F)	Australia
Interviewee AUS-12	Tier 1 construction company (F)	Australia
Interviewee AUS-13	Tier 1 construction company (F)	Australia
Interviewee AUS-14	Tier 1 construction company (F)	Australia
Interviewee AUS-15	Tier 1 construction company (F)	Australia
Interviewee AUS-16	Tier 1 construction company (F)	Australia
Interviewee AUS-17	C & D recycling company (E)	Australia
Interviewee AUS-18	C & D recycling company (H)	Australia
Interviewee AUS-19	C & D recycling company (G)	Australia
Interviewee UK-1	Construction company (J)	UK
Interviewee UK-2	Construction company (J)	UK
Interviewee UK-3	C & D recycling company (K)	UK

Interviewee UK-4	Construction Equipment Manufacturer (L)	UK
Interviewee UK-5	C & D recycling company (M)	UK
Interviewee UK-6	C & D recycling company (M)	UK
Interviewee UK-7	C & D recycling company (M)	UK
Interviewee UK-9	C & D recycling company (N)	UK
Interviewee UK-10	Construction Equipment Manufacturer (P)	UK
Interviewee UK-11	Construction Company (Q)	UK
Interviewee UK-12	Construction Company (Q)	UK
Interviewee UK-13	Construction Company (Q)	UK
Interviewee UK-14	Construction Company (R)	UK
Interviewee UK-15	Construction Company (S)	UK
Interviewee UK-16	Construction Company (S)	UK

The topics discussed by 50% or more of the interviewees in both countries are examined below. The differences between the countries are also analysed. Of the 19 participants from Australia, 13 were from construction companies. Six were from C&DW recycling companies. All participants had extensive experience, meeting the criteria identified above, either in construction or C&DW. On the other hand, out of the 16 participants of UK, 9 of them were from construction companies, 5 of them were from construction and demolition recycling companies and 2 of them were from construction equipment manufacturers.

The number of quotes about each factor is shared to demonstrate how often the topic was discussed in the interviews (Davis et al., 2019, Newaz et al., 2020).

4 Results and Discussions

The organisational topics discussed by five or more participants (out of 9) in Australia are listed in Table 2. The topics discussed by six or more participants (out of 12) in the UK are listed in Table 3.

Table 3: Organizational factors listed in half or more of the Australian interviews

Organizational factors	Number of quotes	Organisation
Waste Management Plan	44	9
Economic Values	35	9
External Waste Management Policy	21	7
Recycling Returns	15	7
Waste Characterization	13	6
Benchmarking	12	5
Reporting	9	5

Table 4: Organizational factors listed in half or more of the UK interviews

Organizational factors	Number of quotes	Organisations
Waste Management Plan	39	9
Economic Values	20	8
External Waste Management Policy	26	7

It is interesting to note that the sample display convergence with respect to the first three factors.

4.1 Waste management plans

Site Waste Management Plans (SWMP) were discussed extensively. In the UK, SWMP's were compulsory between 2008 and 2013 (Legislation Update Service (LUS), 2013), accordingly participants spoke about them directly. However, Australian interviewees mentioned the concept more generally in collective terms, as the term WMP does not appear in Australian legislation. Interviewee AUS-4 explained that in his company a project management plan was written for each project. "Each project has a project management plan which comprises of quality, safety and environmental sub plans that sit within it." He explained that this plan details how the job was to be conducted, including how to manage environmental considerations. This company has an internal goal of recycling at least 80% of everything that leaves the site, so it is important for them to have a clear plan to trace waste and achieve the objective. In the UK, respondents were more familiar with SWMP's as these had been compulsory for projects over a certain value. Most of the respondents said that they still had waste management plans despite law no longer making them compulsory. Interviewee UK1 explained that a SWMP plan enabled them to improve their waste management, so they decided to keep the plan and include it in a more general Environmental Policy "rather than having a separate policy [it's all]… - it's contained within our environmental policy. So we have a line that talks about waste within that wider policy. The policy is signed off by the CEO."

Interviewee UK-11 explained how detailed their waste management plans were. "There is some software which we use and input into and actually review anyway at the end of the project, within three months I think we have to do that." The amount of waste is predicted as well as the amount of recycling, and the goals are reviewed after the project is completed. Interviewee UK-2 explained that they work with their contractors and especially their demolition contractors to develop the waste management plans. These waste management plans are improved during the project as shows this quote: "That's our site waste management plan for this project. We're up to revision nine." Tam (2008a) explained that waste management plans are useful to propose solutions for waste management and reuse, however its cost can sometimes be an issue for its implementation. An Australian study shows that despite not being compulsory, waste management plans can really help in decreasing waste and also waste management costs (Mcdonald and Smithers, 1998). A study from the UK showed that a lack of a management plan will negatively affect waste management (Domingo et al., 2009).

4.2 Economic values

The economic value factor, despite being directly cited less often than waste management plans, was an underlying topic in most interviews in both countries. The cost of waste management has a big impact on the use of waste management strategies. For example when NSW decided to set a waste levy, it influenced construction companies to try to increase waste management to decrease waste disposal costs (Shooshtarian et al., 2020). Interviewee AUS-4 explained: "With the fees and the levies that have been imposed in New South Wales, I think we've certainly seen an increase in the cost of dealing with waste, whether it's the demolition of the building or the resulting waste from construction activities. We've definitely seen an increase" and "Probably the reason why recycling does get greater is to try and help reduce the cost. "An interviewee working in a concrete recycling business agreed: "Our business only existed - only kick started because of the waste levy. Without the waste levy, no one would bother separating their concrete, bricks or timber". When waste is seen as a cost, companies will be motivated to reduce it, explained another interviewee from the UK (1): "I think attitudes of any - it is still seen as a cost. So, people are fairly open and fairly keen to try and reduce waste wherever possible". Another UK (11) respondent agreed saying: "we're expecting that to minimise waste on our sites, largely to a certain extent on saving the job money, of course, because money's very tight and of course, you have those responsibilities environmentally now anyway". Conversely, if the cost of managing waste is excessive, it can also be a deterrent: "Gyprock and things like that, there's just not the backbone behind us to put it in. You can't price the work to spend that labour or you don't win the job" (Interviewee AUS-1). States and governments need to carefully consider financial incentives to motivate waste management by construction companies without being too much of a burden for them. This agrees with the findings of Shooshtarian et al. (2020) who explains that market incentives to encourage waste management are more welcome than pecuniary imposts such as levies. Their study focused on the Australian situation, but the UK participants in this study showed a similar opinion. This is linked to the third factor identified in both countries, the impact of external waste management policies.

4.3 External Waste Management Policies

In Australia, discussions focused on the Environmental Protection Authority (EPA) and on waste levies. The respondents agreed that a harmonization of the legislation around the country would be beneficial to waste management (i.e. the same levy amount everywhere for waste disposal). The waste levy seemed to be the most important part of the legislation Australian construction companies focused on. In the UK, the discussions were a lot more about compliance with the legislation. "We've got at least 10 processes and procedures around managing waste. If I'm being honest, they are focused on recycling but they're equally as focused on legislative compliance, because it's something that's seen - it always has been seen as a risk, a serious risk of prosecution" (Interviewee UK-2). More companies in the UK were also seeking to validate environment accreditation such as ISO14001 and PAS402 or were evaluated with the Building Research Establishment Environmental Assessment Method (BREEAM) and therefore had to follow external waste requirements. In some cases, it was the clients who required these accreditations: "Well I think most of the clients have a focus on waste. We have requirements on most of our contracts. They set down targets on most of our contracts that they want us to meet. So that's immediately something which - that makes a big difference that a client as a contractor, whether your construction team will put more effort into identifying ways of reducing waste" (Interviewee UK 12). In Australia, clients seemed less strict on their waste requirements: "I think different clients want different things. Some clients have no drive or motivation in relation to waste management. For others it's a key item" (Interviewee AUS-8).

The importance of the external waste management policy was also identified in an Australian study by Davis et al. (2019), that showed that external financial incentives would have a positive influence on waste management. Wu et al. (2017) and Esa et al. (2017) also identified a positive link between strong waste regulation and increased waste management. Both studies, focusing on China and Malaysia respectively, agreed that a combination of incentives and penalties would lead to the best outcomes.

5 Recommendations and Conclusion

This study has highlighted similarities and differences between C&DW management in the UK and in Australia. In general waste management culture seemed stronger in the UK where SWMP are implemented for each project and where a waste champion or a waste manager is usually responsible for C&D waste management. However, similarities were preponderant between the two countries: The need for a site waste management plan, the impact of external policies and the economic value or cost of waste management were the topics most discussed in both countries. Both countries have set targets to decrease C&DW generation and have legislation in place aimed at improving C&DW management (Adjei et al., 2015). Tax levies for example, have been implemented in both countries to motivate companies to optimise waste management. The UK went further in making the Site Waste Management Plan (SWMP) compulsory for every construction project (Legislation Update Service (LUS), 2013). The legislation later changed, but the interviews showed that many UK construction companies are still using a SWMP for every project. Some Australian companies also discussed using a SWMP, but it seems this is not as widespread as in the UK. The legislation affects the organization of C&DW management and can have a positive impact on waste management culture in the construction industry. Having a SWMP on each project requires management teams to think about ways to improve waste management. It allows the identification of people and process factors that will affect waste management early in a project. For example, if a lack of knowledge or experience in managing waste is identified early, training of employees can be organised to optimise C&DW management. Preparing the SWMP for a project also allows the identification of processes to be optimised, such as on-site sorting.

Motivating UK and Australian construction companies to have a SWMP for each project can be through legislation before becoming part of the industry culture and habits. This will facilitate anticipation of issues and improvement of C&DW management in general. This study has focused on organisational factors to improve waste management in construction projects. Future research should also study the people and process factors. An all-encompassing research study, including people, processes and organisation factors is required for sustainable improvement (Van Tiem et al., 2012, Simon et al., 2020, Davis et al., 2019).

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Agile Ways of Working in the Construction Industry

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Abstract
Albeit growth in the industry, infrastructure and construction projects experience unsustainable profit margin and slow investment in innovation, research and development. The World Economic Forum – Future of Construction initiative has proposed Project Delivery to be one of the ten key areas that are challenging to the industry. Being in an ever-changing and complex environment, industry experts seek to improve construction projects and analyse the disruption of the industry through a holistic lens. Agile ways of working (originating from the software industry) is believed to promote innovation and effective team work. The purpose of this study is to investigate the potential and opportunities to apply agile methodologies in construction projects. This study involves understanding the challenges faced using the traditional methods, and the success factors and hurdles for on-time and on-budget delivery. Extensive research and literature reviews on the application of agile practices in other large scale, non-software industries is conducted to explore the suitability of agile methodologies in improving team productivity and solving the identified deficiencies. This paper proposes a framework to integrate agile ways of working within the construction industry. The framework looks at redesigning the construction management processes to manage, assure and control quality in construction projects, as well as to improve workforce productivity and performance.

Keywords
Agile project management, agile construction, building adaptation, construction management, innovation

1 Introduction

Public and private physical assets such as buildings, roads, telecommunication towers, play an essential role in the economic development and social welfare of a nation. The increasing populations and urbanisations are leading to a rising demand for our towns, cities and built environment industries to be more sustainable and globally competitive.

The construction industry, including property and facilities management, is a major industry globally. In Australia, the built environment industry contributes to 16% of Australia's GDP, undertaking more than $120 billion worth of work annually (Sustainable Built Environment National Research Centre 2011).

Most of the built environments that exist today are more than 20 years old and adapting and retrofitting them will be central to preparing for the future and avoiding them from becoming abandoned or under-utilised assets. In the city of Melbourne, the average cost of building adaptation is approximately $343 000 per building and 12% of those are over $1 million per building (Zou et al. 2017). Building adaptation is a key component of sustainability strategy for the City of Melbourne (Wilkinson, James & Reed 2009).

Building adaptation plays a critical role not just for the building owners but also the occupants of the building. However, effective communication, coordination and stakeholder engagement remain a barrier for building adaptation projects to be executed successfully. This portrays the need to connect and enhance participation among the different stakeholder groups in the conceptual and designing stage of life cycle of buildings. Commonly used in the software industry, the agile way of working has strong focus on iterative development, flexibility and human-centred design. It is believed to promote innovation and effective team work.

This paper proposes a framework to integrate agile ways of working within the construction industry, specifically for building adaptation projects. The framework builds on the findings from the literature review as well as evidence from a case study. The case study presented in this paper is of a recent office building refurbishment project. Adoption and use of the agile principles during the planning and design phase was critical in formulating the construction execution strategy thus contributing to the success of the project.

2 Literature Review

2.1 Building Adaptation

The term "building adaptation" often incorporates other terms such as "renovation", "refurbishment", "remodelling", and "retrofitting" of buildings (Wilkinson, James & Reed 2009). Building adaptation plays a crucial role in responding to current requirements such as sustainability and occupants' comfort in terms of aesthetic, acoustic, lighting, quality of indoor air and many others (Seghezzi & Masera 2016). This is even more prevalent in the 21st century where building owners face challenges in reducing the capital investment cycle time, while being responsive to changes in technology and user expectation. In fact, the end of a building adaptation project is the start of another project where the team needs to evaluate and plan for the next cycle of change and investment (Forrest & Bostick 2013).

The building process is non-linear, especially in the planning and design phases. Kiviniemi and Fischer (2005) suggests the design and planning process to be iterative with several changes and revies required. This process is demonstrated in Figure 1. These early phases are critical as many ideas are formed and key decisions such as investment priorities, technology selection and structural design optimisation are formed. These decisions indirectly impact the future design and operation of the building (Clements-Croome & Croome 2004; Kuda & Berankova 2014).

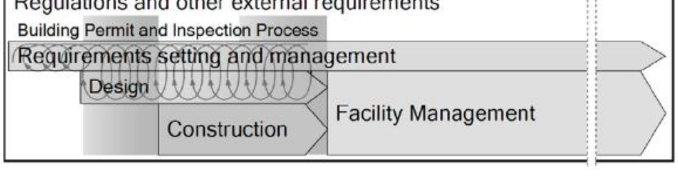

Figure 1: The non-linearity of building processes (Kiviniemi & Fischer 2005)

Building adaptation is a complex process with many stakeholders involved. The stakeholders include designers, architects, contractors, consultants, contractors, clients, facilities managers and many others (Kuda & Berankova 2014; Seghezzi & Masera 2016). These stakeholders may have different and sometimes contrasting priorities (Seghezzi & Masera 2016). Voss (2014) stated that a lack of communication between the different stakeholder groups led to misunderstandings and issues during the various phases. Insufficient communication between stakeholder groups is also one of the reasons for schedule delay in building adaptation projects (Cho, Kim & Hong 2020). Currently, the facility managers are only involved at the handover point between construction and facility management (Kuda & Berankova 2014). Having all stakeholders involved in the early stages is said to contribute to the success of a building adaptation projects, financially and non-financially (Bond 2010).

The planning and design phases of a building adaptation project involves multiple iterations of reviews and changes. In such a dynamic environment with many parties involved, it is important for the team to be open and adaptable to changes to enhance project performance and ensure that the end-users needs are met.

2.2 Agile Development Planning

Agility is an innovation concept that has revolutionised the information technology (IT) sector. The agile manifesto that was developed in 2001 has improved motivation and productivity of IT teams and led to higher overall customer satisfaction (Bambauer-Sachse & Helbling 2021; Rigby, Darrell K, Sutherland, Jeff & Takeuchi, Hirotaka 2016). The agile manifesto and principles that were developed can be summarised into five core elements: (1) Focus on customer value; (2) Iterative and incremental delivery; (3) Experimentation and adaptation; (4) Self-organisation; and (5) Continuous improvement (Larson & Gray 2010). Examples of agile practices include frequent communication and collaboration, continuous delivery, customer interaction, and failure-resilient approach (Corral & Fronza 2018).

While the agile manifesto was developed in 2001, industry experts believe that traces of agile practices are applied informally since 1620, such as the Plan-Do-Study-Act (PDSA) methods to improve products and processes and a team-oriented approach applied throughout the development process for at companies such as FujiXerox and Honda (Rigby, Darell K, Sutherland, Jeff & Takeuchi, Hirotaka 2016).

The success stories on the application of agile practices in the software industry has inspired other industries to adopt agile practices in their work processes. Industries that have adopted agile practices include digital marketing, management consulting, and tourism and many others (Almeida 2021). Owen et al. (2006) did a comparison between the traditional and agile management principles and the findings are tabulated in Table 1.

Table 1: A comparison between the traditional and agile management principles (Owen et al. 2006)

	Traditional	**Agile**
Attitude to change	Control and avoid change	Embrace change
Approach to risks	Reactive	Proactive adaptation
Management structure	Close and hierarchical	Flat and team-based
Attitude to customer involvement	Irritating obstruction	Key to organisational learning
Nature of planning	Sequential and comprehensive	Delayed decision on planning

The agile concept was originally developed to accommodate small team sizes. However, standalone agile methods are inadequate to deliver the desired results in complex interdisciplinary industries (Han & Bogus 2013). As such, numerous conceptual models for agility implementation to address this challenge (Tseng & Lin 2011) For example, Tseng and Lin (2011) designed an agile enterprise conceptual model that can enhance the agility of an enterprise and ensure a competitive edge. The model was applied on an IT enterprise and the stakeholders involved were generally supportive of the approach. In manufacturing, Gunasekaran (1998) developed a conceptual model to illustrate the concept and enablers of agile manufacturing. The framework considers business process development, cost management, information technology and other elements. It is designed to allow agile manufacturing enterprises to thrive in a competitive environment and adapting quickly to change. The manufacturing industry has observed significant improvements in productivity, waste management and cost savings through the adoption of agile (Chikwendu, Constance & Chiedu 2020). In recent years, research is conducted to study the application of agile practices in the construction industry. However, the publications and materials available are sparse. Han and Bogus (2013) have developed an agile construction management system to deal with construction delays. Similar to the agile enterprise conceptual model, the components in the agile construction management system include capabilities, drivers, enablers and metrics.

Table 2: A comparison of components in different agile models

Components	Agile enterprise conceptual model	Agile construction management system
Capability	YES	YES
Driver	YES	YES
Enabler / Provider	YES	YES
Metric	NO	YES
Goals	YES	NO
Strategies	YES	NO

While there is an agile framework that could be applied in the construction industry, the framework created by Han and Bogus (2013) is at its conceptual phase. Besides that, the framework is tailored for generic construction projects and has strong focus on construction delay. The framework does not address its application on building adaptation projects, nor its suitability to minimise coordination and communication challenges. The goal of this paper is therefore the development of an agility framework on building adaptation to enhance stakeholder communication, improve occupant satisfaction and drive workforce efficiency.

3 Research Methodology

This paper was divided into three stages. Firstly, a comprehensive review of existing literature was carried out to establish the need to apply agile development planning methods to improve collaboration and communication. Secondly, an agile building adaptation system was created as an integrated methodology to enhance agility as a proactive option to effective communication and coordination. This framework is derived based on the outcome of literature reviews. This framework aims to illustrate how the major capabilities of agile building adaptation should be supported and integrated with appropriate agile enablers to create a collaborative and adaptable project environment. Each component of the framework is obtained through literature review and explained in detail in the findings sections. It acts as a guideline for industry professional to apply agility in building adaptation projects.

Finally, a case study involving a building refurbishment project was conducted to validate the components of the framework. The case study project was not an unusual refurbishment with common challenges during the planning and design phases. These challenges include schedule pressures, silos between stakeholders of different expertise level, uncertainties in requirements and others. The information was collected through observations, which is a common method used in qualitative research. In this instance, non-participatory observation is used to validate the various components of the framework as observations are suggested as a useful approach to gain a holistic understanding of contexts for research that involves implementation. It is a valuable way for investigation where there is a the dynamic interaction between different aspects, and in this case, the different components of the framework (Eldh et al. 2020).

4 Findings and Discussion

The goal of this framework is to enhance satisfaction among users and project teams. This framework is designed to unite the resources of a project to create value. It outlines the possible resources to improve agility and provides an integrated procedure to be agile in building adaption project. The framework is shown in Figure 2.

The attributes of this framework are built based on the ideas and results obtained from agile enterprise, agile manufacturing and agile construction. Each building adaptation project is viewed as a temporary organisation. The attributes of this framework include the agility drivers, agility goals, agility capabilities, agility strategies, agility providers and agility metrices. This model specifically links agility "drivers" to five essential capabilities. These capabilities are supported and integrated with the relevant agile providers. It contains the logical procedures to coordinate the various agility providers, ensuring they can satisfy the capabilities and drivers, and ultimately transforming these components to meet the strategic goals of the project.

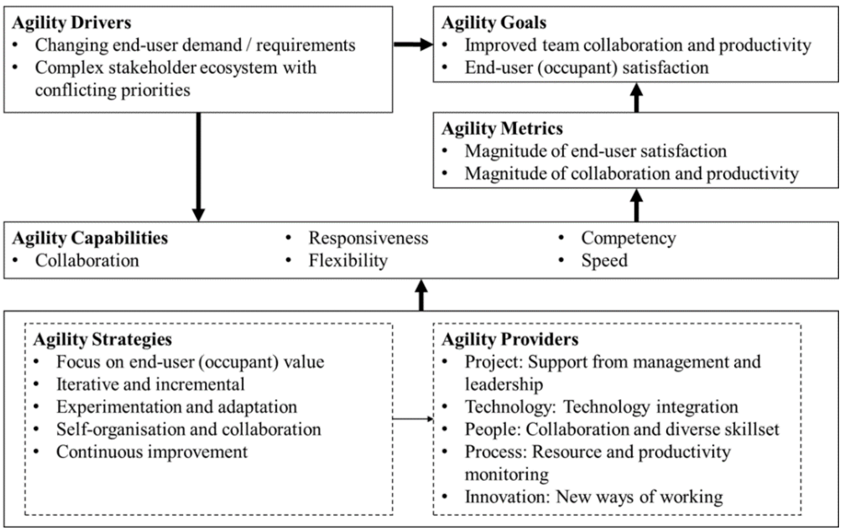

Figure 2: A framework to apply agile practices in building adaptation

The framework acts as a guideline for innovative engineering, construction and property management organisations to adopt agile practices, both at the project and enterprise level.

4.1 Attributes of the framework

The agility driver is the motivation to adopt agile methods. In a building adaptation project, the agility drivers include the complex stakeholder ecosystem and the constant change in requirements during the planning and design phases. There is also an increase in end user's expectations and demand. A building adaptation project involves many stakeholders such as project managers, architects, engineers, and many others (Kuda & Berankova 2014; Mitropoulos & Howell 2002). Agile methods are suggested to put customers in the centre and enhance team collaboration. The agility drivers and agility goals often work together where the agility goals are the targets of the agility system in relation the project goals.

The agile capabilities are the characteristics of being agile. There are five common agile capabilities, including coordination, responsiveness, competency, flexibility and speed (Han & Bogus 2013; Tseng & Lin 2011). Coordination and communication are enhanced through agile practices such as the daily stand-up. Another capability of agile is responsiveness which is the ability for the team to adapt quickly to changes in requirements. This is followed by competency where the team is efficient and effective in reaching the project goals. The fourth agile capability is flexibility where the team is open to implementing different ways of working that suits the needs of the team and the end-users. In addition to flexibility, an agile team displays the speed attribute, that is the ability to complete an activity in the shortest possible time (Han & Bogus 2013; Tseng & Lin 2011).

The agility strategy attribute is the foundation to implement the agility providers. It is the how-to for responding to changes and uncertainties. Some of the strategies in the building industry that are aligned to agile practices include:

Focus on end-user value: To ensure the building delivers financial and non-financial benefits, the team needs to consider the comfort, well-being and performance of the occupants.

Iterative and incremental: As described in earlier section, the building adaptation process is iterative with constant changes and revisions.

Experimentation and adaptation: To ensure that these changes are managed effectively, the team needs to be open to adapt to these changes, and experiment with potential solutions.

Self-organisation and collaboration: Through the application of agile practices, this model encourages all relevant actors to participate in decision making during the early phases.

Continuous improvement: Continuous improvement is about creating a culture of assessment for building facilities. It can be applied either between phases or between projects.

The agility providers need to align with the agility strategy. They are a series of agile methods that lead to agile performance throughout the project (Han & Bogus 2013; Tseng & Lin 2011). The providers in the framework are explained in detail below:

Project: For agility to be enabled, the project organisation needs to have the support from leadership to incorporate agile methods (Shibeika & Harty 2015).

Technology: Technology integration in building adaptation projects is increasingly more important these days. Examples of technologies used in the sector include building information modelling (BIM) and prefabrication (Ding et al. 2019; Shibeika & Harty 2015).

People: A building adaptation project involves people with diverse skillset such as management, design, engineering, and others. For agile to be applied effectively, an integrated team needs to be formed at the beginning, with the end-users involved in the process.

Process: In many building adaptation projects, it is common for ideas and key decisions to be formed during the early stages. Hence, prioritisation and on-going monitoring (common practices in agile) need to be applied to ensure cost optimisation.

Innovation: Innovations is another key enabler for agile practices to be applied in building adaptation project. Khalfan (2020) suggested the a few agile ways of working that can be applied in construction projects, such as the use of Scrum practices to obtain ongoing feedback.

The final attribute of the framework is the agility metrics, which is used to measure the agility level of the project and the influence of the agility providers (Tseng & Lin 2011). The agility metric is an important means to measure the success the framework. The agility metrices proposed are the magnitude of end-user satisfaction, collaboration and productivity.

4.2 A Practical Case Study

The building owner is a key player in developing and maintaining commercial, retail, logistics, warehousing and residential property in Australia. The building owner has a clear vision which consists of four pillars: Customer Experience, Sustainability and Environmental, Social and Governance (ESG), Sustainable Community and Customer Inspired Technology. The four pillars contribute to the following key outcomes such as having a return on investment, attracting the current and future target market as well as providing a building that can integrate frictionless technology. The building owner is looking at enhancing an A Grade office tower in Melbourne's CBD through a refurbishment project.

Traditionally the building owner will provide a development brief, the architect will draw from the brief and generate a layout. The building services or facilities management team will follow suit and design their services around the built environment. This will be overseen by project managers who coordinate between the project design team and the building owner. A common approach for project of this nature is a "like-for-like" service replacement with the intent of maximising profit and attracting tenants. Similar to most projects. it takes a considerable amount of effort to get all the project stakeholders aligned to collaborate and provide an output that is aligned with the building owner's values.

However, in this instance, the building owner adopted a different approach. An engineering consultancy was engaged to stimulate diverse ways of working, where agile methods are incorporated. The consultants determined the business owner's core needs by facilitating a human-centred design workshop with the intent to gather project stakeholders and other industry leading professional to discuss fundamental requirements for the project. The participants of the workshop have various backgrounds and experience, thus enabling different perspectives to be gathered and to disrupt the "Business as Usual" mindset. The workshop facilitators set the ground rule by encouraging the participants to be mindful of one another's opinion and assured the participants that the workshop is a safe space for an open discussion. This is an example on how collaboration (an agility provider) is applied in alignment to the agile strategy, which is to focus on end-user value.

Apart from discussing ideas that are relevant to the business owner's values, the consultants also deployed a gamification method to encourage the project team to prioritise their investments choices. The project participants are encouraged to provide a reason for their choices. The choices and reasons are documented and analysed, and to provide an output such as a list of deliverables. The deliverables are grouped into two categories which are the "must have" and the "nice to have" items. This unique way of working, which is aligned to the process and innovation agility providers, encourages the team to be more responsive to the needs of the end users and the market.

The agile strategy of continuous improvement is also incorporated and is demonstrated through the "Process" agility provider. The consultant undertook regular reviews of the services designs during concept stage and introduced a series of design critique sessions during the schematic and design development phases. These sessions are intended to challenge the respective designers by engaging in a review or discussion with different parties. The outcomes are incorporated in the designs and key risks are also identified and subsequently mitigated. The consultant also proposed a value tracking initiative to measure the key design outcomes.

In addition to the previous example, technology integration, an agility provider or enabler, is also observed to enhance the agile capability of being flexible. This project took place during the COVID-19 pandemic where physical site visits are restricted. To be flexible and adaptable to such working condition, the consultant utilised a laser scanner and generated a point cloud of the most service intensive areas in the basement of the building. This allows the project team members to take accurate measurements by virtually walking around the basement.

This model shows how market driver and company objectives can be efficiently and effectively connected by ensuring that the agility providers are aligned to the agility strategies and drivers. It also shows how an unconventional way of working and incorporation of human centred design helps to enhance the understanding and coordination by different stakeholders.

5 Research limitation and future research

Although this new framework is feasible and efficient for applying agility in a building adaptation project, literature review and a single case study do not necessarily provide a true measure of success of this framework. Further research should be performed to bring this framework to maturity and compare its effectiveness in different aspects of a building adaptation projects such as risk management and others. Not only that, agility drivers, goals and strategies may vary with projects and organisation, and this model does not consider all agility factors. Other evaluation methods should also be incorporated such as agility index methods, fuzzy agility index methods, analytical hierarchy process (Tseng & Lin 2011).

6 Conclusion

Accommodating the change in user expectations and effective communication and collaboration remain a challenge in most building adaptation projects. Agile, a concept that originates from the software industry, advocates for putting the customer first and the importance of team collaboration. The benefits of agile go beyond the software industry and they are also observed in manufacturing and other environments. In this paper, the authors studied the potential for agile methods to be applied in building adaptation projects and a conceptual model is developed to incorporates the various agile concepts and providers. Through a case study, attributes of this framework are observed and validated. While additional research is required to measure the effectiveness of this framework, it is hoped that this paper will reinforce the future research in setting up an agile building adaptation project.

7 Acknowledgement

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Challenges of Green Building In Nigeria: Stakeholders' Perspectives

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Abstract
Green building has become a trend in recent years in an effort to improve the well-being of its inhabitants, community, environmental health, and life-cycle cost. The system's added benefits are the driving force behind the call to use it. Increased acceptance and adoption of green building systems in developed countries have increased awareness in many developing countries, particularly in Africa. As a result, the Green Building Council of Nigeria (GBCN) was established to regulate, monitor, and promote the use of green buildings in Nigeria. Unfortunately, because there are few or no green buildings in Nigeria, adoption has been slow. The aim of this research is to identify the challenges of green building in Nigeria from the perspective of stakeholders, as well as to assess the criticality of each obstacle. To achieve this aim, 86 stakeholders in the construction industry, including government representatives, clients, and professionals, were polled using a series of questionnaires. The findings indicate that the challenges differ depending on the stakeholder. Nonetheless, the common challenges were a lack of understanding and awareness about the economic benefits and opportunities of green buildings, insufficient government support, inaccessible legislation, and the perception that green buildings are expensive. The study recommends that the government take the initiative and lead in proactively preparing the country's urban landscape for green buildings.

Keywords
Challenges, green buildings, Nigeria, perception, stakeholders.

1 Introduction

Sustainability has become a concept that the entire world embraces in all aspects of life, and green building is no exception. Green buildings were unheard of a decade ago but emerged as a modern approach in the 1990s (Fisher et al. 2010). Green building construction has since become a trend in the industry, particularly among those who are aware of its benefits. According to Izran et al. (2014), the advantages of green building construction include not only noble environmental concerns but also money gained through higher rental rates and government incentives such as tax and stamp duty exemptions. Sustainable building construction reduces the use of finite raw materials and labour, as well as energy and water consumption, and thus the release of hazardous pollutants into the environment (McMahon, Marks, and Wallace 2015). Green building was perceived as the main principle of sustainable construction in developed economies such as the United States, referring to a resource-efficient method of building construction in terms of economy, durability, utility, and comfort (U.S GBC

2012). The benefits of constructing green buildings outweigh any disadvantages. As a result, there is a shift towards green building construction in developed economies, as well as increased interest in developing economies.

In response to a growing housing deficit, energy issues, and environmental risks, many developing countries are shifting to more sustainable building practices; however, it is unclear whether Nigeria's built environment is ready to adapt (Onososen and Osanyin 2019). Despite the numerous benefits of green building, it is still in its infancy in Nigeria, competing with the traditional building method, which is backed by government policies and relied on by a large population of stakeholders. This means that in order for green buildings to be adopted, drastic measures involving some critical steps must be implemented. The first step is to identify the challenges. It is clear that there is a paucity of research about the challenges of adopting green buildings among Nigerian construction stakeholders, indicating that the concept is yet to be effectively implemented in Nigeria, as it has in many developed countries. As a result, this paper investigates the challenges to sustainable building, also known as green buildings, in Nigeria by sampling the opinions of construction stakeholders.

The remainder of this paper is organised as follows: section 2 provides a concise review of the literature, and section 3 describes the methodology used for the study. Section 4 presents the findings and discussion, while Section 5 concludes the paper. The findings of this study will educate and inform construction professionals and policymakers about potential barriers to green building construction, allowing them to make sound judgments and informed decisions about whether to adopt and incorporate green building construction into the Nigerian construction sector.

2 Concept of Green Building System

Green building construction entails adapting a building and its site to the tropical environment, site layout, culture, and society in order to reduce resource consumption, increase resource availability, and improve life quality and complexity while incorporating all of these into a specific design (Dahiru et al. 2013). In other words, it is a building performance management strategy that ensures the success of complementary design through interdisciplinary teamwork (Dahiru et al. 2013). It is not an amalgamation of environmental modules nor a piecemeal reconfiguration of an already engineered standard building, but rather a building ideology in which environmental and economically viable features are incorporated (Dahiru et al. 2013). Green building, also known as sustainable building, creates structures that meet social, economic, and environmental standards. According to Gidado et al. (2017), green building design takes a thoughtful approach to energy and environmental sustainability, particularly when designing for the built environment. As a result, the concept of green building aims to reduce the negative environmental impact of buildings by improving efficiency and modernisation in the use of energy and materials, as well as environmental sustainability (Unalan and Tokman 2011; Sirinja 2013; Khalfan 2015). However, several challenges are impeding the adoption of green buildings.

2.1 High cost

According to several studies (Hakkinen and Belloni 2011; Ametepey et al. 2015; Byrd and Leardini 2011), one of the barriers to the use of green building is the fear of higher investment costs for sustainable structures compared to conservative buildings, as well as the risk of unplanned costs. The additional cost of incorporating green building components into construction projects in most developing countries, such as Nigeria, may be determined by local environmental factors including temperature, building conventions, and labour skill levels, and may significantly impede the establishment of green buildings. The high cost of green building, according to Shi et al. (2013), is primarily due to the overestimation of energy-saving strategies, increased consultancy fees, and underestimation of cost-saving methods. This implies that while the actual cost of constructing a green building is not prohibitively expensive, the associated costs are, suggesting the importance of accurate cost estimation.

2.2 Scarcity of green building materials

Another barrier to green building adoption is the scarcity of green components and materials in the construction industry. Several studies (Davies and Davies 2017; Aktas and Ozorhon 2015; Shen et al. 2017) showed that the majority of building projects in developing countries face difficulties obtaining green supplies locally. Ecologically friendly goods with a lower environmental impact that are required for the implementation of green building standards are not widely available in the building construction industry. Although, eco-friendly building materials such as bamboo, engineered wood, straw bale, reclaimed wood, cork, mycelium, earthen materials (Sivarethinamohan and Sujatha 2021), and others including martian concrete, self-healing concrete, smog-eating cement, wood foam, and glass brick have been developed; but they are not readily available in commercial quantity. Even in countries where these supplies and resources are readily available, delivery times are frequently lengthy. This necessitates the identification and development of locally sourced green building materials, as well as effective supply chain management.

2.3 Scarcity of information and expertise

The scarcity of expertise and information on the economic benefits and opportunities of green building is a barrier to its adoption. In most developing countries, a major source of concern is a lack of knowledge about the economic benefits of green building (Bernstein 2013; Abidin et al. 2012; Nguyen et al. 2017). Similarly, Azeem et al. (2017) noted that a lack of understanding, awareness, and information is a major impediment to the successful implementation of sustainable building practices. It is obvious that information and understanding are inextricably linked, which suggests that providing clear and concise information about the benefits of green building may increase its adoption. Similarly, the method and approach used to disseminate information can be critical. This implies that information should be tailored to the individuals who will be receiving it.

2.4 Lack of incentives/motivation

Construction industries in most developing countries appear to be underperforming in terms of providing subsidies to contractors who meet green building standards and experts who incorporate green building techniques into their models (Azeem et al. 2017; Ndihokubwayo et al. 2013; Oguntona et al. 2019). Previous research (Chan et al. 2018; Darko and Chan 2016) has found that a lack of government subsidies is a significant barrier to the adoption of sustainable building technologies. As a result, Serpell et al. (2013) proposed that providing incentives for green building can be a tool to reduce contract costs, shorten contract duration, and maintain an acceptable level of safety and health in construction projects, resulting in increased adoption of the concept. This implies that, in order to encourage the use of sustainable buildings, the government must implement effective financial and non-financial incentive schemes that will assist in mitigating the significant investment required for sustainable building.

2.5 Cultural and Social resistance

Many construction industry professionals in most developing countries have a general lack of concern about green building and a strong proclivity to continue traditional construction practices (Ahn et al. 2013). The lack of green building practice affects a variety of stakeholders, including built environment professionals, design authorising bodies, departments of lands and housing, and community development authorities. Furthermore, the majority of developing countries' construction industries are driven by construction parties who are uninterested in risky and costly green technological innovations (Ametepey et al. 2015). Construction professionals in such cases encourage the use of traditional methods while discouraging the use of alternative methods such as green building construction. It may be difficult to change the status quo of using concrete mixtures and concrete blocks, also known as wet construction. However, additional training and continuing professional development courses are required to help construction professionals understand green building systems.

2.6 Technological challenges

One of the primary impediments to the development of green buildings is a lack of technology and manpower. According to Hakkinen and Belloni (2011) and Opoku and Ahmed (2015), this barrier is due to a lack of competence in green building approaches and their long-term viability. Construction stakeholders are expected not only to be knowledgeable but also to form an embedded team comprised of all the built environment stakeholders (Opoku and Ahmed 2015). The International Labour Office agrees, arguing that changing skill requirements are the primary cause of labour shortages and a lack of industry skills in the construction industry (International Labour Office 2011). Because of the rise of green construction designs, technology, and practices, previously appropriate skill sets will need to be updated. As a result, Opoku and Ahmed (2015) recognised the importance of capacity development in the advancement of green construction methods.

3 Research Methodology

Two steps were taken to achieve the research goal. First, secondary data sources such as books, publications, workshop/conference papers, journals, magazines, and internet sources were used to examine works of literature on green design and construction. With the help of Google Forms, a structured questionnaire highlighting the many barriers to green building was created for the final step. The questionnaire was piloted with five construction stakeholders: an architect, a builder, an engineer, a quantity surveyor, and a project manager. This was done to identify any other specific barriers impeding the adoption of green building in Nigeria that had not previously been identified, as well as any other important information. Their exploratory comments and observations were incorporated into the final questionnaire.

A link to the online form was distributed to construction stakeholders via emails and social media platforms of relevant built environment professional bodies in Nigeria. The structured questionnaire consisted of two parts. The first section provided the respondents' profiles, which included their age, gender, educational background, years of experience, and level of experience in building construction. The second section, on the other hand, determined various constraints impeding the application of green building in Nigeria based on literature. The various responses to each factor were categorised using a five-point Likert scale. At the same time, participants were asked to rate their responses in order of importance to outline the statistical significance of each factor. Responses were classified in order of priority using the Likert scale, where 5 represents strongly agreed, 4 represents agreed, 3 represents undecided, 2 represents disagreed, and 1 represents strongly disagreed.

4 Results and Discussions

A total of 105 questionnaires were distributed via email and other social media platforms, with 86 properly completed and returned, which represents a response rate of 82%. This response rate can be considered appropriate when compared to previous studies on the subject that reported a low response rate. For example, in a study conducted by Dahiru et al. (2014), 50 questionnaires were distributed and an 80% response rate was reported. Similarly, Nduka and Ogunsanmi (2015) reported a 61% response rate. Table 1 summarises the demographic information provided by respondents.

Table 1. Demographic data of respondents

Gender	Frequency	Percentage (%)
Male	75	87.2
Female	11	12.8
Total	86	100.0
Stakeholder's Age	**Frequency**	**Percentage (%)**
25-35	37	43.0
36-45	29	33.7
46-55	15	17.4
56 and above	5	5.8
Total	86	100.0
Stakeholder's Qualification	**Frequency**	**Percentage (%)**
HND	4	4.7
B.Sc.	24	27.9
M.Sc.	52	60.5
Ph.D.	6	7.0
Total	86	100.0
Designated Organization	**Frequency**	**Percentage (%)**
Contracting organization	21	24.4
Consulting firms	39	45.3
Client	8	9.3
Academia	11	12.8
Government Agency	7	8.1
Total	86	100.0
Working experience	**Frequency**	**Percentage (%)**
Builder	1	1.2
Engineer	15	17.4
Architect	61	70.9
Project Manager	9	10.5
Total	86	100.0

Table 2 summarises respondents' perspectives on the challenges of implementing green building in Nigeria. The mean score (MS) was used to analyse the data, which adds all individual factor scores and divides them by the number of total scores (TS).

Table 2. Challenges of adopting green building in Nigeria

S/N	Item	1	2	3	4	5	N	TS	MS
1	**There is a lack of understanding and awareness about the economic advantages and opportunities of green buildings.**	13	10	9	26	28	86	304	3.53
2	**Government support is insufficient.**	15	15	5	28	23	86	287	3.34
3	**Unavailable legislation**	11	14	16	29	16	86	283	3.29
4	**Green building is thought to come at a high price.**	12	24	6	18	26	86	280	3.26
5	**There isn't a single unified/standard green building rating system in place nationally.**	10	20	13	23	19	86	276	3.25
6	**Low incentives for green buildings, both financial and non-financial**	14	12	14	30	15	86	275	3.24
7	**Professionals in the built environment face a technology/capacity hurdle.**	11	27	11	26	11	86	257	2.99
8	**Desire for traditional construction methods**	15	26	9	28	8	86	246	2.86
9	**Oppositions from key stakeholders on cultural and social differences**	13	23	21	22	7	86	245	2.85
10	**Green building supplies aren't readily available locally**	17	28	7	22	12	86	242	2.81

1-Strongly disagree, 2- Disagree, 3-Neutral, 4- Agree and 5- Strongly agree; TS – Total Score; MS - Mean score

As shown in Table 2, the highest mean score (3.53) is a lack of understanding and awareness about the economic benefits and opportunities of green building. Stakeholders are unaware of the numerous benefits of green building construction. This finding reflects Nigeria's lack of green buildings, as construction professionals will find it difficult to implement what they do not understand. Poor and ineffective sensitisation among stakeholders may be responsible for their lack of awareness and understanding. If this barrier is not properly checked, it will be a major issue. Previous studies (Bernstein 2013; Abidin et al. 2012; Nguyen et al. 2017) have also identified a lack of understanding and awareness of green building systems as a major factor affecting its implementation. This finding implies that the industry should increase stakeholder awareness through training and continuing professional development courses. Raising stakeholder awareness of not only the economic but also the environmental and social benefits can lead to increased adoption. Furthermore, more research is required to identify cost savings, environmental benefits, and social factors associated with the use of green building construction.

Insufficient government support ranked second (MS 3.34) among the challenges to green building adoption in Nigeria. The government can help with the implementation of a system or technique in a variety of ways, including financial and non-financial support. To encourage the adoption of green building construction, the government can provide grants, subsidies, and incentives to both clients and the industry. Non-financial assistance, on the other hand, can take the form of advice, information services, and training. Unfortunately, according to the findings of this study, none of these resources is available. Inadequate government support may be attributed to a lack of direction on the part of the government regarding the benefits of green building adoption. This finding is consistent with the study of Chan et al. (2018) and Darko and Chan (2016), who discovered a lack of government subsidies to be a major impediment to the adoption of sustainable building technologies. The implication of this finding for the government as a signatory to the sustainable development goals (SDGs) is to honour the call to protect the planet by providing both financial and non-financial support for the adoption of green building. Through this act, the government will contribute to several SDGs while also mitigating the significant investment required for sustainable building.

The lack of available legislation for the adoption of green building was ranked third (MS 3.29). The top-down approach, in which the government makes laws that citizens then follow, is the most common method for implementing a new technique or system in Nigeria. In order for a system or technique, such as the green building, to be fully implemented in the country, it will require legislation. This result, however, demonstrates that the necessary legislation does not exist. A number of factors may be responsible for the lack of legislation. One example could be a lack of pressure on the government to enact green building legislation from construction professionals including housing and urban planning agencies. Similarly, policymakers may believe that the green building system will not be politically advantageous. This finding is in agreement with the results of a study conducted by Darko and Chan (2016), who identified a lack of legislation as one of the obstacles to green building implementation. The implication of this finding is that construction stakeholders should continue to put pressure on the government to pass legislation that encourages the construction of sustainable/green buildings and the use of locally sourced materials.

Other challenges to the adoption of green building in Nigeria and how they rank are shown in Table 2. It is important to note that the majority of these challenges are human-induced, which means that adequate training, sensitisation, legislation, support (both financial and non-financial), and teamwork can ensure that many green construction concepts are implemented.

4.1 Relationship between the challenges and demographic data

A Pearson's correlation test was used to determine the relationship between the challenges impeding green building adoption and the demographic data of respondents. Stakeholders' profession, experience, and qualification were specifically considered to better understand the various characteristics that may exist among them. A Pearson's correlation (r) exists at a significance level of 0.05 (also known as alpha) for the purpose of this study. With a value of 0.05, there is a 5% chance of determining that there is no relationship when there is. The p-value indicates if the correlation coefficient differs from zero in a statistically significant way. According to the findings in Table 3, stakeholders' professions and experiences have no relationship with the challenges of implementing green building in Nigeria. Their level of qualification, however, is linked to two of the factors impeding the adoption of green building in Nigeria. The findings show that two factors (professionals in the built environment facing a technology/capacity barrier and opposition from key stakeholders on cultural and social differences related to stakeholders' qualification) have a small positive relationship with the challenges. These were reflected with a 0.01 level of significance (2-tailed).

According to the findings, the way stakeholders perceive technological advancement in the built environment changes as their qualification advances. This implies that as they gain more qualifications, they become more aware of the technology at their disposal. A stakeholder with a PhD, for example, may be more familiar with current technology in researching green building practices than a stakeholder with a BSc. Their level of exposure as they gain more qualifications could be responsible for this change. The implication of this finding for stakeholders is for them to consider further study leading to a qualification, which could aid them in understanding how green buildings work. They will be able to incorporate green practices into their projects in the long run.

Oppositions from key stakeholders on cultural and social differences vary as qualification advances. This implies that the key stakeholders' staunch opposition to adopting green building concepts will soften as they gain more knowledge. The current status quo, which is the traditional method of construction, has been in place for a very long time and changing it may be extremely difficult due to how well it has blended into society and culture. As a result, stakeholders are unwilling to give green building construction a fair chance. According to the findings of this study, this could change with increased education. The implication of this finding is that stakeholders must understand that change is constant and that they must be prepared for changes in the industry. With the adoption of various technological advances in the industry, such as green building, digital construction, robotics, artificial intelligence, and building information modelling, the importance of education, training, and continuing development of stakeholders cannot be overstated.

Table 3. Relationship between the challenges and demographic data

Item	Profession	Experience	Qualification	Correlation
There is a lack of understanding and awareness about the economic advantages and opportunities of green buildings.	-.029 .790 86	-.057 .605 86	.207 .056 86	r p-value N
Government support is insufficient.	.013 .902 86	-.096 .381 86	.128 .240 86	r p-value N
Unavailable legislation	.083 .449 86	.089 .417 86	.170 .118 86	r p-value N
Green building is thought to come at a high price.	-.022 .842 86	-.077 .483 86	.137 .207 86	r p-value N
There isn't a single unified/standard green building rating system in place nationally.	-.040 .719 86	-.017 .875 86	.110 .316 86	r p-value N
Low incentives for green buildings, both financial and non-financial	-.041 .709 86	-.114 .300 86	-.028 .800 86	r p-value N
Professionals in the built environment face a technology/capacity hurdle.	.117 .282 86	.067 .540 86	.269* .012 86	r p-value N
Desire for traditional construction methods	-.151 .166 86	-.166 .127 86	.059 .590 86	r p-value N
Oppositions from key stakeholders on cultural and social differences	-.085 .435 86	-.093 .394 86	.235* .030 86	r p-value N
Green building supplies aren't readily available locally	-.051 .642 86	-.016 .885 86	.078 .474 86	r p-value N

Correlation is significant at the 0.01 level (2-tailed) *.

5 Conclusion

From the standpoint of stakeholders, this study assessed the challenges of implementing green building in Nigeria. The most critical challenges identified were a lack of understanding and awareness about the economic benefits and opportunities of green buildings, insufficient government support, unavailable legislation, and the perception that green buildings are expensive. Nonetheless, it was determined that the government must take the lead and take proactive measures to prepare the country's urban landscape for green buildings. This is significant because the tactics described are critical for policymakers and industry leaders to develop a strategy for green building adoption in Nigerian cities. Furthermore, the study investigated the relationship between critical challenges and professional demographic data such as experience and qualification. According to the results of the Pearson's correlation test, qualification has a significant impact on two key factors: professionals in the built environment face a technology/capacity barrier, as well as opposition from key stakeholders based on cultural and social differences. This reflects the fact that the higher the qualification of the various stakeholders in the construction industry, the greater their perception of the strength of these individual factors as they relate to the adoption of green building in Nigeria. It is therefore recommended that stakeholders in the construction industry hone their skills and pursue further education in order to gain a better understanding of the importance of technology adoption and cultural and social differences in the construction environment, thereby increasing their knowledge on technologies required for green building adoption in Nigeria. Material suppliers form part of the stakeholders in the built environment. Unfortunately, these stakeholders were not included in this study, which is one of its limitations. As a result, the findings of this study cannot be generalised to all stakeholders in the built environment. Future studies may include suppliers in order to have a holistic conclusion regarding the adoption of green buildings in Nigeria.

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Career Choice and Professional Preference of Architecture Students in Nigeria

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Abstract

Architectural profession is known to be a career specific major. Studies have linked students' motivation to study a course and their intention to remain within the profession after graduation. Today, the number of the architecture schools in Nigeria is steadily increasing, as is the number of students enrolling for this course. However, most of these students complete their degrees and then leave the profession. This study examines the pyschological factors associated with career decision-making of architecture students. A quantitative approach was employed using a questionnaire survey to investigate students preferred area of specialization and factors influencing students' choice of studying architecture. A total of 167 students from a public university completed an online survey. Both inferential and descriptive statistics were carried out on the data collected. Findings revealed that interior design, 3D visualizer, architectural consultancy services and project manager were ranked 1st, 2nd, 3rd, and 4th most preferred area of specialization. Personal interest, expected salary, role models, and image of the profession were identified as the top four factors influencing the choice of studying architecture. Analysis of gender differences showed that there was a statistical difference between the male and female respondents with respect to factors influencing career choice and professional preference. In conclusion, the study makes recommendations for a dynamic architectural education with a focus on successful mentoring.

Keywords

Architecture, Career, Decision-Making, Gender, Professional Preference, Students.

1 Introduction

Globally, the construction industry seeks sustainable design solutions and best practises to reduce energy consumption, raw material usage, and climate-related impacts in order to achieve a sustainable built environment (US Green Building Council 2016). Architecture is a major career in the construction industry that holds a unique position in that it is the art and science of building design, as well as the creation, definition, and delineation of spaces for human habitation and uses. The role of an architect as a professional is intertwined with the expertise of other professionals in the industry. This bestows on architects the critical role of building industry leaders. As a result, architects play a significant role in the development of design solutions such as green buildings, which are essential for a sustainable built environment (Gucyeter 2016).

To facilitate the knowledge, skills, and competency required to meet the changing needs of society, the architect requires education and an intern professional development programme

(Adedeji et al. 2011). Schools of architecture have been established in several institutions across Nigeria in response to an increase in demand for architectural expertise (Magaji and Sa'adiya Ilyasu 2016). Students at such institutions receive training and practical experience aimed at preparing them to reframe their role in the professional environment (Mania 2018). The profession and practise of architecture in Nigeria has grown gradually. The Architects Registration Council of Nigeria (ARCON) has approximately 5000 registered architects as of 2020. Unfortunately, the nation requires at least 20,000 registered architects to meet the rapidly growing population's demand for housing and other infrastructure (Okafor 2017). In order to meet these requirements, architecture schools must produce graduates.

As previously stated, architectural education must attract and retain students.Therefore, it is important to understand the factors that can promote early career success. This relates to career choices and the expectations of prospective workforce. Young people have a lot of options when it comes to tertiary education. Choosing a career is an important decision that every young person or adult must make at some point in their lives. Making career decisions is a dynamic process influenced not only by an individual's preference but also by the interaction of several other factors (Sultana 2014). As a result, studies have been conducted to better understand students' career choice narratives in the architecture, engineering and construction industry (AEC) focusing on female students (Bigelow et al. 2015; Malone and Issa 2013; MacDonald and Durdyev,2020; Oo et al. 2018). This is due to the fact that construction-related degrees are overwhelmingly male-dominated, and most studies seek to investigate how female students can be encouraged and retained. However, in order for architecture programmes to meet industry demand, it is critical that efforts be effectively tailored to both male and female students to ensure success.

Studies on architectural education in Nigeria examined gender issues in learning of architecture (Fulani, 2017), entry qualification (Adewale and Adhuze 2013) education curriculum (Magaji and Sa’adiya Ilyasu 2016), satisfaction with grades (Ogunmakinde et al. 2017), and student performance (Opoko, Oluwatayo and Ezema 2016). Likewise, architecture students’ motivation for choice of course and retention in the profession have been studied (Adeokun and Opoko 2015). Despite the strides and progresses made in architectural education research, to the best of our knowledge, this study will be the first to holistically evaluate factors associated with undergraduate architecture students’ career decision-making of in Nigeria. Therefore, the research questions include:

1. What are the factors influencing students’ choice of studying architecture?
2. What are the professional preference of architectural students?
3. What are the gender differences in the factors influencing architecture students’ career choice and professional preferences? ?

To increase the supply of suitably qualified graduates and meet the future needs of professionals in the built environment, we must first understand what motivates people to pursue an environmental programme and a career in the environment. Regardless of the career, the influences that affect decisions about which higher education programme and career to pursue are likely to be similar. As a result, developing an understanding of the influences on people when they are considering their future careers would help us consider how to attract people to a specific profession, such as architecture. In essence, the purpose of this article is to gain an understanding of the factors that influencecareer decisions. Findings of this study have implications for architectural educators, architectural firms and other stakeholders in architecture profession in order to effectively manage and develop human resources in architecture.

2 Literature Review

Career is the job or profession that someone undertakes for a significant period and with opportunities and progress (Arthur and Rousseau 1996). Career choice is the process of choosing a career and this involves choices regarding education and training for a given career. The choice of a career is one of many important decisions that students make in determining their future plans and self-satisfaction with their chosen career (Yusoff et al. 2011). Theoretically, the factors influencing students' career choices is grounded in Social Cognitive Career Theory (SCCT) which was developed from Bandura's general Social Cognitive Theory (Lent, Brown and Hackett 1994). According to SCCT, an individual's self-efficacy determines whether or not an action will be pursued, how much effort will be invested in that pursuit, how persistent the individual will be in the face of obstacles, and how well the action will be performed (Carnasciali et al. 2013). Researchers in this field argued that understanding students' choices and perspectives could aid in the design of effective changes in a profession's education and practises (Sheppard et al. 2009). Furthermore, it is beneficial to become acquainted with the existing starting point in order to connect current and prospective students.

Literature on career choice indicates that a range of influences may be important, these include personal factors (e.g., personal interest, passion, and love), external factors (e.g., parents, peers, role models, and guidance counselor) and environmental factors such as career opportunities, prestige of the profession ad expected salary (Bigelow, Bilbo, Matthew, Ritter, & Elliott, 2015; MacDonald and Durdyev,2020, Thomas, 2017)For example, Ayodele (2018) discovered, using a survey research approach, that personal career ambition and interest is the most significant factor influencing career choice among Nigerian real estate students. In a study of why students choose to study engineering, Matusovich et al. (2010) discovered that personal interest is the predisposing factor in career choice narratives. In a similar vein, Snyder and Slauson (2014) discovered that personal interest in information systems major influences students' career choices. The influence of parents, close family members, teachers, and role models has also been established. For instance,Mangaoil, Rungduin, Abulencia and Reyes (2017) asserted thatearly exposures to the role of teachers and influence of close family members contributed to the preference to pursue education as a program in tertiary education. In South Africa, Shumba and Naong (2012) explained that family and teachers were significant factors that influence the career choice and aspirations of students. This was also corroborated by Durdyev and Ihtiyar (2018) in a study that found that the people around the student were the most influential factor for new intake in AEC majors.

As a result, some studies have identified the impact of environmental factors. Durdyev and Ihtiyar (2019) asserted from undergraduate students in AEC that the construction industry's image and level of compensation influenced students' choice of major in architecture, engineering, and construction. Similarly, Sugahara et al. (2008) found prestige/image of the profession to be a prevailing factor in career choice narratives in a study of accounting students in Australia. Extrinsic motivations such as salary and working conditions, for example, are more important factors in choosing a career as a teacher in developing countries (Azman 2013; Watt et al. 2012). Ruder and Noy (2017) discovered that job security is an important factor in university students' career choice decision-making in the United States. Bigelow, Saseendrana, and Elliott (2017) investigated factors attracting students to construction education programmes from a gender perspective. According to the study, career opportunities were found to be the most influential factor in attracting students of both genders to construction management programmes, followed by internships, non-internship work experience, and fieldtrips to job sites. Similarly, MacDonald and Durdyev (2020) discovered that personal interest in the subject, career opportunities, expected salary, financial considerations, and the industry image influenced students' choice of AEC major. Kolmos, Mejlgaard, Haase, and Holgaard (2013) discovered that social good, financial security, parental support, and mentoring were all factors influencing design discipline students' career choices (including architecture and design).

3 Research Methodology

This study was conducted at the Department of Architecture, Federal University of Technology, Akure, Nigeria. The architecture programme is accredited by Architects Registration Council of Nigeria (ARCON) and National Universities Commission (NUC). The department runs different academic programmes, but this study was limited to undergraduate students only. Out of the 291 undergraduate students in the department, 167 completed the survey, for a response rate of 57.4 percent. For this study, a quantitative research approach was used. This was accomplished through the use of an online questionnaire survey hosted on Google forms. The survey link was sent to the students, and the study objectives were included to help participants understand the study. The questionnaire was divided into three sections. The first section was used to collect information about respondents' profiles (gender, age, mode of admission, grade, and work experience), while the second section was designed to elicit information about factors influencing students' decision to study architecture. The factors were rated on a 5-point Likert scale ranging from 1 (not at all influential) to 5 (extremely influential) (extremely influential). In the third section, students were asked to rank the nine architectural career options. Data analysis was carried out using the SPSS statistical package, in accordance with the data collected for this study. Descriptive statistics (frequency and mean) were used to extract the key factors from the respondents' opinion rankings. The mean rating of factors influencing career choice and professional preference was determined through data analysis.

4 Findings and Discussion

Table 1 shows the demographics of the respondents, including their gender, age, mode of admission, level, and current grade point average. Additionally, work experience of students prior to matriculation was taken into account. The findings revealed that 77.8% of respondents are male and 22.2% are female, demonstrating the gender bia nature of the architecture profession. In terms of age, 35.9% of respondents are under the age of 20, 61.7% are between the ages of 21 and 25, and 2.4% are between the ages of 26 and 30. This finding suggests that the majority of students are mature enough to make decisions about their future careers when they apply for admission to university. In terms of academic year, 24% of students are in the 100 level, 25.7% are in the 200 level, 24.6% are in the 300 level, 9.0% are in the 400 level, and 16.8% are in the 500 level. The mode of admission of the students was also sought; 2.6% percent were admitted through DE, 24.6% through the predegree science programme, 3.0% through UABS, and 68.9% through UABS. Furthermore, the majority of the students have a cumulative grade point average (CGPA) ranging from 3.5 to 4.49. Approximately 42.5% of the students had previous work experience, while the remaining 57.5% had no work experience.

Table 1. Respondents' Profile

	Frequency	Percentage
Gender		
Male	130	77.8
Female	37	22.2
Total	167	100
Age		
Below 20	60	35.9
21-25yrs	103	61.7
26-30yrs	4	2.4
Total	167	100
Mode of admission		
Direct Entry (DE)	6	3.6
Pre-Degree Science (PDS)	41	24.6
University Advanced Basic Science (UABS)	5	3.0
Unified Tertiary Matriculation Examination (UTME)	115	68.9
Total	167	100
Level		
100	40	24
200	43	25.7
300	41	24.6
400	15	9.0
500	28	16.8
Total	167	100
GPA		
0.00-1.49	11	6.6
1.50-2.39	3	1.8
2.40-3.39	17	10.2
3.50-4.49	92	55.1
4.5-5.0	44	26.3
Total	167	100
Work experience		
Yes	71	42.5
No	96	57.5
Total	167	100

4.1 Factors influencing choice of studying architecture

The factors influencing respondents' decision to study architecture were investigated. Personal interest, expected salary are the top two factors when considering the total respondents, as shown in Table 2., as shown in Table 2. This finding is consistent with previous studies (Ayodele 2018; Onu and Ikeh 2013) that found personal interest to be a major factor influencing career choice. The finding suggests that students who aspire to be architects must possess essential qualities such as artistic ability and creative flair in order to pique their personal interest in architecture. A desire to improve personal creativity and learn more about its application in architecture, on the other hand, is more likely to influence students' decisions. Influence of a role model is ranked next to expected salary, this implies that students' prior experience with someone within the profession motivates them to pursue a career in architecture.. As noted in previous studies (Ghani et al. 2008; Ng et al. 2017), exposure to people working in a profession, particularly renowned personalities, influences students' career choices. The finding of this study suggests that when architects perform their professional duties properly and reach the pinnacle of their careers, they inspire young adults to pursue a career in architecture. The profession's image was ranked as the fourth most influential factor in architecture students' career choice narratives. This study's findings are consistent with those of a study conducted among undergraduate AEC students (Durdyev and Ihtiyar, 2019), which asserted that the construction industry's image and level of compensation influenced students' choice of major in architecture, engineering, and construction.

Table 2. Factors influencing choice of studying architecture

	Total (*n=167*)		Male (*n=130*)			Female (*n=37*)			*t-test*		
Factors	Mean	r	Mean	SD	r	Mean	SD	r	F	p-value	MD
Personal interest and ablity	4.228	1	4.22	.964	1	4.27	.838	1	.235	.754	-.055
Expected salary	4.174	2	4.19	1.020	3	4.11	.906	2	.046	.651	.084
Role model	4.156	3	4.05	.901	4	3.92	1.010	4	2.084	.435	.135
Image of the profession	4.024	4	4.22	.980	2	3.95	.911	3	.447	.136	.269
Awareness of career opportunites	3.922	5	3.95	.931	5	3.78	1.031	5	2.459	.340	.170
Performance in related subject	3.593	6	3.69	1.160	5	3.24	1.188	6	.554	.040	.449
Influence of relatives or parents	2.659	7	2.68	1.376	7	2.57	1.324	7	.128	.646	.117
Influence of friends/peers	1.802	8	1.86	1.59	8	1.59	.985	8	2.333	.195	.267
School adviser/councellor	1.635	9	1.68	1.234	9	1.49	.961	9	2.923	.388	.190

Where r = rank; SD = standard deviation; MD = mean difference

The comparative analysis found very few differences in the factors that influence male and female students' career choices. Personal interest and ability, image of the profession, and expected salary are the three most important factors influencing male respondents' decisions, while personal interest and ability, expected salary, and image of the profession are the three most important factors influencing female respondents' decisions. This study's findings are consistent with those of a previous study that looked into what motivates women to pursue AEC majors in New Zealand. Personal interest in the subject, career opportunities, expected salary, financial considerations, and industry image were found to be predisposing factors for career choice in the study (MacDonald and Durdyev 2020). A similar pattern was observed among students enrolled in construction courses at several universities in the United States (Bigelow et al. 2018). In contrast to the study's findings, it was concluded that the most influential factors for attracting female students were awareness of career opportunities, internships, having a father in the industry, work experience, and fathers taking their daughters to work.

An examination of the statistical differences between men and women in terms of factors influencing their decision to study architecture revealed that all of the factors had a positive mean difference. As a result, both males and females rated all of the factors significantly high. The high ratings given by both men and women may have been influenced by the fact that architecture is a professional course that requires students to have prior knowledge and interest before enrolling. The t-test revealed that only performance in related subject ($p = 0.040$) had statistical differences between male and female respondents at a significance of $p < 0.05$. This disparity could have been influenced by variation in the subjects required for admission. Technical drawing, fine art, and building construction are all subjects related to architecture. A strong foundation in these subjects provides a solid basis for architectural practise.

4.2 Career Preference

Today, in the midst of globalisation, architecture is associated with more than just building design and construction; rather, it offers a wide range of specialisations to meet the changing needs of the built environment. As a result, the career interests of architecture students were investigated. Table 3 shows that interior designer, 3D visualizer, Architectural cosultancy, project/construction management and real estate developer.

Table 3. Career preference

	Total (n-167)	Male (n-130)			Female (n-37)			t-test		
Career preference	Mean	Mean	SD	r	Mean	SD	r	F	p-value	MD
Interior designer	4.066	4.02	1.027	2	4.24	.925	1	.190	.226	-.228
3D Visualizer	4.000	4.05	.926	1	3.81	1.050	2	2.788	.174	.243
Architectural consultancy services	3.814	3.85	1.012	5	3.68	1.002	4	.075	.345	.178
Project/Construction Manager	3.766	3.88	1.086	4	3.38	1.277	6	2.214	.019	.499
Real estate developer	3.760	3.92	1.152	3	3.19	1.198	7	.001	.001	.734
Landscape architect	3.575	3.61	1.171	6	3.46	.989	5	1.525	.484	.148
Architectural Photography	3.551	3.51	1.170	7	3.70	1.175	3	.003	.373	-.195
Public Service	3.263	3.36	1.019	8	2.92	1.115	8	.000	.024	.443
Educational/research institution	2.982	3.08	1.179	9	2.65	1.086	9	.224	.049	0.428

Where r = rank; SD = standard deviation; MD = mean difference

The career preferences of architecture students were investigated further from a gender perspective. All career options had a significant mean rating ($x \geqslant 3.00$) among male respondents. Male students' top five career choices are 3D visualizer, interior designer, real estate developer, project/construction management, and architectural consultancy services. This result is surprising, given that architectural education in Nigeria currently focuses on architectural consultancy services and construction management. Female students' ratings show that working in public service and educational/research institutions had a non-significant mean rating ($x<3.00$). This implies that female students are uninterested in these career options. The top five career options were interior designer, 3D Visualizer, architectural photography, architectural consultancy services, and landscape architect. Despite the fact that architectural consultancy service and construction management are among the top-rated areas of specialisation, students prefer to pursue areas of specialisation that provide opportunities for entrepreneurship and flexible working conditions to balance their work and life. In summary, this study found that students of both genders desired similar areas of specialisation.

A career in educational/research institution was the least preferred, implying that students are uninterested in pursuing a career in academia. Ayodele (2018) discovered a similar pattern among real estate students. This could be attributed to the low pay and intellectual demands of this field of study. Using the t-test, statistical differences between the two genders revealed that educational/research institutions ($p = 0.049$), public service ($p = 0.024$), real estate developer ($p = 0.001$), and project/construction manager ($p = 0.019$) had statistical variations between male and female respondents at a significance of $p< 0.05$. These findings imply that these career options are gender sensitive. From the foregoing, it is clear that students no longer associate architecture solely with the design and construction of buildings, but rather aspire to other areas of specialisation.

5 Conclusion

Several studies have been conducted to investigate the factors that influence the career decision-making process. However, this study has addressed factors influencing students' choice of architectural profession and what they intend to gain from the practise after graduation. Personal interest, expected salary, role models, and image of the profession were identified as the top three factors influencing the choice of studying architecture with interior design, 3D visualizing and architectural consultancy services and project/construction management being the most preferred careers options. Architecture students expect that the practice of architecture should give financial security, a well-paying job, and opportunities for career options.

The goal of architectural education, which is primarily concerned with advancing the profession of architecture, is to contribute to the creation of a humane and responsive environment. As a result, architecture students should be trained based on their interest in a specific area of specialisation. Therefore, this is a wake-up call for university administration, architectural educators, and professional bodies to implement schools of architecture with diverse areas of specialisation in response to visionary change in order to secure and guarantee the future of architectural education and practise. Architectural education must incorporate new technologies and combine existing knowledge to create new knowledge. Another major finding of this study is that architectural firms should pay attention to physical outcome expectations in order to promote retention and job satisfaction. Remuneration of professional service rendered by architects must be paid as stipulated in the architects' conditions of engagement and consultancy service agreement. Unlike some academic majors, architectural education requires students to have pre-requisite craftsmanship in order to improve their academic performance.

One of the study's limitations is that data was only collected from one architecture school in Nigeria. As a result, the results may not be generalizable. However, the findings may be similar because most architecture schools in Nigeria use the same admission and entry requirements. Future research may include more architecture schools in order to obtain a more comprehensive picture.

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A Simplified Approach in Teaching Construction Cash Flow Forecasting – Embedding Basic Cash Flow Techniques using a Spreadsheet to Chart a Projects S Curve

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Abstract

A review of the Masters of Construction Management (MCM)program at University of Melbourne (UoM) focused the teaching staff in this area of teaching of Construction Cash Flows. In a new subject offering called ABPL90413 Construction Cost Planning, a dedicated module on cash flow techniques was proposed. This was to be a simplified approach in teaching Construction Cash Flow Forecasting by embedding basic cash flow techniques using spreadsheets and charting. The method proposed for teaching cash flow is linked to the generation of a basic cost plan for a simple residential project and producing a cash flow S-curve. Building on students access to and familiarity with Office 365 spreadsheet tools such as Excel, the module was designed as a step-by-step approach to taking elemental level cost data that students had generated in a cost plan into a time series cash flow statement. On delivery of the new cash flow teaching module in first semester of 2020, a Qualtrics survey instrument was used to gain feedback on student learning experiences and garner sentiment towards the delivery of the module the results of which are presented here.

Keywords
Cash-flow, S curve, Construction Educators, Spreadsheets,

1 Introduction

It is a common mantra in the construction industry that "cash is king". Educators in Construction have stressed the need to make the understanding of cash flows a central theme early in a student's education. Construction Cash Flow Forecasting techniques have an important relationship to the over-arching development of industry relevant financial literacy in graduates. The ability to teach construction economics and management students how to develop a basic statement of a project cash flows competes in construction studies with newer developments in curriculum such as 5D costing utilizing BIM based financial models and the cash discounting or 'time value of money' approaches to life cycle analysis.

This approach contrasts with early developments of several decades ago, of more specialized Quantity Surveying/Construction Economics degrees that commonly had an Accounting or Finance subject, teaching students cash flow analysis as a fundamental and generic skill within any business entity. It is now rare to find a bespoke Finance or Accounting subject in Construction Management (CM) programs these days as core teaching.

An internet-based desktop survey of Australian University Construction programs with course(subject) descriptions revealed that whilst cash flow teaching does not warrant a whole individual subject area or complete course of study it is found in such courses or subjects as;

- Basic and Advanced Quantity Surveying
- Construction Cost Planning

- Building Economics and/or Construction Economics
- Estimating and Scheduling
- Construction and Cost Management
- Project and Risk Management

Typically, in Construction Economics and Management programs students are first introduced to project financial models that are based on first principles estimating and breaking down a project into various Trades (ASMM) or Elements (NPWC/ASMM). A scheduling approach gives students the sense of construction work as a series of planned activities were resources of labour, materials plant and equipment are brought to bear on the project. Establishing a clear and realistic budget is also essential in the preconstruction stage, as is creating a schedule that realistically outlines key milestones and deadlines. Scope, budget and schedule plans are best developed concurrently, as issues related to all three often correspond with one another.

A review of the Masters of Construction Management (MCM) program at University of Melbourne and particularly the subjects of the Cost Management stream of the program afforded the teaching staff in this area to revamp the teaching of Construction Cash Flows. It was found that there was a lack of emphasis on basic cash flow forecasting techniques and the understanding of the time v cost equations that are so fundamental to construction projects. In 2020 a new subject offering in the MCM program (ABPL90413 Construction Cost Planning), incorporated a dedicated one week module on basic cash flow techniques and theory. This was to be a simplified approach in teaching Construction Cash Flow Forecasting by embedding basic cash flow techniques using spreadsheets and charting for a single stage uncomplicated residential building project.

2 Literature Review – Construction Cash Flow Teaching

Student-centered approaches in teaching construction based financial models using gaming and capstone projects are evident in the academic literature (Shim et al 2013). Smit & Coffey (2009) developed a cash flow & interim valuations module as part of a final year core Construction Management subject at Queensland University of Technology using simulation software. In this subject student were introduced to a United States (US) developed organizational culture survey instrument which included spider graph charting similar to charting features of MS Excel. The UK based version of the building simulation game AROUSAL (Lansley, 2018) was then introduced to these students during week 8 and the software was demonstrated, and briefing documents handed out and students self-organised into groups sized between 8 – 10 persons. Students were tasked with a group assignment including oral presentation of their results.

It has been found the whilst the non-bespoke or common spreadsheet method provides only an introductory and elementary understanding of cash flow statement construction, its ease of use encourages an earlier presentation in the classroom and supports the efforts by educators to provide a balance between users and preparers of financial accounting information (Brickner and McCombs, 2004). Students may struggle to understand the indirect method of modeling cash flows (Vent and Cocco, 1996) because the method of constructing the cash flow statement is not intuitive (Hodder, Hopkins, and Wood, 2008). This was evident in Smit & Coffey's subject experience where they introduced a more user-friendly version of the spreadsheet software and automated charting function in which students appeared to be able to work with much more easily than the initial program.

It is worth noting that the AROUSAL program that has been used by Construction educators since 1982 has ceased according to its creator Dr. Lansley, who stated that "*After 33 very successful years, in 2018 I ceased running AROUSAL courses for industry and universities and issuing software licenses for the use of AROUSAL*." Several competitions based on simulation games are currently on offer to participating Construction Management students, such as the MERIT based CIOB competition and the US based American Association of Construction Educators (AACE) Regional student competitions. The MERIT acronym stands for Management Enterprise Risk Innovation and Teamwork. The simulation is designed to demonstrate the interdependence of the various managerial decisions and the interlocking nature of the variables that determine the success or failure of a construction company.

While computer scheduling software can estimate cash-flows for a construction project (Kaka 1996), no software provides the complete set of capabilities needed for forecasting cash-flow at a project level: cost-loading activities, simultaneous loading of costs and contract values, and allowing the specifications of credit terms for payments. Due to the combined impacts of several factors on cash-flow, learning cash-flow forecasting requires an understanding of the factors mentioned above and their impacts on cash-flows at first. Then, students can forecast the cash-flow of a construction project (Elsey 2013). Teaching cash-flow forecasting may be performed in multiple approaches of which one is presented here.

3 Methodology – ABPL90413 module delivery and survey

This case study module is presented as an action research type classroom exercise in which the author presents an ordered narrative to share with fellow academic practitioners at AUBEA 2021. The module description that is presented in the study was delivered during COVID-19 teaching and conducted wholly online using the Canvas Learning Management System (LMS) of the university and using Zoom tutorials. It is hoped that the benefits of the methodology adopted have become obvious to the reader as the story is unfolded and the student's evaluation findings reported here.

The study employed a survey administered using the University of Melbourne's QUALTRICS survey instrument. The study was undertaken by the students of the Construction Cost Planning ABPL90413 subject, which is a 12.5 credit core subject of the Cost Management stream of the MCM program. They were invited to reply to an online questionnaire based on their experience with the week 10 cash flow module as part of the subject which has a focus on developing students cost planning knowledge and skills. Students were asked to answer eleven questions. Participants were recruited from the enrolment list within the Canvas Learning Management System (LMS). The link to the online survey was sent to all enrolled students with the study's objectives. Participants were made to understand that their consent to participate was implied by submitting the survey and that the survey was voluntary.

4 ABPL90413 Cash Flow Module

The week 10 Cash Flow module follows a conventional approach to incorporating lecture content and tutorials delivered in online mode. Teaching and learning tools of the LMS and Zoom tutorials use break out rooms and chat features for Q & A during the tutorials which facilitate student interactions and guide students in assimilating the content and gain competency in modelling and manipulating project financial data using spreadsheets under the guidance of their lecturer and tutor (see fig. 1 below). A supplementary short weekly online quiz was available within Canvas providing formative assessment of a student's learning and comprehension.

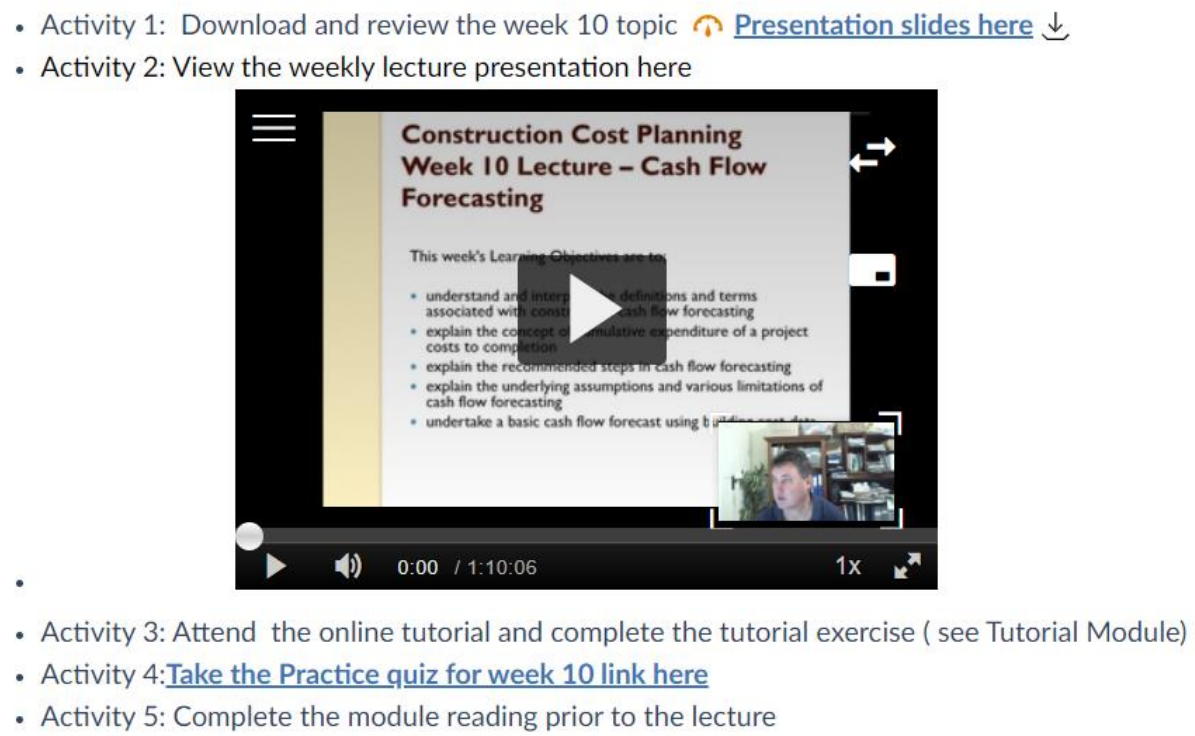


Figure 1. The dashboard in LMS for week 10 cash flow module.

2.1 Understanding of the performance of building contracts and the lazy s-curve

Students in any Construction Management degree learn early on, that a construction project involves progressive payments related to progress of the works over a lengthy time period. They learn also that for construction project financing it is unrealistic to expect the contractor to fund the whole works from their 'own pocket' to be paid only a lump sum on completion. Fundamentally and irrespective of the procurement route, until the main contractor has been appointed, client cash flow projections are likely to be based only on agreed fee payment schedules for consultants and a simple division of the construction cost over the likely construction period (or perhaps an allocation of construction cost over an s-curve distribution).

This basic modeling approach is an excellent mechanism by which students can develop schemas that increase their ability to assimilate and interpret financial statements (Hodder et al., 2008). Other subjects in Procurement and Contract Management delve more deeply into 'bespoke' or alternative funding arrangements that might occur on large private partnership projects or speculative developer lead projects. (Aranda-Mena, G. and Vaz-Serra. P. 2019). This is where more sophisticated cash flow models and projections can be taught to students.

2.2 The EXCEL spreadsheet as a model tool for cashflows

The method proposed for teaching cash flow formulation to the ABPL90413 students sought to minimise issues identified as creating problems or learning obstacles (refer sect. 2 of paper) by reducing the complexity of the task using basic Excel spreadsheet techniques. As part of the suite of Microsoft Office programs Excel familiarity is expected in university education and all students are given Microsoft Office 365 accounts. Nonetheless, the supplementary reading and guidance notes for students encouraged wider reading and engagements in this area such as;

- ‘**Excel for Dummies’** is a popular electronic resource running to some 801 pages, aimed at beginners with tips Getting to know your way around Microsoft Office Excel begins with launching the start-up window and learning the functions of the Excel Standard and Formatting toolbars to create and manage your spreadsheets.
- **Youtube** provides an almost unlimited array of Excel tuition videos on a range of features of the program. This has grown almost exponentially each year of the several decades that Excel has been the dominant spreadsheet program and Youtube has become an open source of these tuition videos.
- **Vimeo and Slideshare** are less widely known and used as Youtube however contain a range of academic style presentations, some limited construction and cash flow related topics incorporating spreadsheet analysis techniques.
- **LinkedIn Learning** an American website offers video courses taught by industry experts in software and business skills. The ABP Faculty at UoM had bought a subscription to the online learning environment. Cash Flow is a rich source of content with various Instructors and modules on such topics as 492 Results for “cash flow” there are 24 separate courses listed, typically courses are in video presentations of 1 – to if 3 hrs.

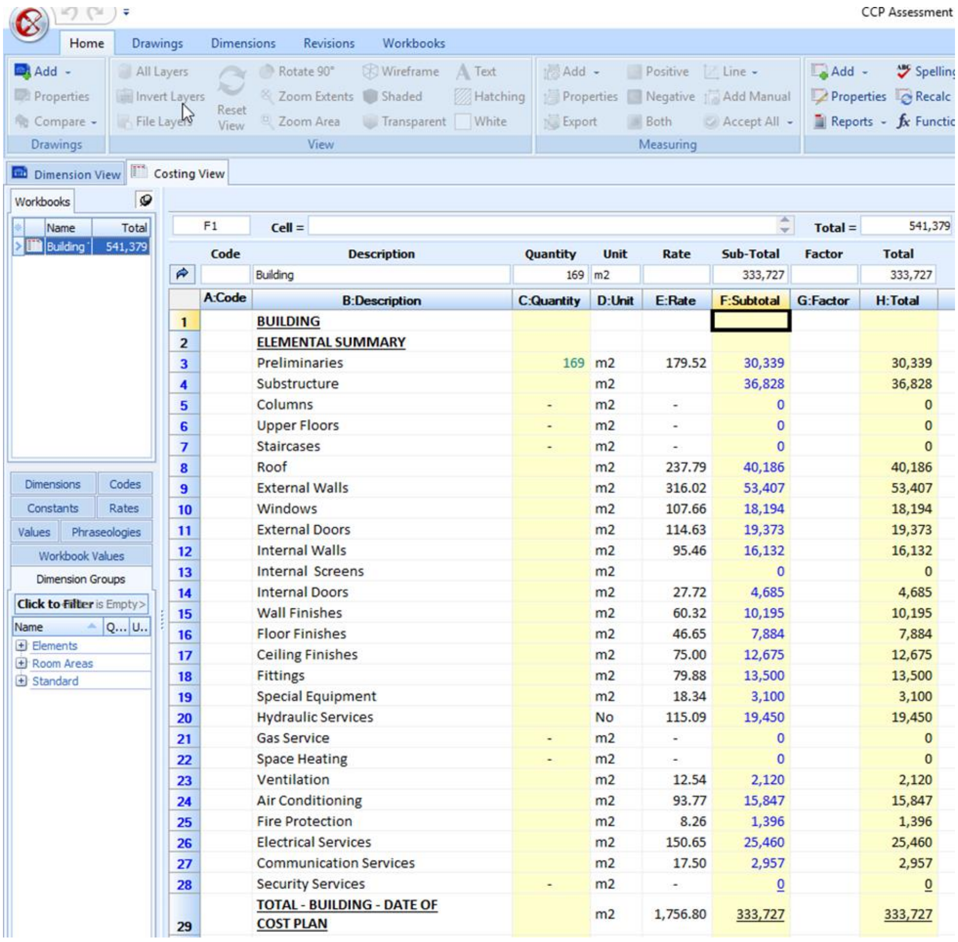
This wide array of external content could be potentially overwhelming for a Construction student so caution and a focussed approach to searching for extra support material was encouraged. Neither should these resources be considered outsourcing of program teaching as the subject had its specific learning objectives in tailored lectures and two hour long weekly tutorials and summative assessment of the learning areas in examinations. Perhaps the value in resources such as LinkedIn Learning and Youtube videos is to provide students with additional help in understanding the features of the Excel spreadsheet program and use this under instruction to produce their cash flow and S curves.

2.3 Steps to generate a basic spreadsheet cash flow

The steps outlined in this section mirror the workflow of students engaged in the online tutorial. The financial data is based on a predicted cash flow for construction of a residential project that they have developed a full cost plan in the earlier week’s modules. Extracting the elemental budget from the CostX onscreen measurement and estimating program. An educational institutional or student version of CostX comes with restrictions which relate to the Import and Export of data. There are no exports of data from workbooks to any external formats such as Excel and CSV.

The entire schedule cannot be copied to the clipboard however individual rows, columns or cells can in a user-friendly way. Whilst a ‘Drag and Drop’ of Dimension Groups in CostX to Excel is a disabled feature in the educational software, it is a relatively easy task to open the workbook and Cut and Paste the relevant cells of a Workbook summary and in one go capturing the data into an open Excel worksheet. It is important when pasting the cells to import as ‘Values’ rather than a Cell formula or a transposed array.

Step 1: Cash values are derived from the Cost Plan tutorial file which they have developed and priced in earlier modules of the subject and for which an assignment has been undertaken. The Elemental Workbook in CostX is used (see fig. 2 below). Students can cut and paste the rows and columns to Excel, the quantity unit and rate columns become redundant in the cashflow spreadsheet.



	A:Code	B:Description	C:Quantity	D:Unit	E:Rate	F:Subtotal	G:Factor	H:Total
1		BUILDING						
2		ELEMENTAL SUMMARY						
3		Preliminaries	169	m2	179.52	30,339		30,339
4		Substructure		m2		36,828		36,828
5		Columns	-	m2	-	0		0
6		Upper Floors	-	m2	-	0		0
7		Staircases	-	m2	-	0		0
8		Roof		m2	237.79	40,186		40,186
9		External Walls		m2	316.02	53,407		53,407
10		Windows		m2	107.66	18,194		18,194
11		External Doors		m2	114.63	19,373		19,373
12		Internal Walls		m2	95.46	16,132		16,132
13		Internal Screens		m2		0		0
14		Internal Doors		m2	27.72	4,685		4,685
15		Wall Finishes		m2	60.32	10,195		10,195
16		Floor Finishes		m2	46.65	7,884		7,884
17		Ceiling Finishes		m2	75.00	12,675		12,675
18		Fittings		m2	79.88	13,500		13,500
19		Special Equipment		m2	18.34	3,100		3,100
20		Hydraulic Services		No	115.09	19,450		19,450
21		Gas Service	-	m2	-	0		0
22		Space Heating	-	m2	-	0		0
23		Ventilation		m2	12.54	2,120		2,120
24		Air Conditioning		m2	93.77	15,847		15,847
25		Fire Protection		m2	8.26	1,396		1,396
26		Electrical Services		m2	150.65	25,460		25,460
27		Communication Services		m2	17.50	2,957		2,957
28		Security Services	-	m2	-	0		0
29		TOTAL - BUILDING - DATE OF COST PLAN		m2	1,756.80	333,727		333,727

Figure 2. Tutorial Cost Plan Summary sheet used for cash flow exercise.

Step 2 The newly created workbook in MS Excel (cashflow model workbook) is opened and a column for weighted % is added to the immediate right of the element amount column. (See figure 3 below). This gives students a sense of the proportion of each element, noting that in their cost plan such elements as substructure, roof, walls and mech & elec services are of greater order cost. A cost plan in Trade format with Trade amounts could be substituted if desired.

Step 3 Once the cash values and weighted % amounts are entered, 2 further rows are added to the worksheet in figure 3 immediately after the row with total amount and total weighted percentage (100%). The first of these 2 rows are for the Total % of work in each month using the SUMPRODUCT formula applied to the array of cells in each monthly column. The second row will be used to show the cumulative percent complete each month which a calculation is based on the addition of 2 cells only, being the % completed in any one month plus the % completed in total prior months.

3	Amount	Weighted %	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Total
4	30,339	9.09%	10%	10%	10%	10%	5%	5%	5%	5%	10%	10%	10%	10%	100%
5	36,828	11.04%		33%	33%	33%									100%
6	40,186	12.04%				33%	33%	33%							100%
7	53,407	16.00%				33%	33%	33%							100%
8	18,194	5.45%					75%	25%							100%
9	19,373	5.81%					25%	35%	40%						100%
10	16,132	4.83%									50%	50%			100%
11	4,685	1.40%				20%	30%	30%	20%						100%
12	10,195	3.05%							50%	50%					100%
13	7,884	2.36%							33%	33%	33%				100%
14	12,675	3.80%						50%	30%	20%					100%
15	13,500	4.05%						33%	33%	33%					100%
16	3,100	0.93%									50%	50%			100%
17	19,450	5.83%		20%		20%	40%	20%							100%
18	2,120	0.64%					50%	50%							100%
19	15,847	4.75%							50%	50%					100%
20	1,396	0.42%												100%	100%
21	25,460	7.63%					25%		25%	25%			25%		100%
22	2,957	0.89%											100%		
23	**333,728**	**100.00%**													
24			0.91%	5.75%	4.59%	15.38%	20.32%	18.35%	12.14%	9.16%	4.58%	3.79%	3.70%	1.33%	100.00%
25				**6.66%**	**11.25%**	**26.63%**	**46.95%**	**65.30%**	**77.44%**	**86.60%**	**91.18%**	**94.97%**	**98.67%**	**100.00%**	
26			$3,034	$19,200	$15,310	$51,334	$67,814	$61,236	$40,519	$30,566	$15,280	$12,650	$12,356	$4,430	
27				**$22,234**	**$37,543**	**$88,878**	**$156,691**	**$217,927**	**$258,447**	**$289,012**	**$304,292**	**$316,942**	**$329,298**	**$333,728**	

Figure 3. Spreadsheet of cash flow values and monthly progress amounts.

Step 4 For each element that has a cash value a % of completion in any month must be allocated. Rather than typical start and finish dates which might be derived from a Construction projects program timeline, the exercise is simplified by assuming progress in each element's construction is largely continuous and uniform (with some exceptions e.g., Electrical has a break due to 1st fix and 2nd fix considerations). Preliminaries has a 10% monthly completion in each of the first and last 4 months however only 5% in the middle four months. An explanation being somewhat higher fixed preliminaries at start up and handover/clean up.

Step 5 The projects 's' curve can be generated by the Cumulative Cash Flow array at the bottom of the sheet. Note this has been derived based on the weighted % of each element and the duration of each element across the 12 months of the project. One the cumulative cash flow array of cells is highlighted an Insert Chart function is activated and the recommended chart type is a simple 2D Line Type as shown in fig. 4 below.

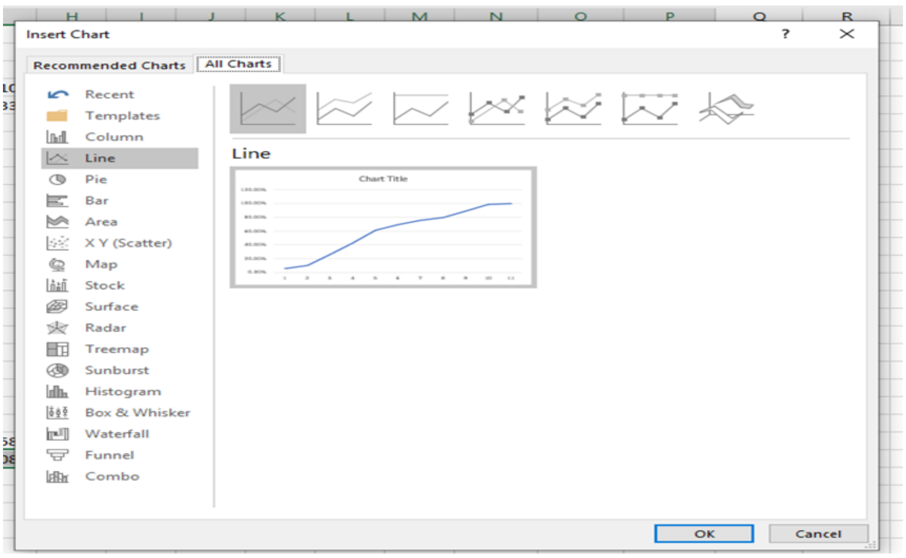
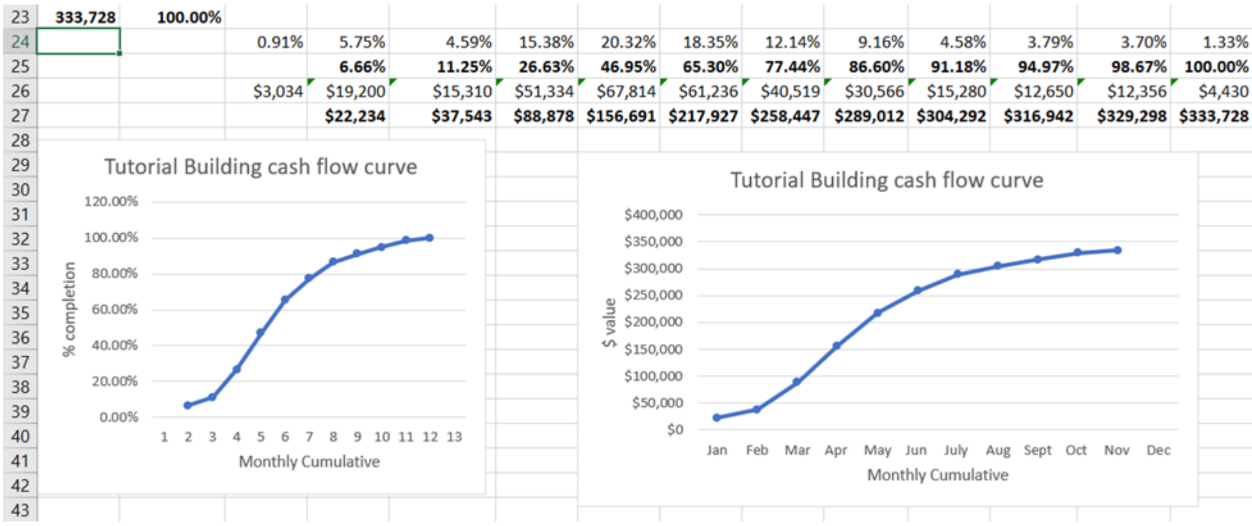


Figure 4. Index of charting options in Excel (Line chart option)

Step 6 Charting in Excel has added functionality and the Chart that exists as linked to the data in the cell array can be manipulated and labels added to each axis and can be placed in any position on the same sheet at will. Given our project time line follows a calendar month we can format the horizontal 'time' axis to shown months rather than units by using the Axis label range and point to the data array which is the monthly header on top of the sheet.



23	**333,728**	**100.00%**												
24			0.91%	5.75%	4.59%	15.38%	20.32%	18.35%	12.14%	9.16%	4.58%	3.79%	3.70%	1.33%
25				**6.66%**	**11.25%**	**26.63%**	**46.95%**	**65.30%**	**77.44%**	**86.60%**	**91.18%**	**94.97%**	**98.67%**	**100.00%**
26			$3,034	$19,200	$15,310	$51,334	$67,814	$61,236	$40,519	$30,566	$15,280	$12,650	$12,356	$4,430
27				**$22,234**	**$37,543**	**$88,878**	**$156,691**	**$217,927**	**$258,447**	**$289,012**	**$304,292**	**$316,942**	**$329,298**	**$333,728**

Figure 5. Applying the data in the spreadsheet to generate the cash flow curves.

Step 7 Generating a projects cash flow curve (as per fig. 5 above) demonstrates the progressive nature of expenditure. It is important to understand that whilst the 'lazy s curve which is typical of construction projects, the charting in excel can bend or stretch the curve that represents values as in the two different curves in fig. both are based on the same values however the curve on the left has shorter horizontal axis intervals and produces a more pronounced 'S' shape.

5 Module Evaluation – Student survey results and discussion

Of a student enrolment of 64 a total of 16 responses were received (25% response rate). Survey questions 5,6 and 10 are not reported here due to some vague responses and paper length limitations. The questions (in italics) with results discussions are listed in numerical order as follows;

Q 1. The question asked students *whether they took ABPL90413 as CORE subject or Elective*. 3 out of 4 students who responded were taking the subject as part of their core subjects in the Cost Management stream of the MCM program.

Q2. From the responses received to this open-ended question, *rate you prior knowledge (before taking the module) and prior skills in generating cash flow from a project tender breakdown*. Some 50% of respondents indicated they had not covered concepts of cash flow in any other subjects. Responses mentioned a specific subject taken in year 2 or 3 of the program ABPL90027 Life Cycle Analysis and Sustainability.

Q 3. *Can you please indicate which (CLICK on ANY or ALL) of these specific learning objectives were covered in week 10 cash flow module*?

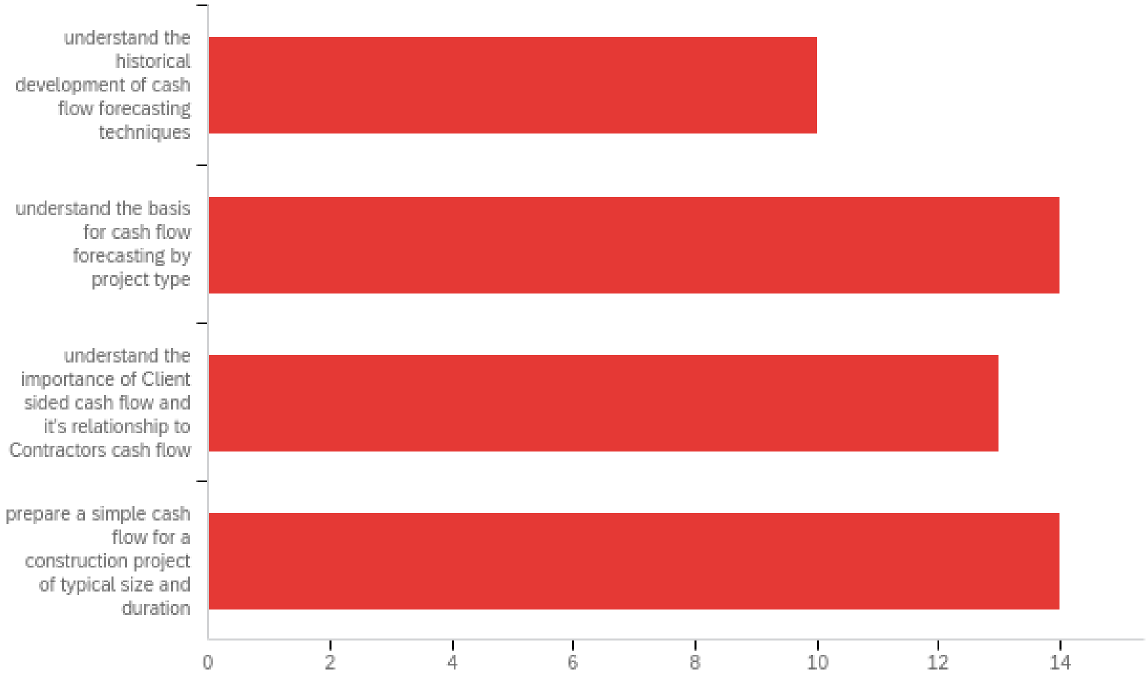


Figure 6. Responses to Question 3.

The responses as shown in Figure 6 above indicate that most students felt the intended module learning objectives were being achieved though *Understanding the historical development of cash flow forecasting techniques* was somewhat lower in coverage.

Q. 4 *In the recorded Lecture the difference between an ORGANISATIONAL cash flow and a PROJECT cash flow was outlined. Do you feel you understand this difference in cash flows?*

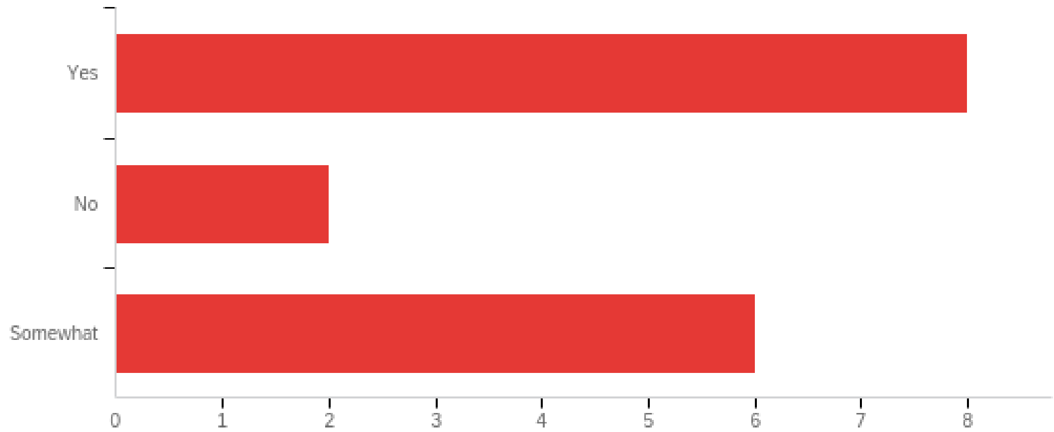


Figure 7. Responses to Question 4.

Q7 - *The Muddiest Point. What did you find a confusing point or something missing from the module?* All but one student answered NO, this student responded, *"Maybe set an example to illustrate how does cash flow work in a specific project."*

Q 8. *What (if any) supplementary EXCEL cash flow tuition have you sourced in your studies.*

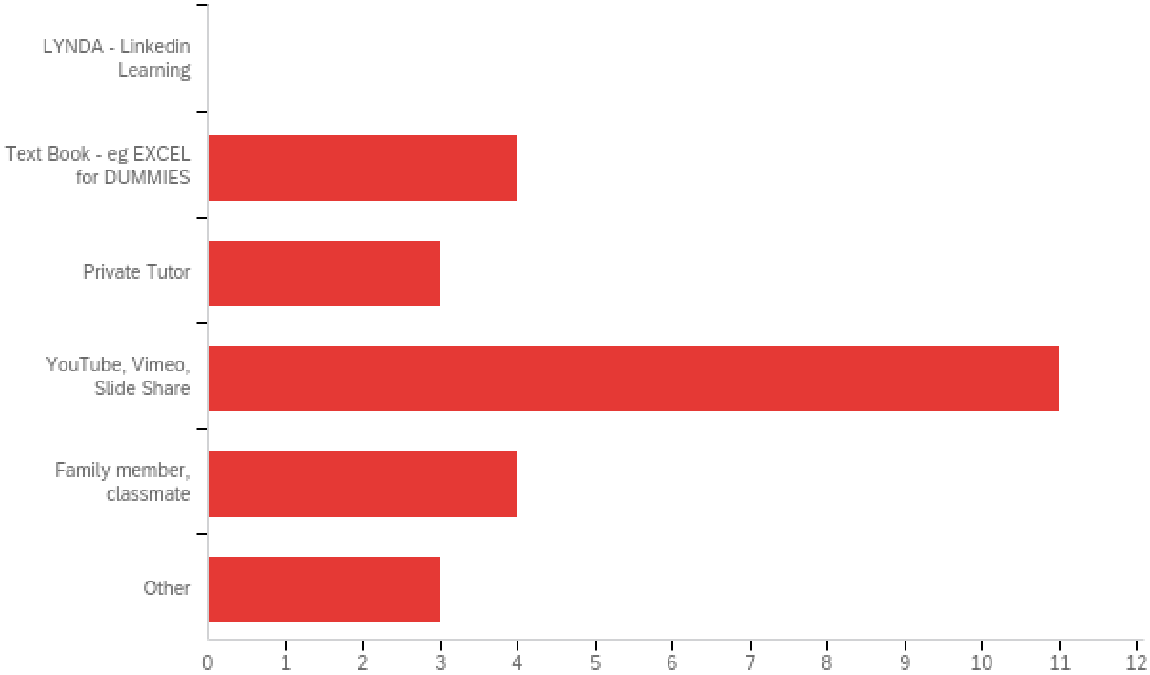


Figure 8. Responses to Question 8.

The responses to Q.8 indicate that YouTube/Vimeo/Slideshare resources on the internet are commonly used by students with some students reverting to classmates or a private tutor for further support. Interestingly no students indicated using the LinkedIn Learning platform which the Faculty makes available under a library managed subscription.

Q 9. *The online PRACTICE EXAM quiz contained cash flow questions, did you find these helpful?* The 16 responses were YES (15 no), NO (nil) and SOMEWHAT (1 no)

Q 10. Students indicate a confidence post module in their interpretation of cash flows as per, *Using the dial (1 - 10) and say how would your rate your knowledge and post module ability now to generate a monthly project cash flow from a project tender breakdown and basic project schedule.* A mean value was 7.5 out of maximum 10 (highest confidence), see fig. 9 below.

Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
Using the dial (1 - 10) and say how would your rate your knowledge and post module ability now to generate a monthly project cash flow from a project tender breakdown and basic project schedule	5.00	10.00	7.50	1.62	2.63	16

Figure 9. Responses to question 10 showing Min. Max. Mean and Std. Deviation/Variance.

Q11 - *What was the key takeaway from the Module? Do you have any suggestions or comments generally?* Typical responses were as quoted below;

> *"This module was actually nice. Perhaps we need a specific cash flow example in practice and learn something how professionals prepare and work for cash flows in their projects."*
>
> *"More case studies may be effective for us to learn"*
>
> *"It builds a knowledge foundation in project cashflow for me, and thus is useful for further developed study."*

6 Conclusion

It is imperative for a university to work closely with the industry into which graduates will step out following completion of their studies to ensure that they possess the skills, knowledge and potential expertise to be immediately useful to that industry. Clearly, when teaching students how to interpret and construct a cash flow statement for the first time, a preferred method is one that reduces the intrinsic cognitive load students will face and removes, to the extent possible, extraneous factors that increase cognitive load.

The approach adopted in ABPL90413 using spreadsheets and charting simplifies the process, reduces the error rate, and allows even novice students to generate accurately predicted cash flows using typical monthly progress schedules. Based on the actual cost planning for the project covered in earlier subject modules it therefore allows students to better understand how the cash flow statement connects to the budget for the building elements. This method of teaching construction cash flows is advantageous for students because it reduces the initial complexity and extraneous cognitive loads that typically accompany their introduction to the topic of cash flow in construction. To summarize the simplicity in this method, the module that was developed:

- Presents all data in a single screen worksheet with simple rows and columns (proximity compatibility principle).
- Gives minimal instructions for data gathering, delivered directly in the worksheet (i.e., uses the original cost plan which students are familiar with and set % allocations of anticipated progress in each element).

- Uses only seven steps in a logical and iterative process to convert balance sheet budget amounts from the cost plan estimate to a monthly cash flow basis (reduced complexity).
- Uses standard cell referencing and only one more advanced formula SUMPRODUCT in Excel, to convert balance sheet expenditures to monthly cash basis (reduced complexity).
- Makes use of a visual charts that illustrate the cash flow statement in graphical format.
- Provides a rapid result that allows students to more quickly arrive at the values in the cash flow statement (reduced complexity, e.g., Figures 3, 4 & 5).
- Readily facilitates the understanding of basic project cash flow, time series and construction budgets and simplifies the process of categorizing them.

The key benefit of using this method in construction cost management classes has been that students can quickly model cash flows using Excel much more quickly and with much less frustration that might be with specialized accounting or project management software in only a few short steps as shown in section 4 of the paper. The result is that students can spend their time developing a better understanding of the accounts that impact their cash flow without first needing to master the structure of complicated cash flow statements. An additional benefit is that the cash flow statement created is actively linked to the elemental cost plan they created for a residential project. It also allows students to model changes to cash flow statements and directly see the impact on the cash flow statement within Excel.

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COVID -19 responses at Uni of Adelaide and Uni of Melbourne: impacts affecting Construction and Project Management programs

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Abstract
This study provides an analysis of Covid measure responses both generally in Australia and across two universities where the authors work that have established Project and Construction Management programs. It was initiated in the first half of 2020 against a background of deteriorating global pandemic conditions, and it seeks to demonstrate and report on how construction academics in Australia have coped in delivering programs during the Covid pandemic. Drawing on the experience of the authors being AUBEA academics, the paper investigates early-stage institutional and administrative responses, the tracking of and welfare of Travel Ban students, support for HDR students, some contrasting approaches to teaching arrangements, assessments and academic integrity issues. It was found that much is expected of academics to respond to the challenges, with indifferent levels of support and budget constraints. The paper concludes with a wider discussion of the grave impacts of the pandemic across higher education and lessons learnt for the future of CM and PM degrees In Australia.

Keywords: Covid-19 Impact, online teaching, online assessment, travel-ban students

1 Introduction

The teaching in Australian University Construction Management (CM) and Project Management (PM) programs in the past 18 months has seen unprecedented challenges for academics and faculty administrators. Early in 2020, State and International cross-border travel bans, and suburban lockdowns resulted in a move to off-campus course delivery and the difficulty for many overseas students to either return to Australia to resume studies or begin new studies. Some of the most affected institutions are several older established universities that have grown student demand in postgraduate programs with students mainly from China. University of Melbourne (UoM) and the University of Adelaide (UofA) have several programs of project and construction management that have proportionately large Chinese cohorts. These are universities with long-standing reputations and established programs and are part of the Go8 universities group.

This paper for a Covid delayed AUBEA 2021 Conference looks at responses to Covid 19 and academic adjustment strategies from both a human and technical perspective within the two institutions mentioned. The study commenced during a period of rapid response to a global pandemic, strict lockdowns, mass panic buying of essential goods and concern for health. The Construction industry for which the graduates were being prepared was considered under grave threat (Heaton 2020) and industry bodies such as the Australian Construction Industry Forum (ACIF 2020) demanded efforts by Australian Federal and State governments to ensure that the threat to building projects was mitigated to the greatest possible extent. The study presents an ordered narrative of early institutional measures to deal with Covid restrictions and wider support measures under government initiatives. It details teaching and administrative strategies and responses within the two institutions that are in different states and operate under conditions. It is a narrative that might be somewhat familiar to an AUBEA teaching academic yet reveal significant differences in approaches.

2 Early Stage Institutional and Faculty Responses

2.1 Early Responses and Tracking students

The first case of novel coronavirus in Australia (nCoV-19) was reported in Victoria on 25 January 2020, with an additional three cases confirmed in New South Wales later that day (Hunt & Murphy 2020). The significance of this for Australian Tertiary education became more apparent some 7 weeks later when Australia closed its borders to all non-citizens and non-residents. The entry ban took effect from 9pm AEDT Friday, 20 March 2020, with exemptions only for Australian citizens, permanent residents and their immediate family, including spouses, legal guardians and dependants.

For Australian Universities, the effects of the bans on recruitment of new students from overseas are documented by Hurley (2021) who stated that between July and November 2020, about 17,000 new students enrolled while overseas, whereas during the same period in 2019, about 115,000 new students had enrolled. Of concern, was the situation of enrolled students from overseas, many out of the country on holiday or family reunion breaks and those on student visas still residing in Australia. The timing was also against recent devastating bushfires in Victoria and other parts of Australia such as SA and NSW, affecting communities in regional areas, including staff and students at higher education institutions.

The challenges presented by the Coronavirus global pandemic were multi-stranded being across society at large and the whole economy. Academic institutions were having some unique and varied challenges with a situation changing rapidly such as in a communication to staff (Maskell 2020a) at UoM underlining that whilst the situation and its shocking impacts were still emerging, UoM was endeavouring to support affected staff and students.

> *"Novel coronavirus update The University is closely monitoring the circumstances around the novel coronavirus (2019-nCoV) outbreak and is supporting students and staff. The situation is constantly evolving."*

Information about special leave arrangements, financial and wellbeing services and local HR contacts was made available on the staff networks, web-based online staff hubs and the like. Staff were encouraged to make use of these resources and to support affected colleagues to do so. Student and Scholarly Services were mobilised to provide advice to students who may have been affected by travel bans, health concerns, accommodation difficulties or lost employment and more general uncertainty around continuing their studies.

2.2 Roles, Responsibilities and Student Representations

Under a pandemic setting the roles and responsibilities expected of academics in responding to student representations are seen as paramount (UofA 2021). At the University of Adelaide in response to the COVID-19 pandemic, students were stakeholders in decision-making at the University, including representation on the Incident Management Task Group (IMTG) and Student Services Stream group. UoM undertook similar commitments to consult with students via such forums, as well as receiving and considering several petitions concerning Covid response from the University of Melbourne Student Union (UMSU).

Beyond Universities, communications from Governments and Agencies has been somewhat confusing during the pandemic. Amongst these wider community mixed messages and some conflicting information, academics had to deal with students, some stranded off-shore in foreign countries, some not in their country of origin but in transit through other countries under differing pandemic circumstances. Local disruptions to students' lives were both serious and sudden and counselling initiatives at institutions took on a more urgent tone. An example of a student representation (student(anon.) 25/02/20) to a Subject Coordinator is seen in;

> *"I received an email from the University today after the extension of the travel ban. Students like me stuck overseas now face two options:*
> *- enrolling in at least one subject that is available to be taken online, or*
> *- making the decision whether to defer by 13 March.". Deferring will have a significant impact on the students financially and personally."*

With the arrival of COVID-19, international students had to decide whether to stay home or return to campus. While students who remained home avoided the inconvenience of making travel arrangements and limited additional health risks that could arise from travel and living on campus, they lost any sense of normality and consistency with their coursework, in addition to their connection to university campus life.

2.3 Welfare of Travel Ban affected students

Early in 2020, academic staff received communications from management at UoM that they were not expected nor best-positioned to provide travel advice to students impacted by COVID-19. This is related not only to in-bound but potentially out-bound students availing of study abroad options. Information related to policies that student travel to countries rated at Department of Foreign Affairs (DFAT) levels 3 and 4 could only be undertaken in exceptional circumstances where the travel is supported by a risk assessment with suitable controls and approval given by the Academic Registrar. This would enable consideration to be given on a case by case basis and where specific circumstances or need exists. As with staff travel, student travel to DFAT level 1 and 2 destinations would now require approval by the Dean (both for research students and coursework students).

Students opting to withdraw from international travel because of health concerns would not, where possible, be penalized and reasonable adjustments should be put in place. Winter Term and Semester 2 international travel requirements, including arrangements such as for University of Melbourne (UoM) Semester 1 exchange students (the majority of whom were now in-country) were put under consideration by the University (UoM 2020) as per.

> *"Recognizing our passion and care for our students affected by the travel bans associated with COVID-19, it's vital that together we:*
> *- Enable students to have access to the latest support and information through STOP1*
> *- Avoid potentially jeopardising any student's safety and wellbeing, consequential financial implications for themselves or their families in advertently in advising potential travel arrangements*
> *- Encourage students to be fully aware of study options available to them while considering their individual circumstances."*

2.4 Funding and Visa Support

In Victoria, an International Student Emergency Relief Fund was established to support over 33,000 international students (Study Melbourne 2020) who faced financial hardship through lost wages and work because of the coronavirus (COVID-19) pandemic. The fund provided a one-off payment of up to $1100 and was delivered in partnership with Victoria's tertiary education providers. Other relief measures included free groceries at the Foodbank International Student Pop-Up Store in Central Melbourne and one-off rent relief grants for people in rental hardship to help keep renters safe and stable in accommodation. Household utility relief grants were also available to help pay overdue bills. Separate financial support through the Extreme Hardship Support Program for temporary and provisional visa holders and undocumented migrants was delivered by the Red Cross. In South Australia, the state government provided financial relief to international students through their International Student Support Package (Study Adelaide 2020). The SA State Parliament instituted a short-term moratorium on eviction for non-payment of rent due to severe rental distress because of COVID-19. In addition, the Commonwealth government enacted legislation making International students eligible to access their superannuation early, due to COVID-19.

Although the quantum of benefits is unknown, the University of Melbourne in recognition of the impact experienced by students affected by COVID-19 and associated travel restrictions, offered a student support package to support students to commence or return to study. This included support grants which were intended to help students with unanticipated expenses incurred because of the travel restrictions related to COVID-19. Eligible expenses included accommodation costs, fees associated with unrecoverable flight changes, additional costs associated with the 14-day self-isolation period and upgrading technology to facilitate flexible learning.

3 A Pivot to Off-Campus teaching

Pre-Covid, off-campus teaching has been well established, as for several decades Universities throughout the world have paid increasing attention to the possibilities for online delivery of their degree-level programmes. As far back as 2004, a survey of Commonwealth Higher Education Institutions recorded that 54% of institutions expected off-campus online learning to play a major role in their institutional strategy going forward (OBHE, 2004). Faster and more affordable Internet bandwidth, feature-rich mobile devices, lower-cost computing as well as a plethora of web-based learning management systems (LMS) such as Moodle, Canvas and Blackboard have enabled a switch to online modes of teaching that has appeal to many students who regularly cite work commitments and responsibilities that hinder their availability to attend campuses. Nonetheless, campus-based teaching particularly for tutorials and workshops has still been a common feature of CM and PM university-level education pre-Covid.

2.5 Changes to Teaching Practices (Lectures and Tutorials)

Recognising that even after some easing of first phase COVID-19 restrictions, most students would not be able to attend campus (many still enrolled remotely), a swift pivot to online teaching was evident at both institutions in semester one of 2020. At UoM this involved a one-week teaching pause' (Maskell 2020b) as per;

> *"We will pause all teaching, learning, assessment and examinations from midnight tonight, for technical reasons, to allow us to prepare to transition fully*

to the launch of our virtual campus on Monday 30 March. Students will be advised by their subject coordinators of the arrangements for their subjects."

Both UoM and UofA employ the Canvas LMS platform for online mode teaching in subjects and students had familiarity with accessing content for both lectures and support and training via university services. UofA launched the Mixed Cohort Learning (MCL) project to support teaching and learning in classes (such as tutorials) that are delivered both face to face and online, simultaneously. UoM provided support to teachers under a Dual Delivery Contribution. One-off contributions are available to support costs associated with the preparation and delivery of dual delivery subjects. A feature of the delivery was that pre-recorded lectures were often delivered as 15 – 20 min segments rather than longer recordings. Lectures would be Asynchronous recordings on-demand whereas tutorials were Synchronous meetings via Zoom.

2.6 Zoom - the Experience/Experiment

Both UofA and UoM had deployed full licencing of Zoom prior to the pandemic however during the pandemic Zoom as a tool and platform for online meetings and collaboration became ubiquitous (Evans 2020). At UofA under the banner of *I'm having technical issues with Zoom - what should I do?* a set of resources were created to support staff and students. UoM developed a Canvas module 'Zoom for Students' this could be directly imported into a Canvas subject as a discrete module within the subject. Whilst seen as generally successfully deployed when campuses are shut, some common issues with zoom tutorials are evident (Giancone 2021). It was found that the Zoom tutorial experience, as well as Zoom breakout rooms, could leave students feeling awkward and unwilling to participate and interact with people that they don't already know. Students may be shy to ask a question that gets the attention of the whole class looking at the screen or decline to turn their video on and hide behind a screen name or avatar. Construction and Project Management academics at UofA and UoM reported frustration with inadequate engagement through video when running some classes where the lecturer/tutor felt the need to see faces and have the tutorial group see each other's faces.

In a recent study (Ramachandran 2020) conducted at Stanford University in the US, researchers have identified four consequences of prolonged video meetings that contribute to the feeling commonly known as "Zoom fatigue." These included excessive amounts of close-up eye contact, observing yourself during video chats constantly in real-time is fatiguing, reductions in usual mobility and a greater cognitive load in video meetings. Various strategies had been discussed amongst Construction and Project Management academics to overcome the limitations of online tutorials. In some cases, it was felt that all subjects should offer live (synchronous) consultations/tutorials/meetings or some formal Consultation sessions that occur weekly at a designated time.

2.7 Fieldwork, Studio Workshops and Site Visits.

Fieldwork and construction site activities for CM students are found within subjects that seek to incorporate on-site demonstrations and real-world observations. These were initially banned during Covid lockdowns through both Victoria and SA exempted the Construction Industry from full lockdowns (this situation may have changed more recently in the lead up to the AUBEA conference). Access to some smaller residential sites was observed as less restricted than major projects operating under restrictions to densities and operating hours. When out of lockdown the visits were managed locally by the fieldwork organisers, if they are covered by a COVID Safe plan.

Faculty Architectural colleagues running Design Studios and Fabrication Workshops faced particularly challenging circumstances as hands-on campus activities were impossible during lockdowns. Here is was proposed that on-campus activities be deferred, thus students will be able to 'catch up' on their studies in a later offering and will not have to defer the entire subject. A response to Covid for design teachers emerged in online forums and academic associations delivering free webinars on such topics as *Analog Meets Digital*: *Physical Modelling and Virtual Collaboration*, *No Labs No Robots No CNC Machines* and *How can Material and Technological Investigations Continue in a Virtual Learning Environment*? (ACSA 2021). At UoM the faculty’s own academic support unit the Built Environments Learning + Teaching (BELT) group organised resources for virtual site visits using an array of tools like;

- Google Street View in Canvas
- Interactive Static Images in H5P
- Kaltura 360^0 Video
- Create a 360^0 Virtual Tour in H5P
- Microsoft Sway for large physical site documentation
- 3D Vista Virtual Tour Pro

2.8 Staff Working from home or a remote location

In the middle of March 2020, as it became apparent that all staff would soon be directed to work from home, the Construction group at UoM organised a series of meetings under the banner of “technology enablers”. The use of the Zoom tool generated the most discussion and experimentation, staff had to learn quickly the difference between a Zoom meeting and a Zoom seminar. Key UoM Learning Environments(LE) support unit staff were invited to meetings and live demonstrations and Q&A formed part of the agenda. UoM BELT academic support unit initiated a “Celebrating Great ABP Moves Online” website with videos and other resources that captured the creative and valuable approaches to teaching that staff were developing from their own off-campus setup. Examples include some novel workarounds and some outcomes in deploying remote learning technologies that will likely live beyond COVID-19 related challenges.

For some newly appointed staff, significant supply chain disruptions impacted the supply of new computers. This also included difficulty in replacing non-functional computers and supplying large monitors needed for remote conferencing to new and existing staff. It was deemed for UoM to effectively manage the limited stock available, iProcurement computer purchasing would be decommissioned in March 2020 and replaced with a revised computer request form on the Staff Services Portal. Messages to staff across institutions emphasised online access available to support via staff resource guides and that whilst remote working, it is important to stay connected with colleagues, stay healthy and well and look after individual mental health and to avail of these new resources, tools and information to successfully navigate the working from home experience.

2.9 Virtual Library during Covid-19

In both UofA and UoM, borrowing of print library items was suspended during campus closures and due dates for already borrowed items were extended and recall of items on loan had been suspended. The Interlibrary Loan services were limited to the delivery of electronic articles only and print books would not be processed. As with other libraries around Australia and worldwide experiencing disruptions to their services during Covid, the connection to students via social media platforms such as Facebook and Twitter increased markedly. Alushaibini (2018) outlines the challenges and opportunities for libraries to exchange and disseminate information across these media platforms and finds content related to the promotion of services and events generated more user engagement than any other type of content.

Digital Rights Management (DRM) access during Covid campus lockdowns became even more important as students increased access to digitized resources. An example at UoM was access to relevant Australian Standards such as AS4000 Construction Contracts. Unlike previous semesters this required more steps and third party IT involved for students to access these Australian standards via the Library. Downloading any Australian Standard, users now need to create an account with SAI Global and they will need to install the FileOpen plugin available through the University's Software Centre. In comparison to STEM-based areas, this was seen as less of an issue for arts, humanities and social sciences students.

4 Review of Assessment Practices – Academic Integrity

2.10 Changes to Assessments

A feature of assessment in many Construction and Project Management programs are end of term sit down centralised examinations. These generally occur as end summative assessments in subjects and courses and require invigilation. Once it became clear in early 2020 that lockdown restrictions were barring exam hall type activities, academics at UoM and UofA were advised to both (a) Proceed to make any adjustments required for assessment to be undertaken online where face to face would be highly unlikely, and (b) Proceed to make any adjustments required which would allow both in-person and online assessment, potentially creating two different modes of assessment available based on a possible return to campus and lifting of restrictions.

Ultimately, Melbourne's second strict Covid lockdown which lasted over 4 months precluded invoking the second of these options and whilst South Australia invoked less stringent lockdowns in 2020, assessments were moved online. A key feature being, that in an open resource exam (open book) students are permitted to bring notes, texts and other resources into the exam room whereas in a non-invigilated online exam students can access course materials and other resources electronically. Whilst it is beyond the scope of this paper to review the multitude of lived experiences of lecturers during Covid, some research (Barker et. al. 2020) provides learning from online assessment strategies in higher education during Covid.

A comparison of standard UoM and UofA online exam technologies is presented as a matrix in Table 1 overleaf This table can be used to compare different aspects of the four standard online exam technologies that were available and linked to the Canvas LMS at institutions. **Gradescope** is an assessment tool that supports the creation of assignments, combining online and paper-based approaches, enabling students to submit their responses in various formats and streamlining staff grading and feedback processes. Instructors can create Canvas assignments that link to Gradescope assignments, which the students can answer directly online and/or submit photographs or PDFs of their handwritten or hand-drawn work (e.g. graphs).

Gradescope was originally designed for STEM assignments but since it can be used with handwritten and typed assignments, it has evolved and can be used for a multitude of subjects and courses. **Cadmus** is an online assessment tool, where subject coordinators create, and students complete written assessment tasks in a dedicated environment, accessed through the LMS. It is made up of two connected applications: (a) The Cadmus Teacher Environment and (b)The Cadmus Student Environment. In Cadmus, the assignment is digitally 'observed' as the entire assignment writing process is conducted within Cadmus which teaching staff can 'observe' and review as needed.

Table 1: Assessment Features in LMS and third-party applications

	LMS Quizzes	LMS Assignments	Cadmus	Gradescope
Question Banks for Quiz Questions	Yes	NA	NA	No
Turnitin Similarity Checking	No	Yes	Yes	No
Time limit	Optional	No	Optional	Optional
Auto–submit	At end of time limit or at due date and time	No	Yes – when timer used	Yes – for timed "Online Assignments"
Grading platform	SpeedGrader	SpeedGrader	Turnitin – Feedback Studio	Gradescope
Automatic marking	Yes – for some question types	NA	NA	Yes – for some question types
Marking by rubric	Yes – SpeedGrader rubrics	Yes – SpeedGrader rubrics	Yes – Turnitin Feedback Studio rubrics	Yes – Gradescope dynamic rubric that is created and updated during marking
LMS sections available	Yes	Yes	No	Yes – Limited link to LMS sections
LMS groups available	Yes	Yes	No	No
Option to mark by section	Yes	Yes	No	No
Option to mark by group	Yes	No	No – does not sync with LMS groups/sections	No – does not sync with LMS groups
Submissions can be downloaded	Yes – As Excel spreadsheet with all submissions	Yes	Yes	Yes – for uploaded files only

AEAs present in assignment as part of assignment creation	Yes	Yes	No – AEAs need to be created manually	No – AEAs need to be created manually
Countdown to end of exam for students	Yes	No	Yes	Yes

The matrix above in Table 1 is presented not as an exhaustive list of all the features and issues in choosing one option of assessment over another. Generally, at UoM and UofA Canvas Assignments and Exam Quizzes were most frequently used with some limited use of Gradescope and Cadmus. One major issue that presented in using Gradescope for exams was the ability of students to take photos of their work in various formats and then attempt to upload these for assessment. Students experienced some difficulties or delays uploading photos of handwritten pages into Gradescope due to the size of photo files and/or the number of photos. As technical issues with this feature emerged it was strongly recommended that students download and use a scanning app to submit exam papers as PDFs instead of photos. Some academics in the Construction discipline at UoM reported greater efficiencies in marking using Gradescope based on its use of dynamic rubrics and not having to grade each paper individually at one time.

It is further evident in a report from (TEQSA 2020) that in most institutions a variety of different approaches to online assessment have been used which include changing the nature of the assessment tasks from those used in on-campus learning; replacing examinations with more continuous assessment tasks, and engaging in the types of LMS based online examinations such as shown in Table 1 above. Because assessment is so closely related to the attainment of prescribed learning outcomes, some of the adjustments made during Covid had the potential to impact the quality assurance arrangements for both the course and its subjects which have been presented in accreditation and registration documents.

2.11 Marking Scheme adjustments and Students at Risk

Being in a more severe Melbourne lockdown UoM in semester one 2020 revised the method of calculating the Weighted Average Mark (WAM) and subsequently extended this to all second half-year subjects (including winter subjects). For the avoidance of doubt, students were informed this means results from the Second Half Year 2020 subjects would not be included in the calculation of a student's Weighted Average Mark (WAM) unless the mark achieved for the subject is equal to or higher than the WAM the student had achieved at the beginning of 2020. At UofA, this concession was not carried over into 2021 as in a communication from the University (UofA 2020);

> *'You may be aware that the University made temporary adjustment to its grading system for 2020 in response to the rapidly changing global pandemic situation. We have received some enquiries around these grading adjustments and whether they still apply in 2021. I confirm that these adjustments were temporary and Academic Board has confirmed that they do not apply in 2021'*

The adjustments made, and student learning outcomes achieved was to be examined further by Academic Board Course Academic Progress Reviews and into alternative arrangements for the management of academic progress review for coursework students in the first half-year (FHY)

2020. It was agreed that no Course Academic Progress Committees (CAPC) would be automatically convened for 2020 and that any student identified as 'At Risk" for the first time will still have this status applied to them but would not automatically advance to "Probation" should they perform unsatisfactorily in the second half-year (SHY) 2020. Students who had a prior status of "Unsatisfactory Progress" (Probation or TER/SUS) and again made unsatisfactory progress would have their status in the system maintained (at probation or TER/SUS) and any current restrictions on their enrolment maintained where they exist. These students might be required to attend a CAPC meeting but may not be terminated or suspended.

2.12 Academic Integrity – Proctoring and Invigilation

Reedy et. Al (2020) explores the perceptions of academic staff and students to student cheating behaviours in online assessment during the emergency transition to online learning and assessment in response to the COVID-19 pandemic. The study by Reedy was not conducted at UoM or UofA, the 3 universities were in other capital cities or a regional centre. Nonetheless, common themes emerge in the experiences and observations of the authors. It was observed that cheating occurs in all forms of online examinations whether proctored or non-proctored, just as it does in face-to-face examinations. The current debate tends to ignore this fact and focuses on transferring approaches designed for minimising cheating in face-to-face environments into the very different context of digital exams and assessment. Further studies support an integrated approach to minimising cheating in online environments (Sullivan 2016) that combine a focus on assessment design (Brimble 2015) with strengthening a culture of integrity and utilising the affordances of technology. This combination of approaches is likely to be more effective in reducing academic misconduct than technical solutions alone (Sullivan 2016).

At UoM and UofA a dedicated Academic Integrity Module was developed as an LMS friendly 'plug-in' that could be imported into any subject via Canvas Commons. This module helps inform students about the importance of academic integrity when completing regular assignments submitted electronically and open book exams in online mode. Students are made aware of the Turnitin plagiarism checks that can be applied to documents submitted as assessments in the LMS however both Gradescope and Cadmus take a learning-centred approach to academic integrity — the tool does not detect contract cheating or use keystroke analytics.

5 Conclusion

Built Environment (BE) educators at the 2021 conference organised by AUBEA during the second year of a profound global pandemic will reflect on their own and perhaps their colleagues and peers' experiences. Evident in both the recent literature and the measures described by the authors herein are the adoption of similar approaches to the challenges wrought by Covid-19 within the discipline. There are however some institutional and faculty responses and initiatives that are more tailored to individual cohorts, perhaps areas of further research. As with other disciplines in CM and PM programs, this depends highly on what is being taught and where students are located. Far fewer international students are enrolled in programs in 2021 than were enrolling at the beginning of the pandemic in 2020. Many of Australia's overseas students are now studying remotely whilst many other potential students new or continuing students have deferred offers of acceptance to 2022.

As was the case in pre-pandemic times much is expected of academics active in teaching, to respond to various challenges in the higher education landscape, including in different levels of support and budget constraints. Student expectations of quality education have not diminished during Covid-19 whilst the magnitude of travel bans and various restrictions on movement, inevitably have led to a greater reliance on remote off-campus learning technologies. Tracking students is difficult, lecturers observe the different levels of engagement of travel ban students COVID-19 has forced educators and students alike to rethink their understanding of effective education.

A trend to more online learning has reflected the growing acceptance of online education in Australian Universities yet for many students, online learning creates a number of obstacles and inequities that had not previously existed, especially for international students. Within divisions, it is imperative to identify and develop local experts in online assessment design and technologies to provide contextualised advice and support to subject coordinators. Many staff and students perceived benefits in online assessment delivery, with students commenting on the benefits of completing their assessment in a comfortable, familiar space, typing responses rather than handwriting, and the exam questions in ‘open-book' format that lent themselves to the application of knowledge over memorisation

These perceived benefits notwithstanding, staff and students highlighted a range of issues and opportunities for improvement, broadly grouped into the following categories: Technical operations, procedures, roles and responsibilities as well as training and support to ensure academic integrity. Remote, online invigilation or proctoring examinations was held to be highly problematic in both a social and technical sense and was not adopted across the two institutions to which the authors present here. concerns about efficacy, feasibility, bandwidth requirements, privacy and student experience. Others have found that remotely using electronic proctoring to ensure academic integrity was being upheld and this new approach adopted by others during Covid attracted the greatest amount of criticism with students (TESQA 2020) believing their privacy was being invaded.

As we continue to live and learn through our new experiences with academic and social life, perhaps this turning point in history will be a stepping stone for the Construction and Project Management educational system, that could combine the advantageous elements of in-person learning that we took for granted with elements of online learning that we have just begun to discover.

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Critical Appraisal of Building Information Modelling Research in Australia: A Bibliometric Analysis

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Abstract

Interest in advanced digital technology such as Building Information Modelling (BIM) has grown remarkably in the Architecture, Engineering, Construction, and Operations (AECO) industry over the past decade, and BIM research has proliferated globally. In Australia, alongside the increasing rate of implementing BIM within the AECO industry, academic research has also risen on the topic; however, to the best of authors' knowledge, a systematic review of the extant literature on BIM in Australia is missing. This study addresses this lack by offering a Scientometric analysis to explore the state of BIM literature in Australia. To this end, a quantitative approach using the 'science mapping' technique is employed to examine 473 articles in the field and to highlight their academic discourses that have occurred and emerged over time. Findings revealed primary topic areas in BIM research and their connections as well as research institutions active in BIM research, key authors and their collaboration networks, influential countries, and research outlets. The findings are instructive in identifying the gaps in current research. Research in the area of 3D modelling, visualisation, and technical aspects of BIM has dominated BIM research in Australia. There has been less emphasis on the managerial aspect of BIM, education and training, as well as the emerging and interrelated areas such as the Internet of Things, Blockchain, and Digital Twin. Analysis of the collaboration network of the Australian institutions active in BIM research shows that institutions mainly work in isolation with little or no in-country collaboration. From an international perspective, findings demonstrate an increased collaboration with China rather than those identified as leading countries in BIM research such as the U.K. and the U.S. By providing a view from a meta-perspective, the present study contributes to the body of knowledge of BIM in Australia by informing the researchers, the institutions, and the industry of the need for the future research direction and deeper exchange of knowledge.

Keywords

Scientometric, Review, Network Analysis, Education, Publication

1 Introduction

Building Information Modelling (BIM), as defined in the construction industry, is a set of collaborative processes that are used to integrate and manage crucial project information created by key stakeholders throughout the project life cycle (Baldwin, 2019). The advent of BIM has led to significant benefits such as integration of project stakeholders, the way information is shared among the involved stakeholders (Oraee *et al.*, 2017), and effective asset management during the project operations phase (Sacks *et al.*, 2018). Indeed, the significant benefits of BIM have inspired several countries, including Australia, to consider implementing

BIM as an innovative way to improve the delivery process of building projects (McGraw-Hill Construction, 2017). Similarly, as a scholarly domain, BIM research has attracted considerable attention from researchers in the field, with a consequent rise in related publications.

Despite the increased attention in BIM research in Australia, the growth of publications in the field presents certain challenges. Indeed, the volume of existing publications makes it difficult to explore the nature of new and uncovered knowledge, its contribution and impact to the body of knowledge, and more importantly, to identify critical areas that remain overlooked or neglected. In other words, the relatively sizable body of research in BIM in Australia necessitates evaluating the publications from a broader perspective to explore their primary areas of interest and collaboration networks of active researchers and institutions. As discussed by Newton (2016), the construction management domain needs to constantly be engaged with the research communities within the domain and in other domains. Indeed, construction management research is augmented through the promotion of methodological and philosophical diversity (Dainty, 2008) and the utilization of theories from other disciplines (Schweber, 2015). Therefore, a lack of engagement with the state of research may overlook core aspects or duplication of efforts (Yalcinkaya and Singh 2015). To date, however, to the best of the authors' knowledge, no systematic attempt has been taken to demonstrate a comprehensive view of the body of literature of BIM research in Australia. Therefore, this study aims to address this gap by adopting a structured quantitative method to map the existing state of BIM literature in Australia. This approach will uncover gaps in the body of knowledge through visualising researched areas and the associations among the active researchers and institutions in the field. The findings will provide a sound basis to inform future directions and strategies in BIM research in Australia, and assist research planning and funding efforts by policymakers and the industry.

2 Research methods

The primary method for the present study is the quantitative bibliometric analysis of the extant literature. This method was selected over alternative methods, including qualitative methods of review for various reasons. Firstly, systematic qualitative manual methods involve very few researchers and the selection and analysis of the studies may be affected by biased views and the researchers' interests (Yalcinkaya and Singh 2015). Whereas systematic quantitative methods, including bibliometric analysis, are robust to these challenges. Moreover, as discussed by Su and Lee (2010), bibliometric analysis proves its capabilities in mapping systematic patterns in large bodies of literature and can link literature concepts that have been overlooked in qualitative manual review studies. Bibliometric analysis is a quantitative method that refers to knowledge domain analysis and visualisation by using large-scale scholarly datasets of published literature (Cobo *et al.*, 2011). In other words, this method utilises computational tools, based on network analysis principles, to explore the research directions within the existing available literature and to visualise the associations among the active players in the field. In the present study, *VOSviewer* and *Gephi* software were selected for analysis of bibliometric data. 'VOSviewer', where VOS stands for "Visualisation of Similarities", is a software that offers basic operations needed for creating and visualizing bibliometric networks of published studies (van Eck and Waltman 2014). 'Gephi' is an open-source Java-based program seen commonly as a leading tool for network visualisation and analysis. Gephi is used in this study to provide an in-depth view of the extracted information out of the created network by VOSviewer (Cherven 2015).

In this study, as recommended by Cobo et al. (2011), the general process for a scientometric mapping study was implemented. In which, the data procurement and analysis entailed the three main stages: (1) data selection, (2) network creation based on the selected data, and (3) visualisation and analysis of created networks. For data procurement, VOSviewer supports bibliographic records from Google Scholar, Web of Science (WoS), PubMed, and Scopus. However, in this study, 'Scopus' was selected as the database to extract bibliometric records for the present study. This is mainly due to (1) its relatively wide coverage of existing and the most recent publications (Meho and Rogers, 2008), and (2) its capability of exporting essential data in the form of a dataset that can be downloaded, as the source of input for network creation.

To search for publications in Scopus, relevant keywords to the topic including 'building information modelling' and 'building information modeling' were considered. In the first round, the search generated 7143 publications as of 30 May 2021. In the next round, the search was filtered based on the Australian affiliations, which resulted in identifying a total of 473 studies published by Australian researchers since 2005, including all types of publications such as journal articles, conference papers, books and book chapters. In the final round, bibliometric records of these 473 studies were extracted from Scopus to form the dataset in the present study. The developed code in this study to search for publications within Scopus is as follow:

(TITLE-ABS-KEY("building information modelling") OR TITLE-ABS-KEY("building information modeling")) AND (LIMIT-TO (AFFILCOUNTRY,"Australia"))

The analysis of publications in the study's dataset was conducted at five levels namely: (i) identification of major areas of research (ii) collaboration network of Australian BIM researchers, (iii) collaboration network of Australian institutions active in BIM research, (iv) collaboration network of influential countries, and (v) identification of top research outlets.

3 Findings of the study

3.1 Major research areas

In scientific research, keywords represent the focus of published studies and indicate the range of areas researched within the boundaries of any domain (Su and Lee, 2010). As stated by Van Eck and Waltman (2014), "*the number of co-occurrences of two keywords is the number of publications in which both keywords occur together in the title, abstract, or keyword list*". To explore the major areas covered in BIM research in Australia, as recommended by Van Eck and Waltman (2014), co-occurrences analysis of author keywords was applied, which resulted in identifying 1279 keywords. To create a clear and legible graphical network in VOSviewer, in the first round, similar terms were merged. For example, the terms *BIM* and *Building Information Modeling* merged with *Building Information Modelling, Industry Foundation Classes* merged with *IFC,* and *Integrated Project Delivery* merged with *IPD*. Moreover, generic terms such as *Australia, review, methodology, ontology, industry* and *case study* were removed from the list. In the next round, the minimum number of occurrences of a keyword was set to the default value of 5, as recommended by Van Eck and Waltman (2014). This resulted in the creation of a network including 33 nodes connected through 83 links, as demonstrated in Figure 1.

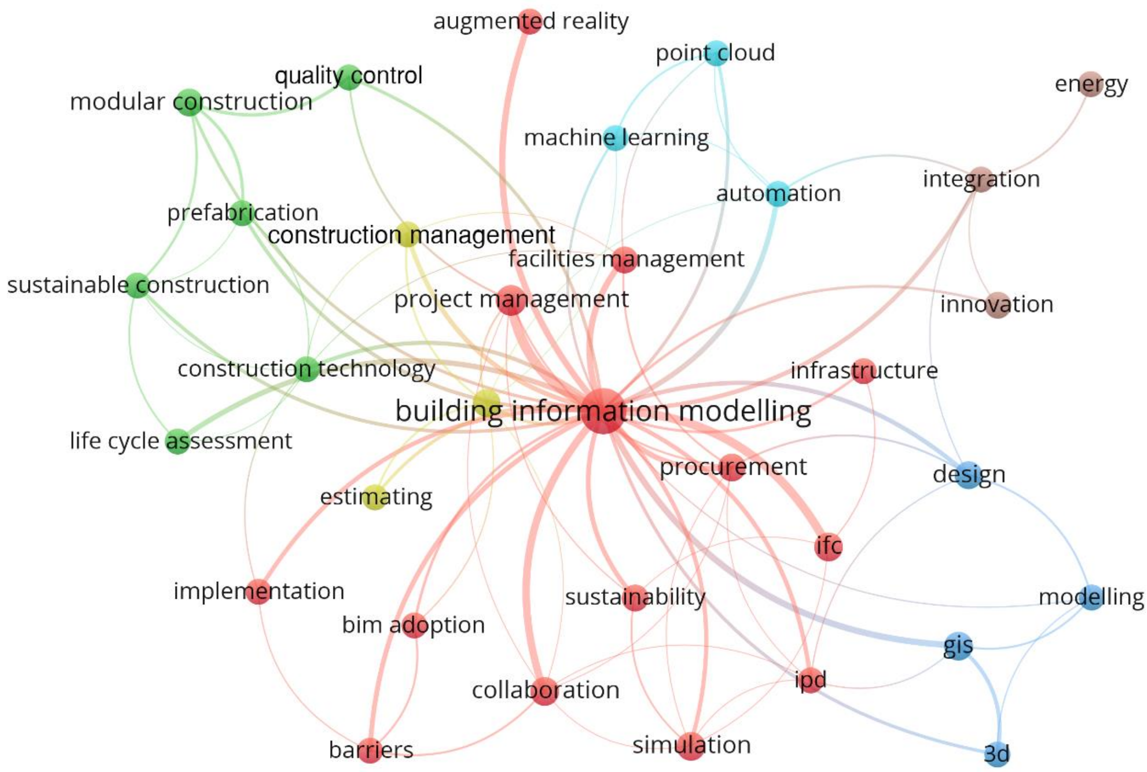

Figure 1. Main research areas in BIM literature published in Australia

Analysis of the nodes and links strength in Figure 1, reveals several interesting findings, reflecting gaps with the published BIM literature in Australia. As shown in Figure 1, *simulation*, *3D, collaboration, BIM adoption, project management, construction technology, integration,* and *asset management* were the major research areas of published studies. Judging from the size of nodes and links, these areas show the main focus of research with links to a wide range of other areas in the domain. However, other crucial areas in the BIM domain have remained overlooked. Indeed, areas such as *BIM education and training, BIM Execution Planning*, as well as interrelated areas including *Internet of Things (IoT)*, *Digital Twin*, *smart contracts, and Blockchain* turned out to be less investigated.

In addition to less explored areas, analysis of Figure 1 revealed the lack of strong links among otherwise tightly connected areas. For example, no direct link was found between 'BIM' and 'energy' area that is located in a different cluster than the more relevant cluster including 'sustainable construction', 'life cycle assessment' and 'prefabrication' areas, which shows a gap in the body of knowledge of BIM in Australia. Indeed, according to the BIM definitions, delivering energy-efficient projects is one of the selling points of BIM in the industry (GhaffarianHoseini *et al.*, 2017, Sacks *et al.*, 2018).

3.2 Collaboration network of researchers

Scientific collaboration networks provide significant benefits to any field of research. These can be traced to benefits such as providing access to available funds, expertise and specialities, assist researchers in the field to reduce isolation, and increasing productivity and boost scholarly communications (Ding, 2011). Indeed, according to Glänzel and Schubert (2004), "Almost every aspect of scientific collaboration networks can be reliably tracked by analysing co-authorship networks". Thus, lack of co-authorship (collaboration in a scientific network) can be considered as a symptom of lower research productivity in any field of research.

In the present study, to create the scientific collaboration network of BIM researchers in Australia, *co-authorship* analysis in VOSviewer was used. To identify the active researchers in the field and have a clear and legible network, the minimum number of documents for? an author was set to 6, which resulted in identifying 14 collaboration clusters, including 50 authors connected through 131 links (Figure 2).

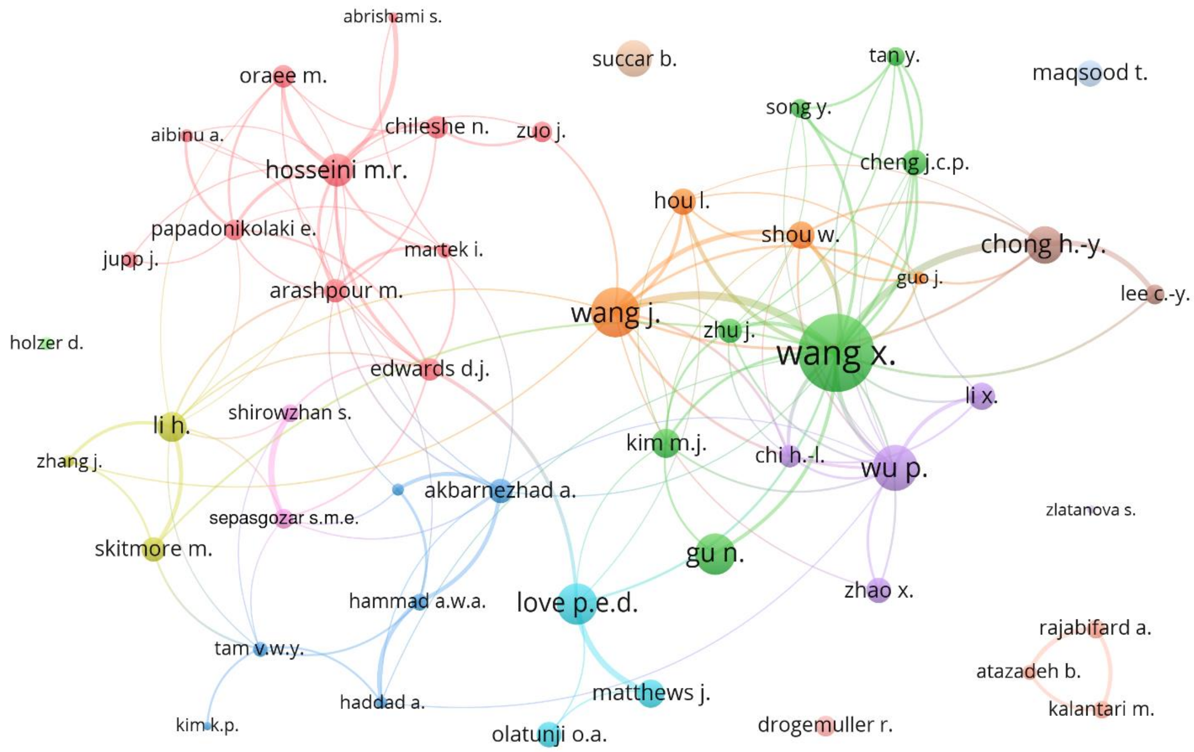

Figure 2. Collaboration networks of active BIM researchers in Australia

Figure 2 illustrates a map of active BIM researchers in Australia, as well as their local and international networks. In this figure, nodes were resized based on their strengths, in which larger nodes indicate higher impacts to the BIM research. As shown in Figure 2, eight out of 14 clusters (including 42 authors) have at least three researchers connected through publishing papers within the same cluster and via common co-authors in other clusters. This seems to be a promising network as most clusters have a reasonable exchange of knowledge and collaborative research activities in BIM. As a minor gap in Figure 2, six clusters (including eight authors) were observed in the network with no links to other clusters.

3.3 Influential institutions

In addition to the collaboration network of researchers in the field, the creation of a collaboration network of involved scientific institutions/organisations benefits the field. In other words, identifying the Australian institutions with high interest and investment in BIM research provides benefits to the field through providing input into research partnership policymaking (Ding, 2011). In this study, to identify the Australian institutions active in BIM research, co-authorship analysis in VOSviewer was utilized. To this end, the minimum number of published documents of an organisation was set to 10. The initial results show 27 institutions including Australian and international institutions, which were exported to ‘Gephi’ for further analysis. In Gephi, the ‘HITS algorithm’ (Hyperlink-Induced Topic Search) was utilised to create the hub scores for institutions. The hub score, as described by Kleinberg *et al.* (2011), represents the number of highly informative nodes to which a particular node is pointing. In other words, a high hub score for an institution indicates that it serves as a directory to other institutions involved in research. This resulted in identifying the top 10 Australian institutions connected through 7 major links (Figure 3).

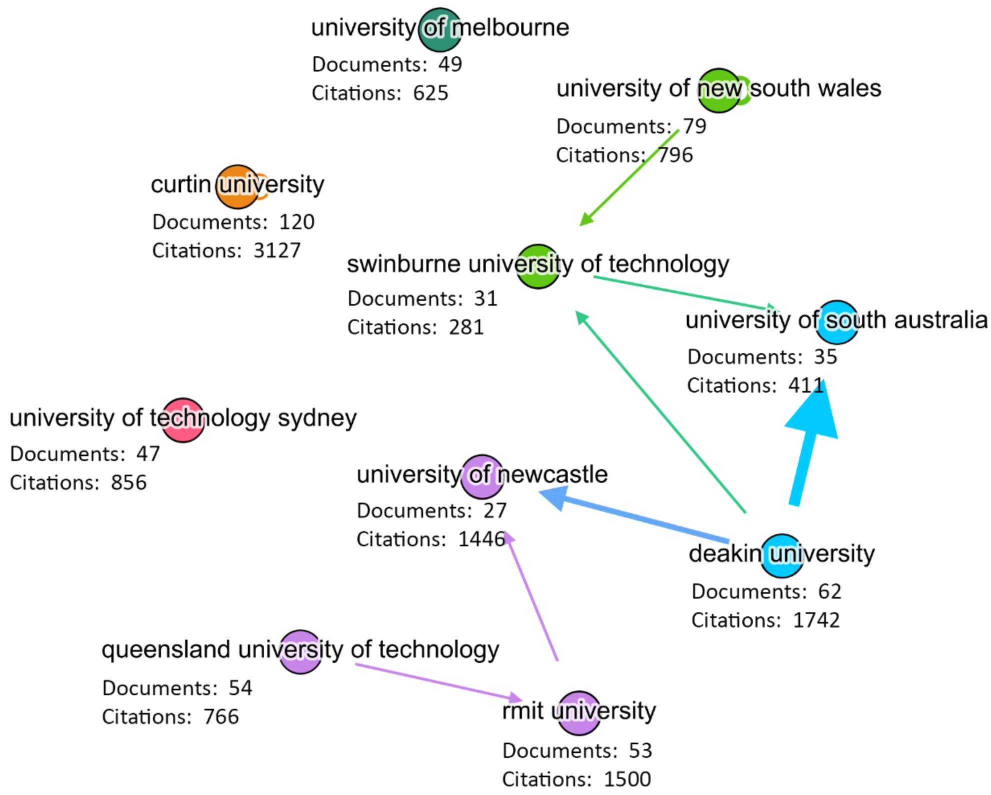

Figure 3. Collaboration network of top 10 Australian institutions active in BIM research

As shown in Figure 3, Curtin University (including the Australasian Joint Research Centre for BIM) ranked one in terms of the number of publications (120 papers) and the citations received (3127). Deakin University stands out among other institutions in terms of the level of collaboration with other Australian institutions active in BIM research. However, the lack of links among the major part of institutions in the network indicates the isolated nature of BIM research in these institutions. This simply reflects a lack of meaningful collaboration and knowledge exchange between the BIM researchers in these institutions and other institutions, which is another problem identified with the existing literature in BIM research in Australia.

3.4 International collaboration network

International scientific collaboration networks in any research field assist researchers in avoiding isolation, enhancing collaboration efforts, and providing access to potential funds, which enhance research productivity (Ding, 2011). In this study, to identify the most influential countries in the scientific collaboration network of BIM research in Australia, a network was created in VOSviewer by analysing the co-authorship network of the Australian BIM researchers and their international links. To have a clear and legible network, the minimum number of documents of a country was set to 5, which resulted in identifying 10 clusters and 16 countries, connected through 44 links (Figure 4). In this figure, nodes and their links were resized based on their degree values, in which larger nodes indicate higher collaboration in the network, and thicker links show strong collaboration between the two countries.

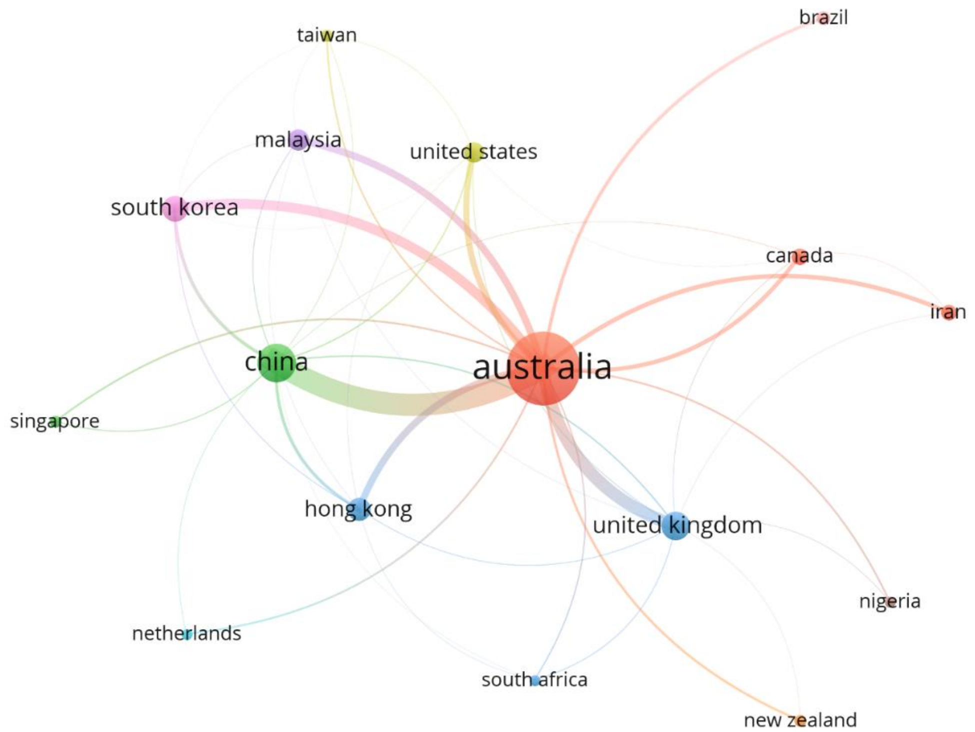

Figure 4. Influential countries to BIM research in Australia

The findings in Figure 4 show a satisfactory collaboration between the Australian BIM researchers and the international researchers in the field. Indeed, the network shows a collaboration network with BIM researchers in Europe, North and South America, Asia and the Middle East. However, for the major part of the network, links are not very strong. Another finding indicates that the strongest link of collaboration was formed by Australia and China, which demonstrates stronger collaboration with Chinese institutions than with the leading BIM institutions in the U.K., the U.S. and Europe.

3.5 Top research outlets

Direct citation analysis of outlets in any field of research provides values to the field and creates an understanding of the key outlets in the given area (Van Eck and Waltman, 2014). In the present study, direct citation analysis of outlets in BIM research in Australia was considered. Indeed, identifying the prominent outlets of BIM research may be of value to authors in terms of identifying the best outlets for publishing. Moreover, it assists editors of journals in their strategic planning and updating their objectives (Guidry *et al.*, 2004). To identify the journals targeted by the Australian BIM researchers for publications, the study's dataset was imported into the VOSviewer, using 'citation' analysis of sources. To have a clear and legible network, the minimum number of documents of a source was set to 5, in which out of 183 sources, 20 sources met the thresholds. Then, the network was imported into Gephi in order to identify the journals with the highest level of impact. To this end, the concept of *Weighted Degree* (WD) was used as an indication of the level of importance of nodes in the network (Bastian et al. 2009). This resulted in ranking the targeted journals in the field (Table 1).

Table 1. Top-ranked outlets targeted by the Australian BIM researchers

Journal	Documents	Citations	WD	Rank
Automation in Construction	55	4419	195	1
Engineering, Construction and Architectural Management	20	347	58	2
Architectural Engineering and Design Management	6	207	33	3
Journal of Construction Engineering and Management	17	286	31	4
Archives of Computational Methods in Engineering	6	134	28	5
Sustainability (Switzerland)	13	109	21	6
Advances in Civil Engineering	7	151	20	7
ISPRS International Journal of Geo-Information	9	307	20	8
Construction Innovation	8	149	16	9
Journal of Cleaner Production	8	274	15	10

As illustrated in Table 1, *Automation in Construction* with a weighted degree of 195 stands out as the most popular outlet for BIM research in Australia. Moreover, *Engineering, Construction and Architectural Management* (a weighted degree of 58), *Architectural Engineering and Design Management* (a weighted degree of 33), and *Journal of Construction Engineering and Management* (a weighted degree of 31) are the next most popular journals with the higher weighted degree in comparison to other journals. Indeed, Table 1 indicates that for the most part, design and construction type journals are mainly targeted by Australian BIM researchers, with less attention on project management and managerial journals. This observation may be due to the greater attention given to the technical and modelling aspects of BIM and an overlooking of the managerial aspects of BIM.

4 Discussion and recommendations

This study uses bibliometric analysis to review the relatively large literature dataset on BIM research in Australia. The findings highlight several main implications for researchers, institutions, funding organisations and policymakers active in BIM research in Australia.

Published studies in the BIM area in Australia have covered a wide range of aspects in the domain, however, gaps were spotted in the research. These include overlooking crucial areas for investigation such as 'BIM Education and Training' and 'BIM Execution Planning', as well as a lack of focus on interrelated areas including 'Internet of Things (IoT)', 'Blockchain', and 'Digital Twin'. These gaps highlight the incomplete nature of current research as being heavily biased towards technical and adoption concerns in BIM. Consequently, this approach not only affects the future research directions but impacts the industry adaptations needed to invest on and promote the use of BIM and its interrelated technologies in the industry.

This study also investigated the collaboration networks among BIM researchers and research institutions in Australia, as well as collaborating countries. For the most part, researchers have reasonable collaboration with active BIM researchers both in Australia and internationally. However, the main problem was spotted in terms of the collaboration network of research institutions, in which the Australian research institutions essentially work in isolation. This necessitates further attention in increasing in-country collaboration and knowledge exchange among the research institutions active in BIM research. Again, the message here is the value of collaboration with key players and proponents in the field. Finally, a strong research collaboration and influence was found between Australia and China rather than those identified as leading countries in BIM research such as the U.K. and the U.S. (Hosseini *et al.*, 2018).

5 Conclusion

This study investigated the current state of BIM research in Australia. As a result, 473 studies published in the field were systematically examined using a Scientometric analysis approach. The findings revealed that BIM research in Australia has performed well; however, a greater focus on collaboration should be considered. Indeed, greater attention on the overlooked and interrelated areas, along with more in-country collaboration among the institutions active in BIM research is recommended. Despite the contributions offered in this study, several limitations must be considered. As discussed, the analysis is based on the bibliographic records extracted from Scopus, thus the findings are affected by the limitations of Scopus in terms of coverage, as well as the keywords used to search for relevant studies. Future research can be conducted using more databases to reveal the evolving nature of BIM literature in Australia and monitor its ongoing integrity and development. In addition, further analysis in different periods could identify how some networks have developed and the changing emphases of research. Lastly, analysing how influential cultural and institutional ties are in collaborative networks could shed further light on how networks develop and strengthen.

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Integrating the 4th Industrial Revolution in spatial planning curricula: the case of South African tertiary institutions

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Abstract
The 4th Industrial Revolution (4IR) – the narrative of change associated with technology-related disruptions through the proliferation of cyber-physical systems – is set to have a profound impact on the built environment. Technological applications that include big data analytics, cloud computing, and machine learning will affect spatial conceptualisation and design, construction activities, building operations and management, and real estate activities. The statutory and strategic nature of spatial planning processes may be disrupted by future technological applications. Equipping current and future spatial planning practitioners with the necessary skills is essential in maintaining property sector productivity and catalysing renewed efforts toward spatial transformation in South African human settlements. The objective of this research is to evaluate current approaches in tertiary education institutions in effectively transferring knowledge regarding 4IR as it relates to the spatial planning discipline and equipping said students with the relevant skills to prolong sector competitiveness. A qualitative case study analysis is applied, which includes the assessment of the curricula of selected accredited spatial planning schools and their relevant integration of 4IR applications. Research findings highlight the limited inclusion of 4IR and related multidisciplinary, practical, and theoretical themes in spatial planning education. Recommendations include increased knowledge transfer on the theoretical synergies between 4IR and spatial planning; development of computer-based skills; and implementing existing competencies, including critical thinking and problem solving, to foster sectoral adaptability.

Keywords
4th Industrial revolution, adaptation, built environment, spatial planning, tertiary education.

1 Introduction

Profound technological advances, encapsulated by the narrative of change (Avelino *et al*. 2014) promoted as 4IR, is set to disrupt production and consumption processes across sectors and economies (NEDLAC 2019). The broad proliferation of cyber-physical systems (Baldassari & Roux, 2017), the application of which include big data analytics, cloud computing, and machine learning, will not be limited to the information technology sectors or activities, but will also affect the built environment. Associated functions, including spatial conceptualisation and design, construction activities, building operations and management, and real estate activities, are all subject to disruption on the back of advanced technological application (WEF 2017). Spatial planning, including statutory and strategic planning procedures, may also experience profound disruption. This is already apparent in the limited automation of land development application processes and the integration of sensor-based machinery in cities to allow real-time data collection and analysis of urban systems.

In South Africa, as with most countries (Bock 2015), the built environment constitutes an important arena of national investment in the form of infrastructure and property development, which includes a broad value-chain of subsectors and stakeholders. Adaptation and adaptability to the potential changes inherent to 4IR, as with other disturbances (Martin & Sunley 2015), is important to sustain sectoral productivity and wider economic growth. In addition, targeted interventions by the public sector (DHS 2021) in order to alleviate the spatial challenges and inequality as a consequence of apartheid spatial planning (Abrahams & Everatt 2019) illustrates a central dynamic of the South African built environment and the role of sectoral practitioners. Accordingly, the resilience of this sector transcends economic objectives, and is anchored in sustaining spatial reform and socio-economic upliftment.

The training and education of current and future spatial planning practitioners is essential in maintaining property sector productivity and catalysing renewed efforts toward spatial transformation in South African human settlements. Education in spatial planning, specifically on a tertiary level, ought to equip prospective planners with the required knowhow to incorporate and adapt to potential disruptions promulgated by new technological applications. The objective of this research is to evaluate current approaches in tertiary education institutions in effectively transferring knowledge regarding 4IR as it relates to the spatial planning discipline and equipping said students with the relevant skills to prolong sectoral competitiveness. To achieve this objective, a qualitative research methodology is applied, which includes the assessment of the curricula of selected accredited spatial planning institutions and their relevant integration of 4IR themes. The following section provides an overview of the relevant literature, followed by the methodology, findings and discussion, and conclusion.

2 Literature Review

The objective of the literature review is to provide an overview of 4IR, its potential impact on spatial planning, and the education of spatial planning on the tertiary level in South Africa.

2.1 Delineating 4IR

The 21st century society is currently undergoing rapid technological advancements which have been attributed to 4IR. The current revolution, unlike its predecessors, is largely influenced by "a fusion of technologies that are blurring the lines between the physical, digital and biological spheres" (Schwab 2016). 4IR is marked by technologies, devices, and processes that include the Internet of Things (IoT), Cyber-Physical Systems (CPS), autonomous robots, visualisation technologies (virtual and augmented reality), cloud computing, blockchain technology, big data analytics, additive manufacturing, and digital twins (Culot 2020; BCG 2019). All these technologies are merging with human life resulting in "a vast ecosystem of interconnected, complex and dynamic interaction between humans and the built environment, from a single space to a city scale" (Fletcher 2016 cited in Ross & Maynard 2021:p159).

While 4IR presents significant opportunities for society, Ojo-Fafore *et al*. (2021:p57) suggest that Africa's developments in 4IR are stagnant in comparison to the rest of the world, as they are limited to policy statements and challenges such as "poor physical infrastructure, low regulatory, low policy quality, the poor rule of law, high disease burden and lack of adequate skilled workers" that overburden governments and divert their attention and efforts from the realisation of 4IR. This is particularly the case in South Africa which currently ranks 75th globally on a variety of metrics termed 'Readiness for the 4th Industrial Revolution' (Sihlongonyane *et al*. 2020). This situation puts enormous pressure on areas where South Africa is currently lagging or weak. One such area is the built environment sector whereby progress on fusing technology is still in its infancy as the adoption of ICT has been largely concentrated on the use of software such as BIM Platform (Building Information Modelling), GIS (Geographic Information Systems) and Revit as opposed to innovative technologies that propel 4IR agenda (Leal *et al*. 2018).

2.2 Implications of 4IR on spatial planning

Letsoko and Pillay (2019) highlight that the impacts of 4IR have extended to the built environment industry, encompassing architecture, urban planning, and construction, and has consequently disrupted conventional approaches on how they plan and shape urban systems and cities. As a result, the urban planning environment is increasingly turning to specialised technologies to address issues related to sustainability, society, security, transportation, infrastructure, and governance (Audirac 2002). This revolution has accelerated the drive towards the realisation of the smart city concept. Vilajosana *et al*. (2013) highlight that the smart cities concept has promoted the development of Internet of Things (IoT) and through it the incorporation of sensors and big data. Yigitcanlar *et al*. (2020) indicates that IoT supports increased connectivity that leads to the generation of data and its subsequent capture, analysis, and distribution, contributing to better smart city development. This is done through the implementation of a smart environment that is interconnected and interlinked with the internet resulting in application such as e-governance, smart mobility, etc.

Furthermore, Yigitcanlar *et al*. (2020) outline that technologies such as urban artificial intelligence (AI), that is embodied in urban spaces and infrastructure, can significantly contribute to planning as data can be sourced to gain a more holistic understanding of the urban fabric. Batty (2018) explains that such technologies allows planners and policymakers to shift from closed systems (interlinked urban elements) to an open, fragmented, peri-urban fabric that has tangible impacts on density fragmentation, cohesion, and compactness. Additionally, technologies such as remote sensing which involves a technique of data collection from a distance without touching objects are also disrupting conventional urban planning decision making in the era of 4IR. Xiao and Zhan, (2009) indicate that remote sensing technologies are able to provide a spatial temporal analysis of urban expansion and land use change, among other applications.

Similarly, sensor technologies such as drone (also referred to as Unmanned Aerial Vehicles (UAVs)) technologies are useful application for mapping cities. These technologies have largely contributed to the production of 3D models and geospatial information in the depiction and evaluation of planning proposals (Bakogiannis *et al.* 2019) and to capture zoning and land use patterns (Jenkins 2013). This presents an opportunity for South African municipalities to digitize their urban planning practises. In addition, 3D printing can assist planners to better understand spatial perspectives using 3D visualisations, which can also expedite the process of discussions and negotiations and enhance a mutual understanding amongst development practitioners (Ghawana & Zlatanova 2013). Moreover, 3D printing also makes way for printing objects such as houses which will impact construction cost, regulatory frameworks, and spatial planning policy (Cameli 2019).

Technologies, such as augmented reality (AR) and virtual reality (VR), are also changing the way in which planners can shape, plan and design cities. Angelini *et al*. (2020) indicate that AR and VR can help planners receive real-time feedback from citizens and stakeholders. These tools increase public participation through providing communities insight and input into the development process (Allen *et al*. 2011). This is particularly important in the South African context where public participation processes in development projects remain a fundamental challenge.

2.3 Spatial planning education and 4IR

The rapid transformations resulting from 4IR will present different implications for many sectors. Equally, the higher education system will be impacted and needs to be responsive to these advancements. Butler-Adam (2018) indicates that one of the implications of 4IR in the education sector has to do with curricula, including teaching and learning. This revolution demands increasingly more dynamic and adaptable curricula that is connected to the demand for new skills dictated by 4IR (Coetzee *et al*. 2021). Furthermore, the successful implementation of 4IR in education will require appropriate skills. Skills are required to implement, manage, and work with new technology (Butler-Adam 2018). In the near future, it is approximated that 35% of skills currently considered important will change. Hence, new sets of skills will be required for 4IR and for the use of new technology. As such, Kamaruzaman *et al*. (2019) propose that graduates in the engineering and built environment fields would require the following skills in the 4IR era: analytical thinking and innovation; active learning and learning strategies; creativity, originality and initiative; critical thinking and analysis; complex problem solving; emotional intelligence; and system analysis and evaluation. In response, transforming the education system through curricula redesign will increasingly be measured against how educational outcomes meet the requirements of stakeholders in the workplace (Halili 2019).

2.4 Spatial planning education in South Africa

In South Africa, all public universities have to be registered and accredited by the Department of Higher Education and Training (DHET); the Higher Education Quality Committee (HEQC) under the auspices of the Council on Higher Education (CHE); as well as the South African Qualifications Authority (SAQA). Zawada (2020) explains that once programmes have been accredited by the CHE, they have to be registered on the National Qualifications Framework (NQF) which is a qualification and learner register maintained by SAQA. The NQF provides a framework for benchmarking qualifications at both national and international level in order to recognize skills and categorise them to a unified structure of recognized qualifications (Sihlongonyane 2018). In order to advance these objectives of the NQF, SAQA developed level descriptors (ranging from level one to ten) for each level of the NQF with level five to ten being focused on tertiary education qualifications.

Table 1. NQF levels (tertiary education)

NQF Level	Qualification
10	PhD
9	Master's Degree
8	Honours Degree; 4 years + Bachelor's Degree
7	3rd year of Bachelor's Degree; Advanced Diploma
6	2nd year, Advanced Certificate, Diploma
5	1st year (maximum 96 credits), Higher Certificate

Source: SACPLAN (2014a).

The South African Council of Planners (SACPLAN), the statutory council responsible for the regulation of the planning profession in terms of the Planning Professional Act 36 of 2002, aids in the accreditation and the development of the planning curricula in South African tertiary institutions (SACPLAN 2014a). SACPLAN has identified three key competencies that a planner should possess, namely generic, core and functional competencies. The table below provides a detailed outline of these competencies and their descriptions and categories.

Table 2. SACPLAN competency descriptors and categories

Competency	Description
Generic competency	Essential skills, attributes, and behaviours. Competencies common in built and natural environment disciplines. Includes critical thinking, interpersonal competencies, communications, leadership, professionalism and ethical behaviour, social responsibility
Core competency	Specific knowledge, skills, abilities, or experience required by planners to perform successfully as practitioners. Includes settlement history and theory, planning theory, planning sustainable cities and regions, urban planning and place making, regional development and planning, public policy, institutional and legal frameworks, environmental planning and management, transportation planning and systems, land use and infrastructure planning, integrated development planning, land economics, social theories related to planning and development research
Functional competency	Basic skills focusing strongly on techniques and methodologies. A combination of studio-based dexterities and in situ field work. Includes survey and analysis, strategic assessment, local area planning, layout planning, plan making and implementation, participation, and facilitation

Source: Compiled from SACPLAN (2014b).

Furthermore, SACPLAN (2014b) indicates that in order to ensure planning schools adhere to accreditation standards, each school allocates a level of competency (outlined in the table below) for their programmes determined by the number of credits that are allocated to modules.

Table 3. Competency Levels

Competency Level	Description	NQF Level
Level 1	Awareness of and basic understanding of terminology and concepts; and ability to source further information and insights when required in the work environment	6
Level 2	Have a good understanding of a field of knowledge, or an ability to apply a methodology	7
Level 3	Be able to apply or engage with the area of competency with increasing degree of mastery and sophistication	8 & 9

Source: Compiled from SACPLAN (2014b).

Currently, eleven universities in South Africa have qualifications that are accredited by SACPLAN and are related to spatial planning. This includes the Cape Peninsula University of Technology, Durban University of Technology, North-West University, University of Cape Town, University of the Free State, University of Johannesburg, University of KwaZulu-Natal, University of Pretoria, University of Venda, and University of the Witwatersrand. Among the programmes offered by these institutions, three are NQF level six, three are NQF level seven, three are NQF level eight, and six are NQF level nine (SACPLAN 2019).

3 Research Methodology

The empirical investigation employed a case study analysis to evaluate current approaches in tertiary education institutions in effectively transferring knowledge regarding 4IR as part of contemporary approaches to spatial planning education in South Africa. The analysis was completed by evaluating the yearbooks of selected planning schools. For standardisation of the analysis, planning schools were considered for inclusion and evaluation when they offered an accredited undergraduate course at NQF level eight. Three planning schools met this criterium. Note that these schools/institutions will remain anonymous. However, this, and the yearbook references utilised in the analysis, can be made available upon request.

Boud and Falchikov (1989) state that the method of assessment or evaluation, as used for this phase of the empirical investigation, is deemed justifiable providing that two critical elements are included as part thereof: (1) there is a criterion identified and used as benchmark; and (2) the determination is made based upon the extent to which the predetermined criterion is met. Based on the literature review, three themes related to the impact of 4IR on spatial planning has been identified. This includes a multidisciplinary, practical, and theoretical theme. To achieve the objectives of the study, these themes have been developed into the criteria used to evaluate the inclusion of 4IR within spatial planning curricula in South Africa.

Criterium one is the *multidisciplinary* theme. New technology and their application will have diverse impacts across all sectors. This includes spatial planning, but also all the stakeholders in the built environment. The emphasis on a multidisciplinary approach and the effective function of spatial planners within this milieu may foster knowledge transfer among stakeholders and support adaptation to potential future disruptions, including 4IR. The curricula will thus be evaluated in terms of how they foster multidisciplinarity among stakeholders in the built environment and expose spatial planning students to this context.

Criterium two is the *practical* theme. 4IR indicates the increased integration of technology in the production process, which will also be relevant to the activities of spatial planners in fulfilling their function. Accordingly, the curricula of the institutions will be evaluated based on their incorporation of computer-based applications and the exposure of students to relevant software in the design process. Knowhow on the practical application of current and emerging technology in the spatial planning context may foster ease-of-adaption to additional advances in the long term.

Criterium three is the *theoretical* theme. Based on the potential applications of 4IR relevant to spatial planning, increased emphasis has been placed in the creation of smart and sustainable cities through using new, advanced technology as part of 4IR. Broader disruptions to development facilitation, including land use management processes, has also been identified. Therefore, the curricula of the institutions will be evaluated based on their incorporation of these theoretical themes that represent the emerging relationship between the spatial planning field and potential applications of 4IR and related technology within this context.

4 Findings and Discussion

This section provides an overview of the findings of the curricula evaluation. Table 4 indicates details on the curricula of the institutions, with reference to their NQF level, number of modules, the total credits the curricula comprise of, and the inclusion of 4IR themes both in terms of the number of modules that incorporate related themes, and the percentage of credits that these modules represent in the curricula. The inclusion of 4IR is evaluated based on the identified criteria, which include references the multidisciplinary, practical, and theoretical themes inherent to 4IR.

Table 4. Inclusion of 4IR in programmes (number of modules and % of credits)

Institution	NQF level	Modules	Credits	4IR inclusion	
				Modules	**Credits (%)**
Institution A	8	35	544	9	26%
Institution B	8	41	480	11	30%
Institution C	8	46	497	11	25%
Average					27%

As evident in table 4, the curricula of the three institutions utilised in the analysis have 35, 41, and 46 modules, respectively. While these programmes share the same NQF level, their total credits differ. The relevant programme of institution A comprises of 544 credits, while being 480 in institution B, and 497 in C. In terms of the inclusion of themes relating to 4IR, the institutions have a similar number of modules and credits that are linked to this outcome.

Institution A has nine modules to which 4IR themes are relevant, and both institution B and C have 11 modules. Relative to the total number of credits that the identified modules represent, institution B has the highest proportion as 30% of credits are linked to modules that include themes relevant to 4IR. This percentage is lower in the remaining institutions; 26% in institution A and 25% in C. The average for this variable among the three sample institutions is 27%. Table 5 provides a further breakdown of the nature of the 4IR inclusion. This is presented as a percentage of the total credits that are linked to the delineated multidisciplinary, practical, and theoretical themes.

Table 5. Themes of 4IR inclusion (% of relevant credits)

Institution	Multidisciplinary	Practical	Theoretical
Institution A	15%	-	12%
Institution B	8%	8%	14%
Institution C	15%	4%	6%
Average	12%	4%	11%

As indicated in the table, the multidisciplinary theme is the most prominent relating to 4IR among the sample institutions, followed by theoretical and practical themes. On an institutional level, the inclusion of 4IR themes in the curriculum of institution A is limited to the multidisciplinary and theoretical. In terms of multidisciplinarity, institution A includes considerations of the future work environment of spatial planning students and the disciplines involved in designing and installing engineering services; urban design themes; multidisciplinary teams and related participatory planning; and the divergent roles of planners and other stakeholders in facilitating development. Accordingly, 15% of credits in the curriculum are linked to the multidisciplinary theme inherent to 4IR. In institution B this figure is 8%, with the identified modules incorporating architectural and engineering skills, while referencing planning design on different scales and themes relating to sense of place. This curriculum also emphasises the specific role of planners among built environment practitioners. Similar considerations are incorporated in the curriculum of institution C, which has the joint highest consideration of multidisciplinarity among the sample institutions: 15%.

Among the institutions, the practical theme of 4IR is the most limited of those identified. While not identified in institution A, this theme represents 8% of credits in the curriculum of institution B and 4% in institution C. The practical theme is incorporated through reference to automated and computer-based design approaches, integration of design software (e.g. AutoCAD and ArcGIS) in module outcomes, and the broad utilisation of relevant technological applications for academic purposes.

When analysing the theoretical theme of 4IR, it is evident that institutions A and B are placed second and first, with 12% and 14% of curriculum credits linked to this theme. Reference is made to smart cities within the context of creating sustainable and resilient human settlements; transport infrastructure and the future development of cities; analysis and evaluation of land use management systems; processes of development facilitation and administration; and applications of new urbanism and case studies of smart and sustainable cities. Institution C, where 6% of credits are applicable to the theoretical theme, references the future of land use management; processes relating to development applications and procedures; and innovative planning practices.

Accordingly, based on the analysis, there is a limited incorporation of themes relating to 4IR in spatial planning curricula in South Africa, with 27% of credits applicable to either its multidisciplinary, practical, or theoretical themes. Among these, the multidisciplinary theme is the most prominent, being applicable to 12% of curriculum credits in the sample institutions, followed by the theoretical (11%) and practical (4%) themes.

In comparison, spatial planning students in South Africa are entrusted to a greater degree with the knowhow and skills relating to their successful function as part of a broader, multidisciplinary team of professionals in the built environment. In the context of 4IR and the anticipated disruption inherent to the application of new – and as of yet unanticipated– technologies, this holistic contextualisation of the role of planners and integration with related disciplines may allow for more rapid adaptation as technological disruptions proliferate throughout the built environment. Continuous insights gained from related fields throughout the development process and cooperation among disciplines may not only optimise sector-wide adjustments and mitigate the potential effects of disturbances, but also enable the effective positioning of the sector over the long term. While this theme is the most prominent among those relevant to 4IR in current curricula, there is a need further integrate related considerations of multidisciplinarity relevant to spatial planning, including exposure to the skills, functions, and activities of other stakeholders, particularly architects and civil engineers, in the built environment as part of the curricula. An increased focus on multidisciplinary in the context of knowledge transfer in spatial planning education in South Africa, may aid sectoral adaptation.

The inclusion of theoretical themes related to 4IR are also limited in spatial planning education in South Africa. As discussed in section 2, there is significant theoretical overlap between spatial planning functions and potential applications of 4IR in the built environment. Increased knowledge transfer on the theoretical synergies between 4IR and spatial planning may not only enhance the adaptability of future spatial planning students, but also contribute to achieving broader societal objectives, including the creation of sustainable, resilient, and smart cities and human settlements. This is also specifically relevant to the South African urban spatial contexts, and policy objectives which seek to transform fragmented and unequal human settlements.

As evident from the findings of the analysis, there is a significant need for increased inclusion of the practical theme related to 4IR in spatial planning curricula, which currently constitutes 4% of credits. While the full breadth and depth of applications related to 4IR may be currently unclear, it is evident that automated and computer-based processes will grow in prominence. This is also applicable to the use of relevant software in the planning and design process relevant to the function of spatial planners. It is in this context that knowledge transfer on the practical application of current and emerging technology in the spatial planning may be beneficial to spatial planning students. The development of computer-based skills and knowhow may foster resilience to similar technological advances over the long term.

While there is potential for increased inclusion of 4IR themes in curricula, based on the regulatory landscape guided by SACPLAN, competencies inherent to spatial planning education (refer to table 2) empower students to be critical thinkers and creative problem solvers, in addition to gaining and applying the relevant knowledge in their field. The successful incorporation of these competencies in spatial planning education in South Africa may enable adaptability and resilience of planning professionals in the face of diverse external disruptions. These skills are of particular importance in the face of uncertainty regarding the long-term impact of 4IR on the built environment, where the application of new technology will require ongoing innovation, analytical thinking, active learning, creativity, and complex problem solving. While revised curricula may enable skills development relevant to the multidisciplinary, practical, and theoretical themes of 4IR in connection to spatial planning, striving toward the effective transfer to existing competencies to spatial planning students will enable adaptability within any disrupted context.

5 Conclusion

Significant disruption is expected in the built environment and spatial planning with the onset of 4IR and the related proliferation of advanced technologies. Spatial planning curricula in South Africa ought to be reviewed with the objective of increasing the inclusion of 4IR, including related multidisciplinary, practical, and theoretical themes. This will include knowledge transfer on the synergies between spatial planning and 4IR, the role and function of spatial planners within diverse teams of stakeholders, and the development of computer-based skills in the planning and design process. While this may increase sectoral adaptability in the face of the wide-spread implementation of advanced technologies that may revolutionise production processes, the empowerment of spatial planning students with existing competencies of SACPLAN, such as critical thinking and problem solving, may also foster long-term adaptability regardless of the nature of disruption. A future avenue of research include primary data collection with the objective of gaining input from current students and professionals in spatial planning and the built environment on their perceived preparedness for sectoral disruption caused by 4IR. Additional comparative research between different tertiary education contexts may augment the findings of this research, with the focus current limited to the South African milieu. A limitation to the current research is data availability, with the extent of curriculum analysis and evaluation limited to the detail provided in the programme overviews of each institution.

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The impact of drafting styles on contract readability: An objective assessment of the New Zealand quantity surveying consultancy contract

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Abstract

Standard forms of contracts are usually written in the traditional legal drafting style. They are difficult to read and understand by construction practitioners. This study aims to objectively assess the impact of contract drafting styles on the readability level of the revised and clarity-accredited standard form of consultancy contract in New Zealand and compare it with its predecessor version. Clauses from both contract versions were evaluated using a traditional readability formula – Flesch Reading Ease Score (FRES). Results revealed that although the revised version is accredited as clearly written by the Plain Language Commission, only 11 clauses in the revised version are predicted to be accessible to readers ages 14 years old and younger. The results showed that clauses in the revised version are readable at 'difficult' reading grade level, while clauses in the predecessor version are readable at 'very difficult' reading level. But the revised version is easier to read than its predecessor, even though the successor comprises more clauses, words and sentences than its predecessor. Our results provide a further explanation about contract readability from an objective readability prediction perspective with the use of readability formula.

Keywords: Consultancy contracts, FRES, Plain language, Readability, Standard forms.

1 Introduction

Construction contracts are usually written in complex language and understood only by those who are experienced and trained in law. Unfortunately, the primary users of construction contracts are not trained in law. So, the convoluted drafting style employed in a typical construction contract may reduce the contract's readability and affects its reader's understanding. Various studies have been conducted in the past to analyse and compare the impacts of drafting styles in construction contracts. Some of these studies were anecdotal, where authors chose specific contract clauses to showcase the stark difference between a complex clause and a simplified clause (Penman, 1992). Others used readability formulas as prediction tools to investigate the correlations between contract drafting style, risk distribution and reader's perceived comprehension (Rameezdeen and Rajapakse, 2007, Rameezdeen and Rodrigo, 2014, Rameezdeen and Rodrigo, 2013). Most readability studies in the built environment chose building construction contracts in their analyses (Chong and Oon, 2016, Chong and Zin, 2010). No studies have been done to objectively scrutinise the impact of readability in the construction professional's consultancy contract. Therefore, this study aims to fill the existing research gap by conducting an objective assessment of the impact of contract drafting styles on the readability of a quantity surveying standard forms of consultancy contract.

2 Literature Review

2.1 Dispute, communication, and contract

One of the top three ranked causes of dispute in 2018 and 2019 reported by Arcadis (2020) is *'Contracting parties failed to understand contractual obligation or failed to comply with contractual obligations'* (p.11). This aligns with Mitkus and Mitkus (2014) on the effects of disparity of contract interpretation on construction disputes. Disputes in construction contracts usually happen due to contracting parties' inability to understand the legal contents in their contracts (Masfar, 2017). This problem is not new in construction contracts. In 1969, Lord Justice Sachs in *Bickerton & Son Ltd v North West Metropolitan Regional Hospital Board [1969] 1 All ER 977* viewed those clauses in the Joint Contracts Tribunal (JCT) standard form version 1963 should be redrafted so contractors and building owners could understand its contents. Unfortunately, the language problem in standard forms of construction contracts remains unchanged three decades after (Ali and Wilkinson, 2010). Standard forms of construction contracts continue to be written in a complex language in their revised editions. As a result, construction disputes continue to be litigated in courts despite the use of standardised language in the forms of contracts (Nee *et al.*, 2014, Thomas *et al.*, 1994).

A construction contract is a product of communication between parties in a contract (Mitkus and Mitkus, 2014). Rameezdeen and Rodrigo (2014) acknowledge the influence of good communication on a successful project outcome and how it helps projects function smoothly. Communication is viewed as effective if a recipient of a message understands the contents of the message. However, communication is considered ineffective if the recipient of the message does not understand the contents of the message. As asserted by Painter (2008), communication is deemed to be failed if the reader does not understand what was written. One of the barriers to effective communication is the use of ambiguous words and jargon that are incomprehensible by the recipient (Velentzas and Broni, 2014). In law, ambiguity is often associated with a lack of clarity in the language (Schane, 2002). And the language of law is often unclear (Mellinkoff, 1963). Contracts that use language susceptible to more than one meaning would result in ambiguity (Schane, 2002). Ambiguity in contract terms is also one of the top causes of disputes in construction contracts (Arcadis, 2020, Mitkus and Mitkus, 2014). Rameezdeen and Rodrigo (2014) state that a lack of clarity in contract documents can lead to disputes between contracting parties. Mohamad *et al.* (2008) conclude that contract documents should be written in simple language to improve clarity and increase readers' comprehension. Thus, drafting precision and contract clarity are critical to dispute avoidance (Rajoo, 2010) and communication improvement between contracting parties (Mitkus and Mitkus, 2014).

2.2 Standard forms and clarity

The problematic language structure in standard forms of construction contracts adversely affects their clarity (Chong and Zin, 2010). Additionally, various studies revealed that most contracts in the construction industry are written in legal English (Chong and Oon, 2016, Ali and Wilkinson, 2010, Rameezdeen and Rajapakse, 2007, Rameezdeen and Rodrigo, 2013, Chong and Zin, 2010). But what is legal English? Legal English refers to the traditional legal drafting in English language. It is linked to the convoluted drafting style, verbose structure, and viewed as inaccessible to the common people (Burton, 2018, Tanner, 2000, Mellinkoff, 1963, Zhang, 2014, Wydick and Sloan, 2019). The extensive use of legal 'mumbo jumbo' and overly complicated sentences in legal English is also often derogatorily dubbed as 'legalese' (Candlin *et al.*, 2002, Boom *et al.*, 2016). Some key features of legalese include the use of long, wordy and condensed sentences, use of passive voice, the inclusion of nominalisations, and choice of unfamiliar, archaic and Latin words over simpler words (Candlin et al., 2002, Butt, 2002, Wydick and Sloan, 2019).

It is important to note that the primary users of construction contracts are builders, trade specialists, consultants, designers, suppliers, and clients (Ali and Wilkinson, 2010, Rameezdeen and Rodrigo, 2014). These industry practitioners and professionals are not necessarily trained in law (Ali and Wilkinson, 2010). Primary users who are not equipped with the proper skills to read and understand legalese will be affected by the traditional drafting style employed in standard forms. Lack of appropriate skills leads to deprivation of understanding. As reported by Mohamad and Madon (2006) and Mohamad et al. (2008), contractors viewed construction contract documents as incomprehensible due to the inclusion of too many legal phrases. Incomprehension eventually leads to a disparity of contract interpretation. As mentioned earlier, disparity of contract interpretation was observed to cause conflicts in construction contracts (Chong and Zin, 2010, Mitkus and Mitkus, 2014). And conflicts that are not managed clearly would ultimately evolve into disputes (Acharya and Lee, 2006). Therefore, contracts need to be drafted in simple language to be understood by the primary users in the industry, and hopefully, they would be able to reduce disputes.

2.3 Plain language efforts

The antithesis of legalese is plain language. Plain language can be simply defined as clear writing (Butt, 2002, Butt, 2008, Mico, 2013, Painter, 2008). Modern legal drafting is the fruition of plain language movement (Butt and Castle, 2001). Viewed as the cure to legalese, modern legal drafting is used to make contracts clearer so they would become more accessible to the primary users (Chong and Zin, 2010). However, the uptake of plain language in the construction industry is slow (Ali and Wilkinson, 2010). Despite findings by Rameezdeen and Rajapakse (2007), Broome and Hayes (1997) and Wright and Fergusson (2009) confirming practitioners' preference of the new plain-language NEC form, most standard forms of construction contracts continue to employ legal English drafting in their contract clauses.

Contrary to the international scene, the plain English movement gained better acceptance within the New Zealand construction industry. For example, the New Zealand Standard Conditions of Contract for Civil Engineering and Building Work (NZS3910:2003) by Standards New Zealand, and the two contracts published by the New Zealand Institute of Architects – the National Building Contract and the NZIA Standard Conditions of Contract are noted to use simpler language and shorter sentences in their contract clauses (Ali and Wilkinson, 2010, 2019). The latest New Zealand Institute of Quantity Surveying Contract for Quantity Surveying Consultancy Services (NZIQS CQSCS) is also observed to apply numerous plain language techniques in its clauses. In New Zealand, the NZIQS CQSCS is the first and only standard form accredited by an international plain language entity (Plain Language Commission – PLC) to be written in clear English. However, this form has never been objectively tested to confirm its clarity and readability level. Therefore, this study aims to objectively assess the impact of contract drafting styles on the readability of the new contract form. The objective evaluation results on the new contract form will be compared with its predecessor to see the effects of different drafting styles on the readability levels of both contract versions.

3 Research Methodology

The quantitative method was employed to assess the impact of contract drafting style and contract readability in the NZIQS predecessor and successor standard forms. In this study, we refer the NZIQS Long Form Conditions of Engagement or the predecessor version as the 'old form,' while the NZIQS CQSCS or the successor version as the 'new form.' Only contract clauses were selected as the study's unit analysis. Tables, fillable forms and appendices were excluded from this study.

The text difficulty in the new and old form contract clauses was objectively predicted and compared with the use of a traditional readability formula, Flesh Reading Ease Score (FRES). We employed the following objective scales to empirically observe the textual properties in the new and old forms:

1. Average Sentence Length (ASL) index,
2. Average Syllabus per Word (ASW) index, and
3. Flesch Reading Ease Score (FRES) index.

Both ASL and ASW indices are inputs to the FRES formula. Invented and updated by Rudolf Flesch in 1948, FRES is a mathematical readability formula that predicts a text's reading difficulty index (DuBay, 2004). According to Chall (1958) and Klare (1963) in Kouamé (2010), FRES is the most tested and the most reliable formula compared to the other traditional readability formulas. However, FRES is not perfect as it includes limited variables in their calculations such as sentence length, word difficulty and word syllables (Bailin and Grafstein, 2016, Selzer, 1981, Schriver, 2000, Lang, 2004, Waller *et al.*, 2016). Generally, traditional readability formulas are criticised for their inaccurate results, either by overestimating the level of reading difficulty (Klare, 1976) or oversimplifying the reading process (Selzer, 1981). Since most traditional readability formulas have been around for about 80 years, they are seen as outdated, inappropriate and unreliable to predict readability (Hartley, 2016).

Despite these limitations, FRES is still widely used in various studies in the twenty-first century. Many computer programs and several manual aids have been developed to apply FRES formula (Klare, 2013). Studies across various disciplines, such as communication, health, education, and built environment, continue to use FRES to predict text readability. Kouamé (2010) proposed that FRES is most reliable when used with upper elementary materials (ages between 9-11) and secondary materials (ages between 11 to 18). Therefore, the benefits of FRES in terms of reliability, simplicity, and popularity (Rameezdeen and Rajapakse, 2007, Kouamé, 2010, Hayes *et al.*, 1950, Janan and Wray, 2014) justify the use of this formula in our study.

The details of the FRES formula are as follows:

$$\text{FRES} = 206.835 - (1.015 \times \text{ASL}) - (84.6 \times \text{ASW})$$

Where:

$$\text{ASL} = \frac{Number\ of\ words\ in\ a\ clause}{Number\ of\ sentences\ in\ a\ clause}$$

$$\text{ASW} = \frac{Number\ of\ syllables\ in\ a\ clause}{Number\ of\ words\ in\ a\ clause}$$

The reading difficulty of the new and old forms was subsequently categorised based on the Flesch reading ease levels, as shown in **Table I**.

Table I. Summary of ASL, ASW and FRES indices, and their association with reading ease levels. Adapted from (Flesch, 1949), p.149.

Description of style	*Average sentence length (ASL)*	*Average number of syllables per word (ASW)*	*Reading ease score*	*Estimated reading grade*	*Estimated reading group ages*
Very easy	8 or less	1.23 or less	> 90 to 100	5th grade	10 – 11
Easy	11	1.31	> 80 to 90	6th grade	11 – 12
Fairly easy	14	1.39	> 70 to 80	7th grade	12 – 13
Standard	17	1.47	> 60 to 70	8th – 9th grade	13 – 14
Fairly difficult	21	1.55	> 50 to 60	High school	15 – 18
Difficult	25	1.67	> 30 to 50	College	18 – 22
Very difficult	29 or more	1.92	0 to 30	College graduate	22 or older

Finally, we employed inferential statistics to analyse the effects of contract drafting style on contract readability in both new and old forms. Two hypotheses were developed in this analysis:

H_0: Contract drafting style neither increase nor decrease contract readability.

H_1: Contract drafting style either increase or decrease contract readability.

The *t*-test was used to compare groups with the selected continuous values (FRES indices). The *t*-test is suitable for seeing the effect of experimental manipulation between two groups (Hinton *et al.*, 2014). We observed the 'drafting style differences' in both new and old forms as the 'manipulation element' in this study, whilst the two groups compared in the analysis were the readability indices collected from the new and old forms. A *p-value* lower than .05 was accepted as a statistically significant difference.

4 Findings and Discussion

Our observation reveals that the new form contains 7% more contract clauses than the old form. Despite this, the Microsoft Word readability statistics tool results show that the new form clauses have a lower word count, fewer characters, and a lower sentence count than the old form. We also found that the clauses in the new form have more active sentences than the old form. These results indicate the new form as easier to read than the old form.

Table II. Comparison of word count, number of characters, sentences count, Flesch-Kincaid Grade Level and passive sentences in both standard versions.

	New form	***Old form***
Number of clauses	63	59
Word count	1,983	2,393
Number of characters	10,313	12,449
Sentence count	79	84
Passive sentences	21.1%	40.3%

Table III summarises the comparison of ASL and ASW indices between the clauses in the new and old forms. According to Flesch (1981), plain English should have about 20 words per sentence and 1.5 syllables per word. In other words, the lower the ASL and ASW indices of a clause, the easier it is to read it. The results in **Table III** align with the results in **Table II**. The high number of words and sentences in the old form matches the high ASL and ASW indices in the old form. 79% of the clauses in the old form yielded ASL indices more than 20, while 41% of the clauses in the new form yielded ASL indices of 20 or below. More than 50% of the clauses in both the new form and old form have words of more than 1.5 syllables per word.

However, the proportion of ASW index above 1.5 in the old form clauses is higher than clauses in the new form, with a percentage of 93% against 75%.

Table III. Comparison of ASL and ASW indices of the new and old form clauses based on plain English acceptable threshold.

	Index ranges	*Number of clauses (n)*	
		New form	*Old form*
ASL	Index 20 or less	26	14
	Index > 20	37	45
ASW	Index 1.5 or less	16	4
	Index > 1.5	47	55

As stated before, the minimum FRES index for plain English is 60 (Flesch, 1981). Thus, the higher the FRES index of a clause, the easier it is to read it. As shown in **Table IV**, most clauses in both new and old forms are within the 'Very difficult' and 'Difficult' reading level. Only 17% of the new form clauses yielded FRES indices above 60, whilst none of the clauses in the old form yielded a FRES index above 60.

Table IV. Comparison of the new and old form clauses against Flesch's reading difficulty levels.

FRES index range	*Difficulty level*	*Number of clauses (n)*	
		New form	*Old form*
0-30	Very difficult	18	36
> 30-50	Difficult	24	20
> 50-60	Fairly difficult	10	3
> 60-70	Standard	9	-
> 70-80	Fairly easy	-	-
> 80-90	Easy	2	-
> 90-100	Very easy	-	-

The descriptive statistics results generated with IBM SPSS Statistics for Windows, Version 27.0 showed that sentences in the new form are shorter (M = 26.49, SD = 14.00), with a lower average syllables per word (M = 1.64, SD = 0.28). A lower mean FRES index in the old form (M = 25.99, SD = 14.47) suggests lower reading ease in the older version compared to the newer version. An independent sample *t*-test was conducted to compare the effects of drafting styles on contract readability in both new and old forms. To do this accurately, we only analysed FRES indices from all clauses in both new and old forms. FRES index is the primary objective scale for readability prediction under the FRES methodology. On the other hand, ASL and ASW indices are the two variables that function as inputs to the FRES calculation. Therefore, both ASL and ASW were not considered in the study's statistical testing.

Significant findings in the Kolmogorov-Smirnov and Shapiro-Wilk tests ($p > .05$) indicate normal distributions across both samples in this study. Levene's test result ($F = 2.626$, $p > .05$) also confirms that the data collected from both the new form and old form met the assumption of homogeneity of variances. The independent t-test results reveal that there was a significant difference in the new form FRES indices (M = 41.58, SD = 18.71) and the old form FRES indices (M = 25.99, SD = 14.47); t (120) =-5.121, p = .000. Therefore, the results suggest that the contract clause reading ease increases if the contract clause is drafted in style employed in the new form (plain language style).

Table V. Descriptive statistics for FRES, ASL, and ASW indices.

		N	*Mean*	*Standard Deviation*
New form	FRES	63	41.58	18.71
	ASL	63	26.49	14.00
	ASW	63	1.64	0.28
Old form	FRES	59	25.99	14.47
	ASL	59	28.47	13.48
	ASW	59	1.79	0.18

Our results showed that contract drafting style impacts contract readability prediction. This aligns with findings in previous studies (Rameezdeen and Rajapakse, 2007, Rameezdeen and Rodrigo, 2013, Rameezdeen and Rodrigo, 2014). The results revealed that the mean FRES index in the new form is higher than the mean FRES index in the old form (M = 41.58; 25.99). This suggests that the new form is more readable than its predecessor. Yet, this index is still below the minimum limit proposed by Flesch (1981) for plain language. The NZIQS standard form of consultancy contract only improved from 'very difficult' to 'difficult' reading level in the successive version. This result aligns with the findings by Rameezdeen and Rodrigo (2013), where FIDIC was found to include less difficult contract clauses in its successive version.

Our further analysis confirmed that clauses in the new form are written in plain language. The new form strictly adheres to the guide by Kimble (1992) and Garner (2012) and completely avoids the chameleon-hued word *'shall'* in their clauses. Additionally, it shuns the use of *'and/or,'* conta,'s no legal jargon and does not use parenthetical numerals. However, even with plain language drafting, only 11 clauses in the new form are predicted to be accessible to readers ages 14 and younger. 38% of the contract clauses in the new form are in the 'difficult' reading level and only accessible to readers ages 18 to 22.

While the readability testing results predict the new form to be readable at the 'difficult' reading level, this is only true in respect of the textual properties of the contract clauses in the new form. FRES disregards the meaning of the contract clauses. It neglects the impact of text cohesion on reading comprehension. It is a text-focused methodology. But readability is more than just text difficulty. Readability relates to anything that makes texts easier to read (DuBay, 2004, DuBay, 2007). It hinges on an inquiry into the effects of text properties on communication through written texts (Bailin and Grafstein, 2016). A text is readable if it is legible, easy to read, or easy to understand (Klare, 2013). Readability is not limited to sentence complexity and word syllables. Singer and Donlan (1989) in Schriver (1989) assert that readers play an important role in determining the difficulty level of a text. According to them, a text with high-dense ideas may be textually difficult. But readers with prior knowledge on the subject matter, highly proficient in reading ability, and have high motivation to read the text, may find the text easy to read.

It is essential to highlight that the new form had been clarity-checked and awarded the Clear English Standard accreditation by the Plain Language Commission (PLC). The Clear English Standard is only awarded to documents that satisfied PLC's clear English criteria. However, PLC does not disclose the clear English criteria on their website. Instead, PLC highlights that plain language is not absolute and may, in certain circumstances, call for the use of technical language (Plain Language Commission, n.d.). Some texts may be plain and easy to a specific class of people. Therefore, what is readable is relative to the audience of the text. For example, engineers may find the technical language in engineering specifications as 'plain and readable.' L.' people may find those specifications difficult to read. This notion aligns with findings by Singer and Donlan (1989) in Schriver (1989), as discussed above. Various studies also confirmed the correlation between text readability and readers' context. For instance, Bailin and Grafstein (2016) found that readers' contextual background, such as vocabulary knowledge and the knowledge of conventions associated with a specific genre, significantly impact the readability degree of a text. Factors such as readers' interest and age also influence text readability, especially from the perspective of comprehension (Ball and Hourcade, 2011, Meyer *et al.*, 1998).

Taking all these into account, we view that although FRES predicts the new form to be 'difficult' to read based on Flesch's reading level summarised in **Table I**, the new form could still be clear and readable by construction practitioners. However, this view is supported only by literature on the various facets and variables in reading processes. Reading is a complex task (Ball and Hourcade, 2011). It involves a complex interaction among text, task, reader, and reading strategy (Meyer, 2003). Predicting text readability with a readability formula concerns only limited variables in the reading process. We acknowledge that we did not include reader-centric measurements such as cloze, text recall, paraphrasing or multiple-choice questions to measure the readability of contract clauses in both new and old forms. We only analysed the impact of contract drafting style on contract readability using the FRES formula. Thus, our findings on the impact of drafting styles on contract readability are limited only to readability indices based on the calculations of textual properties in the contract clauses.

5 Conclusion

Clear communication should be encouraged in contracts. One way of achieving this is with the use of a less complex drafting style in contracts. Our study found the new and 'plainer' contract form as easier to read than its predecessor. Our findings denote an improvement in contract readability level prediction with the use of plain language drafting. Therefore, construction contract drafters should aim to use simplified language when drafting a contract, so its primary users can read construction contracts better. With improved readability, it is hoped that primary users can increase their common understanding of the meaning of the contract and consequently reduce the number of disputes in the construction industry. This study also provides a limited objective readability prediction on the impact of drafting style on contract readability. For future research, we propose a broader text-analysis continuum to be included in the study on the impact of contract drafting styles on contract readability. Comprehension tests such as expert-judgement-focused and reader-focused measurements may be considered in future studies to provide a subjective evaluation of the text.

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Drivers for Implementing Effective Waste Trading Practices in the Construction Industry

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Abstract
Conserving natural resources and reducing the pressure on the environment has become high in the agenda of sustainability. Though construction and demolition (C&D) waste have a high potential to yield a substantial amount of valuable resources into the economy, resource recovery from the C&D sector has not reached its maximum level yet. Waste trading (WT) has been recognised as a sustainable strategy to improve the exploitation and efficiency of resources through the circulation of waste materials and thus diverting the waste from landfills. The effectiveness of WT is influenced by several aspects related to waste management (WM). Nevertheless, the wider application of this approach has gained less attention among researchers and WM practitioners in the C&D sector. This study identified 34 drivers from six major perspectives through an expert forum followed by a validation process. From an aggregate perspective, technical drivers have been ranked as the most significant drivers followed by the institutional/organisational, legal/political, socio-cultural and economic drivers. The identification of the drivers can assist in determining which aspects need to be considered in stimulating and advancing the C&D WT practices and driving a shift towards the circular economy. The results of this study also provide a better understanding of the collective efforts required to enhance the effectiveness of WT practices and a basis for future research in assessing the efficiency of WT practices in the C&D sector. The findings are useful to WM businesses in enhancing existing market conditions and establishing new circular business models and to government/regulatory bodies to develop specific policies/legislation and strategies required to promote sustainable construction through trading strategies in the C&D sector.

Keywords
Construction and demolition waste, Drivers, Waste management, Waste trading

1 Introduction

The construction industry is increasingly concerned with improving its environmental performance and reducing environmental degradation, which often results from carbon emission and high volume of waste generated from new construction, renovation or refurbishment and demolition activities including site clearance and excavation associated with these activities as well as from natural disasters. The consumption of natural resources by the construction industry continues to rise more likely in the range of 50–75% compared to the increase in overall resource consumption (Schandl and Krausmann, 2017). The depletion in natural resources, increased global warming and pollution are stimulating the construction industry stakeholders to pay more attention to the issues related to environmental, economic and social sustainability (Park and Tucker, 2017). The future reputation of the industry, therefore, depends on how the industry is being accountable for minimising waste and thus, waste footprint through the careful use of finite resources and their conservation.

The construction industry in Australia contributes to around 27 Mt (44% of the total) of construction and demolition (C&D) waste out of total core waste streams across all industries. During the last 13 years (2006-2019), waste generation by the C&D waste stream has been raised by 32% per capita, showing a different trend in waste generation compared with the other core waste streams: Municipal Solid Waste (MSW) and Commercial & Industrial (C&I). Most of the growth in waste in the past years resulted from the unprecedented levels of development associated with urbanisation and industrialisation due to rapid population growth, predominantly in the major cities of Australia (Pickin et al., 2020). Consequently, management of C&D waste has become a challenging task for both industry and government, from the perspective of engineering, technology, management, policies, and legislation. Whereas waste management (WM) is considered as an inter-disciplinary theme that is escalating the connection with economic, environmental, institutional, social, and political aspects (Arshad et al., 2017, Jin et al., 2019). The major goals of WM, therefore, should focus on waste avoidance and minimisation through recycling/reusing, waste to energy options and safe disposal of residual waste, which is the least preferred final option (Marchettini et al., 2007), while simultaneously promoting the institutional, economic, environmental and social performance of C&D WM at project, industry and national levels (Yuan, 2013).

Though the C&D sector in Australia has great potential in averting the waste materials from landfills, the recovery rate is still at 77% which is less than the target rate, ranging in between 75- 90% across the jurisdictions (Pickin et al., 2020). With a target to optimise each state's potential to utilise the waste at its maximum level, Australian state and territory governments continue to encourage best WM and resource recovery practices in the C&D sector based on the strategies stipulated in the waste hierarchy (Waste Authority, 2013). The key three '3Rs'(Reduction, Re-use and Recycling) strategies are being promoted in WM practices as they offer benefits through conserving natural resources, minimizing the burden of C&D waste reaching landfill (Suthar et al., 2016) and creating economic benefits (Lockrey et al., 2016, Jin et al., 2017). Lu et al. (2020), perceive waste trading (WT) as an innovative approach to achieve cleaner production and sustainability through diverting the waste from landfills by the means of reuse or recycling of waste materials in the construction industry. WT is a well-recognised methodology that increases resource efficiency and minimises the environmental impact associated with the waste streams arising from major industrial and consumer activities while contributing to economic benefits (Corder et al., 2014). Having reviewed the barriers for reuse of waste, Park and Tucker (2017) emphasised the need for a strategy to escalate the effectiveness of reusable and recycled materials which can replace the raw materials used in new construction and renovation activities. WT can be advocated as a strategic solution to construction waste which includes both raw inert construction waste and recycled products made from construction and demolition waste (Lu et al., 2020). However, the notion of WT has not much been assessed and little attention has been paid to waste diversion through WT practices in the C&D waste sector in Australia. Despite the barriers for WT have been recognized, in the long run, it is important to identify the factors, which drive the WT practices in order to boost and expand the WT in the C&D sector.

This study, therefore, is an attempt to address this research gap and aims to identify the potential drivers for implementing effective WT practices from different perspectives in the context of the construction industry in New South Wales (NSW), which is the highest generator of C&D

waste among other jurisdictions. This study is intended to be accomplished by exploring WT as a sustainable waste minimisation approach through the maximum diversion from landfills and saving transport and disposal costs. The comprehensive literature review assisted to identify the existing drivers to WM and their related perspectives and the research gaps in the area of WT. The expert forum and validation process ensures the validity of the outcome and provides more insight to the drivers to WT in the context of the C&D sector.

2 Waste Trading as a Sustainable Approach

According to the Oxford learner's dictionary, trading is defined as '*the activity of buying and selling or of exchanging (one thing) for another, goods or services between people, firms or countries*'. The Environment Protection and Heritage Council (2010) define waste as "*any discarded, rejected, unwanted, surplus or abandoned matter which is intended for recycling, reprocessing, recovery, reuse, or purification by a separate operation from that which produced the matter, or for sale, whether of any value or not*". At the same time, determining material whether it is 'waste', a 'product' or a 'resource' is substantially influenced by some key factors such as regulations, environment, and economy which are essential for managing the waste efficiently from the generation phase to final destination (Hyder, 2012). The C&D waste has been recognised as a potential resource to include a diverse range of high-value materials and resources, which can be used for new construction and renovation once sophistically sorted (Edge Environment, 2012). This study attempts to develop a definition for WT in the context of the C&D sector as follows. "WT is a process of buying and selling (or exchanging) reusable raw inert construction waste, recycled materials, products that contain recycled contents and energy recovered from C&D waste and/or services between people, organizations, interstates, or countries.

The circular economy recognises the closed-loop material cycle concept in which the waste is transformed into a resource for sustainable use and kept within the economy by productively circulating materials by repeated usage (Smol et al., 2015). Through this concept, the maximum economic value of the material is preserved by circulation within the economy through the process of reusing (or re-purposing), recycling, repairing, remanufacturing and remarketing. The circulation process enables to change the linear economy models to substitute 'throwing' waste with 'making use' of waste and bring similar or diverse industries to collaborate through exchanging of resources and sharing WM infrastructure, resulting in reducing disposable waste and lower production cost (Wu et al., 2019). WT, therefore, turns into a promising sustainable solution as it enables the efficient use of waste materials through the 3R principles of the circular economy while contributing to economic growth and complying with relevant waste regulations/legislation (Ratnasabapathy et al., 2021). According to Lu et al. (2020), the major goal of WT in the construction industry is to manage the C&D waste by balancing the demand and supply of waste materials and succeed with a win-win solution for both sides; waste suppliers (generators, recyclers) and consumers. Trading C&D waste between construction sites, to be specific, transporting waste directly from a project's site where it is generated and/or temporarily stockpiled to another site where that waste is required to be consumed is an ideal means of cost-saving for waste generators as it reduces the disposal cost.

Intrinsically, the integration of the WT process into an integrated WM system would be highly effective in the perspective of a circular economy and enable the construction industry to transition to the circular economy through innovative collaborations. Being an alternative process to landfill disposal, WT promotes sustainability through resource efficiency, minimising environmental impact by stimulating innovations in the reuse of waste materials while supporting economic success. This concept is aligned with the theme of industrial symbiosis (IS) that recognises waste as the transformation of resources while the traditional WM system treats waste as an 'end-of-life' product (Zaman, 2013). The WT approach in an integrated WM system provides waste an opportunity for a second life with multiple uses. Simultaneously, the concept of the closed-loop material cycle combines the goal of zero waste through exchange/trading is connected to the principles of IS.

Despite most of the previous studies have focused on the barriers to WM, some research studies have examined the key indicators and enablers for the effectiveness of C&D WM. Ajayi et al. (2015), suggested some key factors as requisites to reduce waste intensiveness of the C&D industry which include tackling waste at the design stage, whole life waste consideration, compliance of WM solutions with Building Information Modelling (BIM), cheaper cost of WM practice, increased stringency of WM legislation and fiscal policies, and research and enlightenment. Yuan (2013) identified the key performance indicators related to the four major aspects which include waste generation, economy, environment, and society that affect the effectiveness of WM. Abarca-Guerrero et al. (2017) observed the motivations for more efficient and effective use of materials in the construction sector. Similarly, Caldera et al. (2020) identified the enablers for effective WM and the establishment of marketplaces for C&D waste in terms of market, operational, and governance-related factors.

Though the trading of reusable/recyclable waste is relatively not a new approach in the industrial WM system, limited studies have been focused on managing waste through WT approaches in the C&D sector (Caldera et al., 2020, Lu et al., 2020, Bao et al., 2020). The previous studies discussed the drivers to WM and few on market development for waste but overlooked the drivers of WT practices in terms of different aspects of WM in particular. Hence, this study aims to explore the potential drivers to WT in the context of the C&D sector of Australia. This study can be taken as an example to draw insight into the potential drivers for the wider application of the WT approach in the C&D industry and hence an attempt to accelerate the industry moving towards the circular economy in C&D WM.

3 Research Methodology

This study primarily adopts a quantitative method approach combining a questionnaire survey conducted during an expert forum and a validation process by industry experts to ensure the reliability and validity of the drivers. Initially, a comprehensive literature review has been carried out to identify the drivers to the reuse/recycling of C&D waste, as well as the drivers for implementing effective WM practices and creating marketplaces in the C&D sector. Subsequently, a questionnaire that was used to collect the data from an expert forum, was distributed to experts who attended an industry-academic forum to evaluate and rate the importance of each driver through the questionnaire survey. The evaluated and newly identified drivers from the expert forum went through a validation process for ranking the drivers again by six industry experts to provide more insight into the findings. Table 1 shows the profile of the respondents involved in the expert forum and the validation of drivers derived from the expert forum.

This study adapted the six aspects of the PESTEL (Political, Economic, Social, Technical, Environmental, and Legal) model as the initial coding categories to classify the drivers. The drivers identified from the literature have been categorised under six main perspectives: Economic, Environmental, Institutional/Organisational, Socio-Cultural, Legal/Political, and Technical. Since C&D waste management is recognised as an inter-disciplinary theme, involving different aspects and issues such as engineering, technology, management, policies, and legislation (Jin et al., 2017, Arshad et al., 2017, John and Itodo, 2013), this study includes the “Institutional/Organisational” category as an additional category that is considered as essential in recognizing the drivers. Moreover, this study has combined political and legal aspects as one category as “Legal/Political” analysing the drivers, for the reason that most of the drivers are comparatively similar general common in both categories.

Table 1. Profile of the respondents involved in the expert forum and validation process

Respondents	Experience (Years)			Total Number
	5-10	10-20	over 20	
Questionnaire Survey				
Contractors/Developers	2	9	2	13
Consultants		2	2	4
Clients/Architects		1	1	2
Manufacturers/Suppliers	1	1		2
Academics	6	3	5	14
Total				**35**
Validation Survey				
Project Manager (Residential & Commercial Development)		1		1
Sustainability and Research Managers (Land and Property Development)	1	1		2
Head of Sustainability Management (Waste Management Service)			1	1
Operation Manager (Waste Collection and Management Service)		1		1
Sales Manager (Waste Recycling Service)		1		1
Total				**6**

Preceding data collection, the survey instrument that involves a questionnaire had been pre-tested for ease of understanding and content validity. Five academics who have expertise in waste management and sustainable construction-related research with a minimum of 5 years of involvement in the industry have been asked to evaluate the questionnaire for clarity and relevance of the drivers to each category suggested. Based on the feedback received from the academics, the questionnaire has been improved to attain content validity and clarity. After the questionnaire was pre-tested, the questionnaire has been circulated among a group of experts who have participated in an expert forum conducted at an industry-academic roundtable. The roundtable event has attracted over 40 experts comprising contractors, consultants, architects, clients, manufacturers/suppliers, and academics. This study has used a purposive sampling method by targeting professionals in the forum based on their experience and knowledge in the field of managing construction projects. Out of the total number of distributed questionnaires, 35 responses have been considered for the analysis as 5 responses were incomplete. All the academics who have participated in the expert forum possess relevant experience in academia and industry in the construction management discipline. The inclusion of academic perspectives is appropriate to enrich the result of this study as WT is still not commonly practised in the industry. Industry-academic participation is essential particularly in cultivating the need for sustainable building construction through research and transferring knowledge to the industry.

The participants have been given a questionnaire which comprises two sections: Section 1 - the respondent's information and Section 2 – the set of drivers integrated with a five-point Likert scale rating. The collected data have been analysed through descriptive analysis which includes the mean value, Relative Importance Index (RII) and grand mean value to determine the significance of each driver, individual ranking and category ranking respectively. The RII is computed based on the following equation;

$$Relative\ Importance\ Index\ (RII) = \frac{\sum W}{AN} = \frac{5n_5+4n_4+3n_3+2n_2+1_{n1}}{5(n_1+n_2+n_3+n_4+n_5)} \quad (1)$$

where W is the weighting given to each driver by the respondents, ranging from 1 to 5, A is the highest weight (5 is the highest weight in this study) and N is the total number of respondents, while n_1, n_2, n_3, n_4, and n_5 are the numbers of respondents who have scored "1" representing Not important at all, "2" representing Less important, "3" representing Neutral, "4" representing Important, and "5" representing Most important. The Analysis of Variance (ANOVA) has been carried out to test if there is a difference in the responses between two groups of participants: academics and industry experts. Cronbach's alpha has also been conducted to test the reliability of the measurement instrument.

4 Findings and Discussion

This study established a wide range of drivers based on the statistical analysis of responses from the experts through which each driver was evaluated and ranked under six main perspectives: (1) Economic; (2) Environmental; (3) Intuitional/Organisational; (4) Socio-cultural; (5) Legal/Political; and (6) Technical. The result of Cronbach's alpha value for all 34 drivers is 0.94 (the minimum value required is 0.75), which confirms the internal reliability of the drivers included in each category in the survey instrument. The ANOVA test has been performed to ascertain the level of agreement on the importance of the identified drivers based on the two groups of participants. The null hypothesis is that both groups are almost in general agreement in their opinions on ranking the importance of drivers. The results of the ANOVA test indicate that there has been no statistically significant difference of the opinions among these two groups as the probability value (p-value) is not less than 0.05 for any situation.

Table 2 shows the identified drivers and their rate of importance based on the mean value of RII. The mean value of drivers from each category is computed individually and used to rank the drivers and the grand mean value is calculated to rank drivers collectively. From a collective perspective, technical drivers obtain the highest grand mean of 4.05 and become the significantly important category among others. The institutional/organisational and legal/political drivers receive the next level of importance with mean values of 4.01 and 4.00 respectively, showing the considerable influence in improving the efficiency of WT practices. Socio-cultural drivers rank 4th followed by economic drivers. The environmental drivers show less influence among all other categories. The following sections elaborate on the implications of all the identified drivers supported with literature under respected categories.

Table 2. Drivers for implementing effective waste trading practices in the C&D sector

Category	Drivers	RII	Mean	Collective Ranking	ANOVA	
					F	p-Value
Economic	Raising levies/taxes for landfilling virgin and recyclable materials and illegal dumping	0.806	4.03	13	0.94	0.34
	Awareness of cost reduction through reduction of material loss and savings of raw materials	0.783	3.91	21	0.63	0.43
	Awareness of cost savings on energy through reuse of waste (electricity, fossil fuels)	0.720	3.60	33	0.05	0.82
	Financial incentives to increase the reuse of materials for new construction or renovation with lower embodied energy	0.806	4.03	16	4.07	0.05
	Awareness of economic benefits through reuse/recycling, exchange/trading, reduction in the cost of transport and landfill disposal	0.846	4.23	5	0.74	0.39
	Availability of markets for different type of recycled products	0.794	3.97	17	1.01	0.32
	Diminishing of legal costs associated with the environmental problems and insurance schemes (fines, compensation)	0.737	3.69	30	0.21	0.65
Grand Mean for Economic Drivers = 3.92						
Environmental	Improving clients' and stakeholders' awareness of the adverse impact of waste on the environment	0.731	3.66	32	0.01	0.93
	Promoting eco-design (consideration for the environmental impacts)	0.737	3.69	30	0.06	0.82
	Promoting green public procurement	0.743	3.71	28	0.17	0.68
Grand Mean for Environmental Drivers = 3.69						
Institutional / Organisational	Improving on-site and off-site waste management facilities including on-site sorting	0.840	4.20	8	1.36	0.25
	Initiating waste minimisation and diversion through trading/exchange strategies from project level	0.789	3.94	20	0.50	0.48
	Improving communication and collaboration between stakeholders to coordinate material reuse	0.863	4.31	2	0.09	0.76
	Improving waste management culture within the organisation	0..851	4.26	4	1.03	0.32
	Improving sector-wide education, training and professional development programmes on waste management	0.771	3.86	25	0.13	0.72

	Following the competitors' strategy in managing waste and promoting competition/market share	0.646	3.23	34	2.02	0.16
	Aligning stakeholders' perspectives on C&D waste management	0.857	4.29	3	2.08	0.16
Grand Mean for Institutional/Organisational Drivers = 4.01						
Socio-Cultural	Increasing research on the applications of recycled waste	0.783	3.91	21	0.01	0.93
	Increasing clients' awareness of the short and long term benefits of reusing materials for sustainable buildings	0.794	3.97	17	0.94	0.34
	Raising awareness of the benefits of managing waste through trading practices at the project, organisation and industry level	0.811	4.06	10	0.01	0.94
	Improving clients' demand for sustainable buildings	0.806	4.03	13	1.14	0.29
	Change of attitudes of stakeholders towards proactive strategies for waste minimisation	0.771	3.86	25	0.24	0.63
Grand Mean for Socio-Cultural Drivers = 3.97						
Legal / Political	Enforcement of C&D waste specific legislation instruments/policies to promote circularity of waste materials	0.863	4.31	1	0.07	0.80
	Imposing green star credit mandatory for construction waste by legislation	0.783	3.91	21	0.17	0.68
	Involvement of authorities to simplify the certification processes for the use of recovered materials	0.806	4.03	13	0.20	0.66
	Making quality waste data and reporting mandatory	0.811	4.06	10	0.70	0.41
	Making effective waste management a criterion for prequalifying the contractors in projects	0.760	3.80	27	2.26	0.14
	Consistent levies/taxes for landfilling and illegal dumping across the states	0.777	3.89	24	0.03	0.87
Grand Mean for Legal/ Political Drivers = 4.00						
Technical	Improving the quality of reliable waste data and reporting	0.811	4.06	10	0.36	0.55
	Availability of user-friendly trading platforms with easy access and high operational efficiency	0.846	4.23	5	1.40	0.25
	Involvement of suppliers to assist with material/product specifications (the circularity of waste material/products specification among stakeholders)	0.743	3.71	28	0.01	0.94
	Specific guidelines, specifications and a clear definition of process standards for the use of recycled materials	0.846	4.23	5	2.59	0.12
	Use of advanced technologies in recycling and management of waste	0.794	3.97	17	2.61	0.12

	Engaging trained workforce for on-site/off-site waste sorting and handling	0.817	4.09	9	0.02	0.89
Grand Mean for Technical Drivers = 4.05						

4.1 Technical Drivers

This study has found that the technical drivers are imperative to the implementation of effective WT practices in the C&D sector. Technical drivers are mostly related to the quality of waste and recycled material related information, experience, skills, education & training required, and integration of advanced technologies in recycling and reporting of waste data & marketing waste materials. Availability of user-friendly & reliable trading platforms with easy access and high operational efficiency was found to be the important driver among others. Corder et al. (2014), claimed that the current and future success of the waste exchange networks, which are fully focused on providing online information support depends on the adequate financial and resource capacity, along with the appropriate technical expertise and knowledge. Lu et al. (2020) recognised that the availability of reliable information on demand and supply of waste is crucial to the success of any transaction in WT. Caldera et al. (2020) acknowledged that technology-based online WT platforms would improve accessibility and user-friendliness of sellers and buyers while Lu et al. (2020) perceived that the construction WT sector shows a preference for a decentralised market as C&D waste is generated from (construction sites) and processed at (processing facilities) many discrete locations spread across the jurisdictions. Blockchain as a decentralised transaction and data management technology is emerging as a targeted invention to create decentralised online trading platforms for C&D waste with improved reliability and traceability of waste information and transparency in the transaction by enabling the sellers and buyers to connect without a trusted intermediary (Ratnasabapathy et al., 2019). Blockchain-based trading platforms can facilitate the matching of waste material information on demand and supply and traceability of such information and hence improve operational efficiency in the transaction and help to overcome the WT related institutional and technical barriers (Ratnasabapathy et al., 2021).

Specific guidelines, specifications and a clear definition of process standards for the use of recycled material, engaging a trained workforce for on-site/off-site waste sorting and handling and improved quality of reliable waste data and reporting have been identified as the major drivers in this study. Consistent terminology, process standards and specification for recycled materials across the jurisdictions would facilitate recycling facility operators to improve the recycling through wider application of their experience and encourage the broader application of recycled products. Furthermore, the establishment of national standards for the production and use of recycled products would significantly encourage the use of such products in projects which are partially funded by the government at the federal level (Hyder Consulting and Encycle Consulting & Sustainable Resource Solutions, 2011). One of the industry experts further identified that enabling the product specification of recycled products at the design stage will promote engineers to include such products in design. The designers need to understand the prerequisite resource management and set the targets with a level of comfort for products/materials that contain recycled contents.

4.2 Institutional/Organisational Drivers

The institutional drivers are associated with the strategies followed in WM, managerial commitment to WM, communication among stakeholders, level of education and training of staff, and WM culture within the organisation. From the collective perspective, improving communication and collaboration between stakeholders to coordinate material reuse obtained the highest ranking among other drivers (mean = 4.31, RII= 0.863). The forward-thinking of circular economy initiatives, such as effective collaboration and communication between key industry stakeholders can bring different stakeholders to the same region so they may exchange resources, share infrastructures, develop new materials, products, and services out of construction waste that was previously considered as the end of life products, and reduce cost of transport, disposal and new materials production. The project manager, who is one of the participants of the validation process, indicated that trading of waste materials such as virgin excavated natural materials (VENM), excavated natural materials (ENM) transported directly from one construction site to another could save around 70-80% of the cost, which is otherwise to be paid to a waste removal contractor since such trading involves only the cost of testing and transporting of materials to another site. Aligning stakeholders' perspectives on C&D waste management and improving WM culture within the organisation received 3rd and 4th ranking respectively. The findings of some past studies also revealed that considering attitudes and insights of major stakeholders involved in WM and WM culture within the organisation, which are related to stakeholders' awareness of resource-saving and environment protection through waste minimisation, are significantly important for finding solutions for effective WM (Yuan and Shen, 2011, Yuan, 2013).

4.3 Legal/Political Drivers

Legislative and policy instruments have been the key drivers for minimising waste through diverting waste from landfills in several countries. Enforcement of C&D waste specific legislation instruments/policies to promote the internal circulation of waste materials received the highest rank (mean = 4.31, RII= 0.863) collectively equivalent to an institutional driver as stated in the previous section. Further, making quality waste data and reporting mandatory across the states and the involvement of authorities to simplify the certification processes for the use of recovered materials have been identified as other key drivers from this study. According to Ratnasabapathy et al. (2021), the opposition of local councils or regulatory authorities in accepting different disposal methods of C&D waste requires changes from legal perspectives to divert more waste from landfills and enforcement of feasible legislation would also drive the trading/sharing of reusable waste materials among construction waste generators. The sustainability management experts during the validation process emphasised that legislating the recycling process to mandatory and enabling rating tools to score recycled content along with the embodied carbon of recycled products would drive recycling and extended producer responsibility (EPR) schemes driven legal instruments for C&D waste would incentivise the secondary sourced materials market.

4.4 Socio-Cultural Drivers

The overall analysis of RII revealed that raising awareness of managing waste through trading practices at the project, organisation and industry level is the key driver which received 10th rank from a socio-cultural perspective. The project's stakeholders' awareness of WM is generally reflected in their attitudes and behaviour toward waste management (Yuan, 2013). Improved awareness and change of attitudes from designers and other major stakeholders towards proactive strategies for waste minimisation have been highlighted by previous studies (Park and Tucker, 2017). Similarly, improving clients' demand for sustainable buildings followed by increasing clients' awareness of the short and long term benefits of reusing materials for sustainable buildings are the other triggers for improving WT practices and these factors have been highlighted as the motivations for implementing waste reduction by past studies (Abarca-Guerrero et al., 2017).

4.5 Economic Drivers

Economic drivers are mostly associated with the cost involved in each WM process, revenue from waste, landfill levies and penalties, current positions of secondary material markets and incentives for recycling and market development (Yuan et al., 2011, Yuan, 2013). Awareness of economic benefits through reuse/recycling, exchange/trading, reduction in the cost of transport and landfill disposal have been ranked 5th collectively. Integrating the WT practices into C&D WM could contribute towards creating new job opportunities by building more circular business models. Raising levies/taxes for landfilling virgin and recyclable materials and illegal dumping and incentives to increase the use of recovered materials with lower embodied energy have been identified as the major drivers of this study. Further, increasing economic incentives to the C&D recycling sector participants, including transporters as well as reprocessors who hold a licence from relevant authorities would improve resource recovery (Hyder Consulting and Encycle Consulting & Sustainable Resource Solutions, 2011). Incentives such as tax reduction by the government would promote construction organisations to reuse waste materials in new construction and renovation projects (Lu et al., 2020).

4.6 Environmental Drivers

Comparatively, environmental-related factors are not much influencing in promoting waste trading activities as those drivers have not been ranked high among others. However, promoting green public procurement (GPP) gains priority among others. Through the GPP, government authorities, being as a client for public projects, can contribute to sustainable consumption and production through the procurement of products containing recycled materials and services which meet defined performance criteria/specifications with less impact on the environment and inclusion of environmental criteria in green supplier selection (Zhu et al., 2013). Involvement of government agencies in the wider application of sustainable procurement practices through the development of specifications, accreditation, quality assurance and raising awareness of implications (financial, social, ethical and environmental) of the recycled materials and services would be beneficial to enhance the market demand for recovered C&D materials (Hyder Consulting and Encycle Consulting & Sustainable Resource Solutions, 2011). Promoting eco-design, through improving clients' and stakeholders' awareness of the impact of waste on the environment has also been identified as the driver. Yuan (2013), recognized that promoting stakeholders' awareness is an important factor in WM which will, in turn, help to raise public awareness of protecting natural resources and minimising C&D waste. Waste generators can also shrink their waste footprint when they raise their awareness of environmental impact through ethical and legal waste disposal behaviour which is essential for sustainable green construction.

In summary, the overall evaluation of drivers from a collective perspective revealed that drivers related to technical aspects are the most significant among others. Out of these first six key drivers, two are from the institutional/organisational category, one is from the legal/political category, two are from the technical category and one is from the economic category. These results indicate that the effectiveness of WT practices is mostly driven by the above four categories in the Australian context. However, the grand mean analysis of validated drivers by industry experts has confirmed the significance of the institutional/organisational drivers followed by technical, legal/political and economic WT. Collaborative efforts are therefore essential to encourage the stakeholders to promote WT practices and help the industry to expand the circular flow of C&D waste and accelerate the construction industry to move towards the circular economy in C&D WM.

5 Conclusion

This study has determined a wide range of drivers for implementing effective WT in the context of the Australian C&D sector. From an aggregate perspective, evaluation of overall drivers has revealed that the technical drivers significantly promote the wider application of WT practices among other categories and this is followed by the institutional/organisational drivers, legal/political, socio-cultural drivers and economic drivers. In terms of individual drivers, the key drivers identified from this study include the following; (1) enforcement of C&D waste specific legislation instruments/policies to promote circularity of waste materials, (2) improving communication and collaboration between stakeholders to coordinate material reuse, (3) aligning stakeholders' perspectives on C&D waste management, (4) improving waste management culture within the organisation, (5) availability of user-friendly trading platforms with easy access and high operational efficiency and (6) specific guidelines, specifications and a clear definition of measurable standards for the use of recycled materials. The evaluation of the drivers assists in determining which aspects need to be highly considered in promoting effective WT practices for the C&D waste stream. It also deepens the understanding of collective efforts required to enhance the effectiveness of WT practices and provides a base for future research in assessing the effectiveness of WT practices in C&D WM.

This data collection for this study has been conducted in NSW which is one of the limitations of this study in terms of the type and size of the sample used to collect the data. However, the findings from this study can be generalised to other states as the drivers for WT have been systematically grouped under six major perspectives which are imperative to promote effective management practices in integrated WM systems. The findings are useful to other states to promote and widen the application of WT in the C&D sector. However, since there is an inconsistency in policies and legislation, findings from the legal/political perspectives may not be generalised. Further research is therefore encouraged to evaluate and validate the potential drivers in other jurisdictions, which will, in turn, contribute to creating a framework of common drivers for WT in the construction industry of Australia. The findings are helpful to WM businesses in enhancing existing market conditions and establishing new circular business models and to government/regulatory bodies to develop policies/legislation and strategies required to promote sustainable construction through trading strategies in the C&D sector.

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SWOT Analysis for Blockchain-based Embodied Carbon (BEC) Estimator

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Abstract
Blockchain has received widespread attention among industry, government and academia. Blockchain technology was initially used for storing and validating cryptocurrency transactions; however, it could be used in other applications in various industries to resolve issues related to transparency, security, trust and so forth. This study developed Blockchain-based Embodied Carbon (BEC) Estimator, a blockchain prototype system, to estimate Embodied Carbon (EC) in construction supply chains. BEC Estimator has incorporated a Supply Chain based Embodied carbon Estimating Method (SCEEM), which uses first principles based value addition method to estimate EC accurately. SCEEM estimates EC accurately and consistently compared to existing EC databases and tools. BEC Estimator was validated through an expert forum. The paper aimed at developing a SWOT analysis for the BEC Estimator, which was achieved through the findings of the expert forum. The identified strengths and opportunities of BEC Estimator could mitigate the weaknesses and threats of BEC Estimator respectively. BEC Estimator is useful for stakeholders in EC estimating, selecting low EC emitting products and decision making.

Keywords
Blockchain-based Embodied Carbon (BEC) Estimator, Blockchain, Embodied Carbon Estimating, Supply Chain based Embodied carbon Estimating Method (SCEEM), SWOT analysis.

1 Introduction

The rapid development in blockchain has grasped the attention of industry, government and academia. Blockchain has a distributed ledger technology that relies on a consensus algorithm to ensure agreement on data and store them among distributed nodes (Ferdous et al. 2021). A combination of peer-to-peer protocols, hashing algorithms, cryptographic primitives and consensus algorithms are used in blockchain technology (Hamida et al. 2017; Perera et al. 2020). Satoshi Nakamoto introduced Bitcoin, the first peer-to-peer electronic cash system that stores cryptocurrency transactions (Nakamoto 2008). Due to blockchain's salient features such as decentralisation, immutability, security, transparency, trust among others, many industries such as art, health, science and so forth have identified its potential to be used in various applications to resolve issues (Perera et al. 2020). Similarly, blockchain has the potential to be used for Embodied Carbon (EC) estimating (Rodrigo et al. 2020).

Carbon estimating has been identified as an important aspect as construction-related activities contribute to climate change and global warming immensely (Baldasano & Reguart 2014). Intergovernmental Panel on Climate Change (2001); Nässén et al. (2007) found that in the industrialised countries, the building sector solely accounts for 40% of primary energy use and 36% of the energy-related carbon emissions. Passive houses and zero-carbon buildings focus on reducing operational carbon emissions (Fu et al. 2014; Su et al. 2020), which result in increased EC. Hence, there is a necessity to reduce EC emissions, for which an accurate EC estimating method is needed. There are inaccuracies in the EC estimates prepared using existing databases and tools due to various reasons such as differences in system boundaries, differences in geographical locations, unavailability of standard calculation method and so forth (De Wolf et al. 2016; Victoria et al. 2015). Rodrigo et al. (2019) introduced a Supply Chain based Embodied carbon Estimating Method (SCEEM) that incorporated first principle based value addition method to estimate EC accurately. Blockchain-based Embodied Carbon (BEC) Estimator, a blockchain prototype system, was developed by incorporating SCEEM to accurately estimate EC in construction supply chains. BEC Estimator was validated through an expert forum and its results are presented in this paper. This paper aims to develop a SWOT analysis for the blockchain prototype system, BEC estimator, which covers the final outcomes of a research project. Section 2 presents the research methodology adopted in the study and Section 3 analyses the key findings of the study while presenting the SWOT analysis of BEC Estimator. The conclusion of the study is discussed in Section 4.

2 Research Methodology

BEC Estimator was presented to domain experts in the expert forum and collected data to identify the strengths, weaknesses, opportunities and threats of BEC Estimator to develop the SWOT analysis illustrated in Figure 2. Semi-structured interviews were conducted with 7 domain experts who were selected using purposive sampling. The sample size is often justified based on interviewing participants until data saturation is achieved. The selection criteria of participants for the expert forum comprised domain-specific knowledge, experience in EC assessment and construction supply chains, and more than 10 years of experience in the construction industry. The details of the domain experts who participated in the expert forum are presented in Table 1.

Table 1. Details of participants involved in the expert forum

Expert Code	Designation	Organisation	Experience in Construction	
			Years	Expertise Area
I1	National Sustainability Manager	Builder	15	Construction Management, Sustainability, LEED and Green Star Accredited Professional
I2	General Manager	Developer	15	Property Economics, Sustainability
I3	Sustainability and Research Manager	Developer	11	Mechanical Engineering, Sustainability
I4	Manager Sustainability Transformation	Builder	20	Applied Science and Environmental Management, LCA and EC Assessment
I5	Director	Design and Builder	31	Construction Management, Building Information Modelling, Licensed Builder
I6	Director	LCA Consultant	24	Environment Engineer, LCA and EC Assessment, LCA and EPD Verification
I7	Innovation Technical Manager	Manufacturer	20	Sustainability, EC Assessment, Green Star Accredited Professional

Figure 1 illustrates the process followed to develop the SWOT analysis. After conducting the interviews, verbatim transcripts were prepared, followed by preparing the interpreted transcripts in three steps. These were analysed in detail to develop the SWOT analysis.

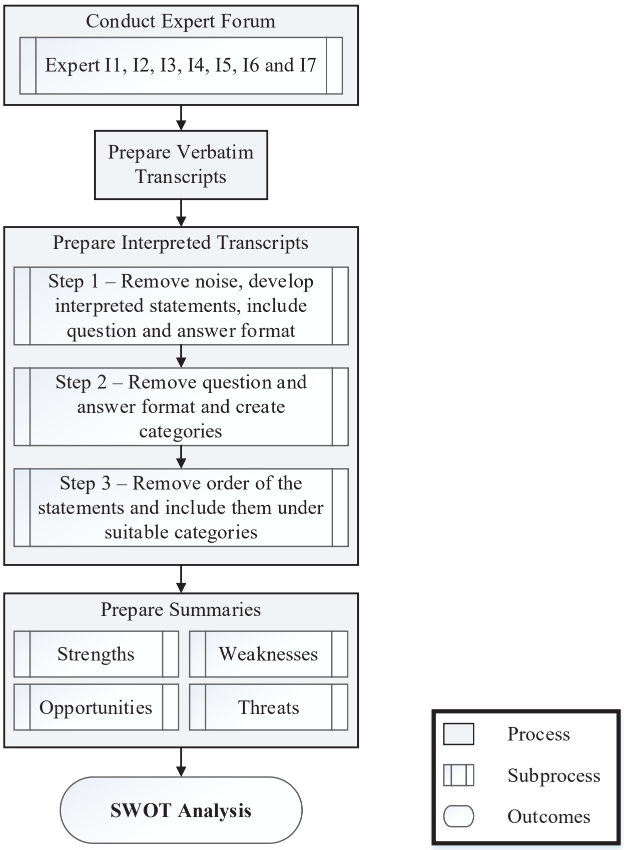

Figure 1. Process for data collection and analysis of findings of the expert forum

In SWOT, strengths are capabilities that assist a unit in performing well; weaknesses are attributes that prohibit the unit from performing well; opportunities are trends, forces, events, and ideas that the unit could capitalise on; and threats are possible events or forces outside of your control that the unit needs to know how to mitigate (Pahl & Richter 2007). SWOT had been used by several practitioners and academics as a tool for strategic analysis (Helms & Nixon 2010). Ahmed et al. (2006) used SWOT analysis to study Air China, the largest air carrier in China, to evaluate the recent total quality management implementation. Sasankar and Chavan (2011) used SWOT to analyse the software development lifecycle models, waterfall model, V model, rapid prototyping model, incremental model, spiral model, among others. Similarly, SWOT analysis was used in this study to evaluate the developed prototype system, BEC Estimator.

3 Findings and Discussion

The findings of the expert forum that assisted in developing the SWOT analysis of the BEC Estimator are discussed in this section.

3.1 SWOT Analysis

The identified strengths, weaknesses, opportunities and threats for BEC Estimator was used to develop the SWOT analysis for BEC Estimator as illustrated in Figure 2. The strengths and opportunities of BEC Estimator could mitigate the weaknesses and threats of BEC Estimator respectively. These have been discussed in detail in the subsequent sections.

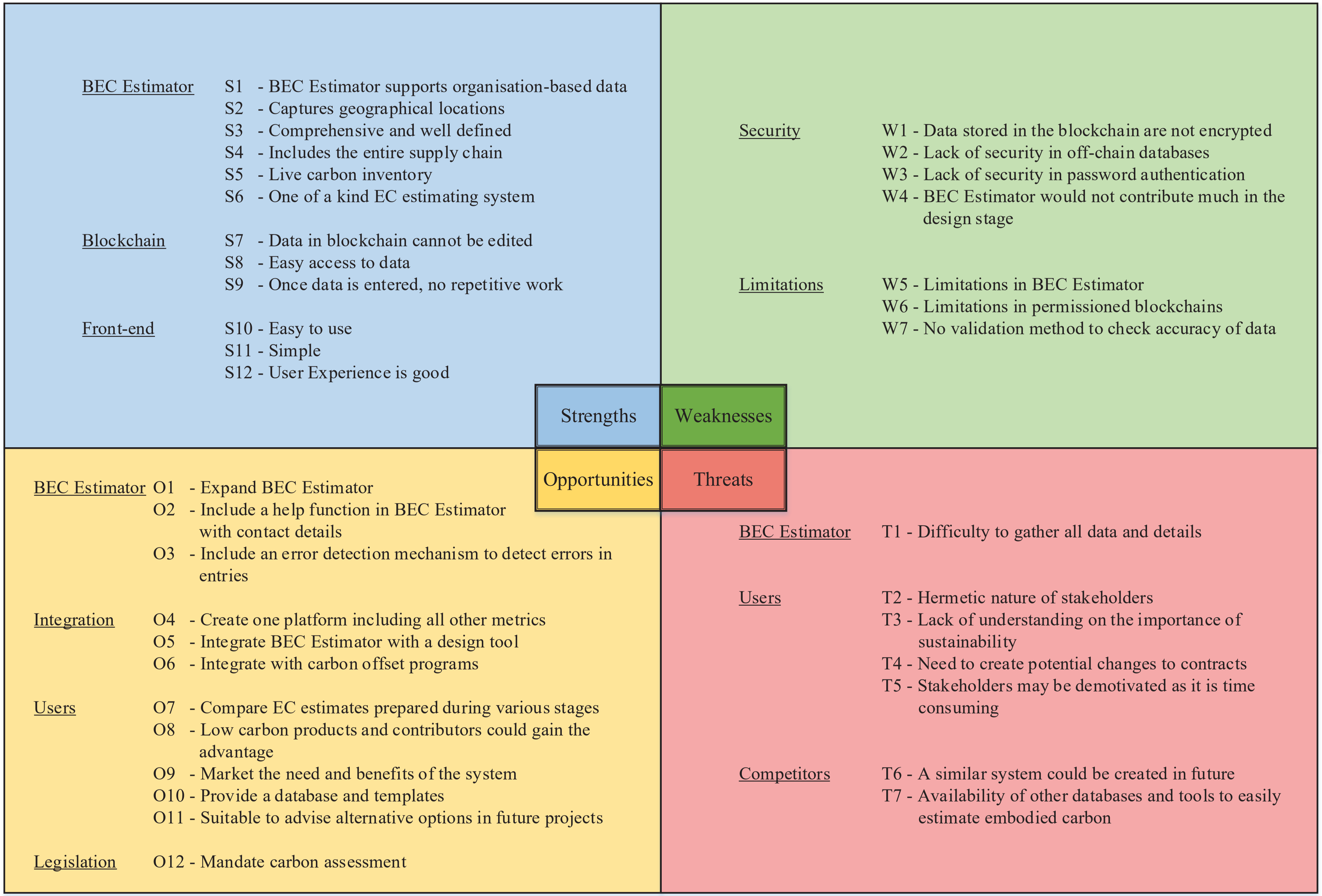

Figure 2. SWOT analysis of BEC Estimator

3.2 Strengths of BEC Estimator

Strengths in the SWOT analysis refers to internal strengths of the BEC Estimator, which are within the scope and control of the system. The identified strengths of BEC Estimator have been categorised under BEC Estimator-related, blockchain-related and front-end related.

3.2.1 BEC Estimator-related Strengths

The strengths applicable to the overall concept of BEC Estimator have been identified in this category. The strengths, S1 to S6, have been identified within this category as discussed next.

BEC Estimator supports organisation-based data (S1) - According to Expert 1, *having organisation-based data is incredibly important* (I1/Q1/S8). This assists in selecting low carbon-intensive products/materials, compare with competitors and reduce their EC emissions.

Captures geographical locations (S2) - BEC Estimator captures geographical locations of EC emissions and demonstrates them on a world map. Expert 6 stated that it is *good to know where the carbon emissions are emitted; the locations and organisations (I6/Q2/S3).* This would assist to identify the carbon-intensive locations and EC contributors to take necessary actions to reduce the EC emissions in future.

Comprehensive and well defined (S3) - BEC Estimator captures comprehensive and well-defined data to provide accurate EC estimates. Expert 7 emphasised that *the level of details is a strength* (I7/Q2/S1) *and that it is a good concept* (I7/Q2/S19). Expert 5 mentioned that *the concept is sound from a development point of view* (I5/Q2/S7). BEC Estimator requires EC contributors to enter basic but minute details. This assists in producing accurate EC estimates.

Includes the entire supply chain (S4) - BEC Estimator captures EC emissions in CSCs and accommodates any system boundary. Expert 2 mentioned that *it deals with the entire supply chain and you end up with a complete answer once all the data goes in* (I2/Q2/S2). Data stored in BEC Estimator could be used to have an idea of the overall CSCs.

Live carbon inventory (S5) - The EC contributors need to update BEC Estimator as soon as EC emissions occur. Therefore, BEC Estimator provides a live carbon inventory. Expert 7 identified that *using real data is a strength* (I7/Q2/S2). Users of BEC Estimator have the opportunity to witness the EC emissions in a live platform and monitor the emissions.

One of a kind EC estimating system (S6) - BEC Estimator is one of a kind EC estimating system that estimates EC in CSCs using the value chain concept and blockchain technology. Expert 2 opined that *I have not seen or heard of anything that's this detailed on one particular topic* (I2/Q6/S1). This makes BEC Estimator a unique carbon estimating tool.

3.2.2 Blockchain-related Strengths

The strengths of the BEC Estimator resulted due to the use of blockchain to develop the system, have been identified under this category. The strengths, S7, S8 and S9, have been identified under blockchain-related strengths.

Data in blockchain cannot be edited (S7) - BEC Estimator is developed using Hyperledger Fabric and the data is stored in its blockchain. The key advantage of using blockchain is that data stored in a blockchain is immutable, which was supported by Expert 1 mentioning that *the data in blockchain cannot be edited* (I1/Q1/S6). This improves the security and trust over the system, for the users to adopt it with confidence.

Easy access to data (S8) - BEC Estimator provides easy access to data. The BEC Estimator stores data in the blockchain of Hyperledger Fabric, which is not visible to the stakeholders. However, with the click of a button in the user interface, the user can view EC data stored in the blockchain. Expert 3 and Expert 5 supported this mentioning that *the information stored is accessible* (I3/Q2/S2) and *the ease of access is enabled by the blockchain* (I5/Q2/S5).

Once data is entered, no repetitive work (S9) - Expert 2 identified this strength and mentioned that *you need to enter data once only. Once you've got the data in the system, then it's not a repetition at all* (I2/Q2/S5) and *it's available at the click of a button* (I2/Q2/S6). Thus, *it saves time, which is another benefit* (I4/Q5/S1). The entered data could be used in future to benchmark and compare with other future projects.

3.2.3 Front-end related Strengths

The strengths identified due to the characteristics of the front-end of BEC Estimator have been identified under this category. The strengths, S10, S11 and S12, are related to the front-end of the BEC Estimator.

Easy to use (S10) - The user interface of BEC Estimator is created in a very simple self-explanatory manner making it very easy to use. Expert 1 and Expert 2 mentioned that *ease of use* is a key strength of the BEC Estimator (I1/Q2/S1; I2/Q2/S4).

Simple (S11) - BEC Estimator is developed in a very simple user-friendly manner. Therefore, any user could use it without the assistance of others. Expert 2 and Expert 3 highlighted this and mentioned that *one of the strengths is simplicity* (I2/Q2/S4; I2/Q2/S1; I3/Q2/S12). Expert 5 added that *as simple as that, it works* (I5/Q6/S2), therefore, *anyone can easily familiarise with the system soon* (I6/Q2/S1).

User Experience is good (S12) - Expert 5 opined that *the user experience seems to be good* (I5/Q6/S3). On the other hand, many experts commented that the system is simple and easy to use as explained under Strength S11 and S10. Therefore, it could be easily concluded that the user experience of the BEC Estimator is good.

The following section discusses the weaknesses of the BEC Estimator.

3.3 Weaknesses of BEC Estimator

Weaknesses in a SWOT analysis are internal attributes, which are within the scope and control of the system. The identified strengths can address the weaknesses. The identified weaknesses have been categorised under security-related and limitations-related weaknesses.

3.3.1 Security-related Weaknesses

The weaknesses related to security have been discussed in this section. The weaknesses, W1, W2 and W3, have been identified under this category.

Data stored in the blockchain are not encrypted (W1) - According to Expert 5, *a weakness is the encryption type used* (I5/Q2/S13). Currently, BEC Estimator does not encrypt its data as there is no such requirement. The data stored in blockchain requires to be visible to users. However, if the requirement arises such data could be stored in off-chain databases to maintain the confidentiality of data. Access to off-chain could be securely controlled by creating a shared network of storage and server resources. Each time a data object is accessed, it would require to be verified using stored hash values to prove that it is the same object that was stored initially.

Lack of security in off-chain databases (W2) - Expert 1 is concerned about the security of off-chain databases and suggested improving *the security of databases* (I1/Q1/S1). Similarly, Expert 5 emphasised that *potentially the quantification of information has to be stored in a highly secure location* (I5/Q2/S13). Off-chain databases could be secured by creating a shared network of storage and server resources as explained under W1.

Lack of security in password authentication (W3) - Expert 1 suggested seeking advice of a computer analyst or security analyst to improve the level of authentication and password authentication for the users (I1/Q1/S1). Park (2018) introduced a two-factor authentication scheme for Hyperledger Fabric using Time-based One-Time Password (TOTP) as an authentication method. This could be incorporated into the commercial application.

3.3.2 Limitations-related Weaknesses

Weaknesses that have been resulted due to the limitations of the system, BEC Estimator or aroused due to features of blockchain have been discussed in this section. The weaknesses, W4 to W7, have been identified under this category.

BEC Estimator would not contribute much in the design stage (W4) - Expert 1 opined that *for the design stage when details are not available, this tool wouldn't be of much help* (I1/Q2/S5). Currently, BEC Estimator does not have many details stored in its blockchain. Therefore, it cannot be used in the design stage. However, when sufficient details have been entered into the system by various EC contributors, the system could be used as a tool to benchmark and compare EC estimates during various stages.

Limitations in BEC Estimator (W5) - Expert 3 mentioned that c*urrently, the system can insert details of 5 equipment, what if there are more than 5 types of equipment working on a particular item?* (I3/Q2/S14). This is a limitation of the BEC Estimator as it was developed to test the feasibility of the concept introduced in this study. Expert 3 suggested adding *help functions to assist the users who have got stuck to resolve the problem by themselves* (I3/Q2/S15). Similarly, Expert 4 mentioned that *the system needs to be intuitive. Therefore, user notes could be included with all the fields* (I4/Q2/S14). Expert 3 proposed *to have data pre-filled. If the same activity is repeated, you could be able to use the previously entered data* (I3/Q2/S16). A commercial application could be developed to address these limitations.

Limitations in permissioned blockchains (W6) - BEC Estimator is developed using the permissioned blockchain, Hyperledger Fabric. According to Expert 3, *one of the weaknesses might be in terms of being a permissioned blockchain. So it's not fully decentralised.* (I3/Q2/S8). Expert 3 added that *being kind of centralised holds back some of what I see as opportunities* (I3/Q2/S10). However, it was a requirement to select a permissioned network. The construction industry is a data-intensive industry where security and confidentiality of data plays an important role, which could be only achieved using a permissioned blockchain. Increasing the number of peer nodes and endorser peer nodes could resolve the centralised nature of storing data and validating transactions respectively.

No validation method to check accuracy of data (W7) - Expert 2 stated that *data accuracy is important and you will have different numbers if people enter indifferent data.* (I2/Q2/S7). Therefore, it is important to validate the data entered the system, to improve the accuracy of data. Expert 4 suggested introducing *a method to validate the data entry. For instance, to upload a fuel receipt, as proof of the amount of fuel that is used* (I4/Q1/S3). The use of a validation method *provides confidence that the numbers that are entered and used for public reporting are correct, auditable and traceable* (I4/Q1/S6). This could be implemented in the commercial application.

The following section discusses the opportunities of BEC Estimator.

3.4 Opportunities of BEC Estimator

Opportunities in a SWOT analysis are external attributes that are outside the direct control of the prototype system, BEC Estimator. Opportunities could have a positive impact on the implementation of the system and could act as levers to improve the system. The opportunities have been categorised into 4 main categories; BEC Estimator-related, integration-related, user-related, legislation-related.

3.4.1 BEC Estimator-related Opportunities

The opportunities, which are directly applicable to improvements of BEC Estimator have been discussed in this section. Opportunities, O1, O2 and O3, are discussed under this category.

Expand BEC Estimator (O1) - The experts opined that BEC Estimator could be expanded further in several ways. Expert 1 suggested *getting data from each of the specialised trades, related to electricians, roofers, etc. to get their level of detail.* (I1/Q2/S7). Expert 3 proposed to *improve the tool through an incubator program* (I3/Q4/S3). Expert 4 suggested carrying *out testing in the real world using a real project engaging all the people involved, to understand the shortfalls (if there is any) in a better way* (I4/Q2/S11). Expert 3 further added that *Green Building Council would be interested, if the system complies with Green Star* (I3/Q5/S1).
Include a help function in BEC Estimator with contact details (O2) - Expert 3 suggested including a help function so that everyone has the confidence that this system works and there's help if the system is down. It could be incorporated in the commercial application as a person has to be appointed to be online and available if any user needs assistance.
Include an error detection mechanism to detect errors in entries (O3) - If erroneous entries were entered into BEC Estimator, many problems could arise. Therefore, Expert 7 suggested *including an error detection mechanism* (I7/Q2/S21). Expert 7 further mentioned *including an automatic comparison with average values to avoid users entering wrong numbers* (I7/Q2/S8). This could be introduced when developing the commercial application.

3.4.2 Integration-related Opportunities

The potential opportunities to integrate BEC Estimator with other software, tools and technologies have been discussed under this category. Opportunities, O4, O5 and O6, are identified under integration-related opportunities.
Create one platform including all other metrics (O4) - Construction organisations tend to use various platforms and software/web applications to get their work done. Expert 4 opined *to have one platform including everything rather than using multiple platforms* (I4/Q2/S5). Instead of software applications such as AutoCAD, Revit, CostX, Aconex and so forth, an integrated platform could be developed along with BEC Estimator to estimate EC.
Integrate BEC Estimator with a design tool (O5) - It was suggested to integrate BEC Estimator with a design tool such as Revit as *no tool integrates design tool with embodied carbon accounting.* (I1/Q3/S2). It would be a revolutionary tool if BIM and blockchain could be integrated to prepare EC estimates.
Integrate with carbon offset programs (O6) - Expert 3 proposed to integrate the prototype system with carbon offset programs. According to Expert 3, *if it was fully decentralised, you could buy the carbon offsets, and use your crypto carbon offset as the fuel or gas to run the process, so you start to contribute the carbon offsets into the system* (I3/Q2/S9).

3.4.3 User-related Opportunities

The opportunities for users of BEC Estimator have been identified under this category. Opportunities, O7 to O11, are discussed under this categorisation.
Compare EC estimates prepared during various stages (O7) - Once the EC contributors have entered data, Expert 3 opined that *it can be benchmarked* (I3/Q2/S2) *to compare the impact during the design stage and construction stage* (I1/Q2/S4).
Low carbon products and contributors could gain the advantage (O8) - Estimator displays EC emissions produced by various EC contributors. This provides an opportunity for clients to select *manufacturers that have lower emissions per square or cube or product* (I5/Q3/S4). *Opportunities will arise for suppliers and materials that are lower in carbon, and probably manufacturers that are working towards the net-zero* (I5/Q3/S2).
Market the need and benefits of the system (O9) - Expert 6 stated that *benefits such as cheaper, easier to use, more accuracy could be used to persuade users* (I6/Q3/S4). Expert 2 opined that *it is important to know the best way to sell the benefit of the system explaining why*

you need to use it (I2/Q2/S7). The opportunity to adopt this prototype system lies with proper marketing to attract users to adopt the system.

Provide a database and templates (O10) - Expert 7 opined that *over time, BEC Estimator would provide a good database when you get more people to enter data in and that would be creating a local database for itself* (I7/Q2/S5). *At a later stage, a smart database could be created using AI to suggest alternative options to people* (I7/Q1/S6). Once the data is inserted by various EC contributors, data templates could be developed and they could be pre-populated to save the users' time and improve the efficiency of the system.

Suitable to advise alternative options in future projects (O11) - In future, BEC Estimator could be used to advise alternative options in future projects (I1/Q2/S4). *It opens opportunities and the ability to select a good vendor, by checking which ones have the lowest carbon intensity for their product* (I3/Q2/S4).

3.4.4 Legislation-related Opportunities

An opportunity related to legislation, which needs to be actioned by the government has been identified under this category.

Mandate carbon assessment (O12) - Mandating carbon assessment has a greater impact on influencing and motivating construction practitioners to adopt the prototype system, BEC Estimator. *If the corporates believe that the prototype system is good, they will mandate it on their contractors* (I2/Q6/S3). Expert 5 opined that *the prototype system would work if the government mandated that manufacturers needed to report CO_2* (I5/Q2/S2). Mandating carbon assessment could be done project-wise by the practitioners by incorporating it in construction contracts or nationwide by the federal government by mandating it in their regulations.

The threats of the BEC Estimator have been discussed in the following section.

3.5 Threats to BEC Estimator

The threats in SWOT analysis refer to external threats, which have a negative impact on the BEC Estimator and stays in the way of the implementation of the prototype system. The threats have been categorised into BEC Estimator-related, user-related and competitor-related. A detailed analysis of each threat is provided elaborating how each threat could be addressed.

3.5.1 BEC Estimator-related Threats

The threats resulted due to the nature of the concept and system are identified under BEC Estimator-related threats. The threat, T1, on the difficulty to gather all data and details have been identified under this categorisation.

Difficulty to gather all data and details (T1) - *According to the nature of contractors, they may not disclose all the information fully* (I3/Q2/S17). For example, *a logistics supplier will be reluctant to mention the fuel quantity as it is directly related to the cost* (I6/Q3/S6). According to Expert 7, *it is extremely difficult to collect data from the sites* (I7/Q1/S4), *especially for the cradle-to-gate system boundary* (I7/Q1/S7). Expert 4 elaborated that *if a contractor is performing multiple activities, it's very difficult for the contractor to separate the amount of fuel used between those activities* (I4/Q2/S8). *If all actors, do not enter the details of the project's EC emissions, the results would be incomplete* (I4/Q2/S1). Implementation of BEC Estimator would be successful, only if stakeholders adopt the system and enter all required details to produce accurate EC estimates. Either EC estimating should be mandated or the importance and need of EC estimating should be explained to stakeholders.

3.5.2 User-related Threats

The threats resulted due to the nature and characteristics of users have been identified under this category. The threats, T2 to T5, have been identified and explained in this section.

Hermetic nature of stakeholders (T2) - According to Expert 1, *the hermetic nature of subcontractors and the supply chain will make it difficult to expect subcontractors to enter the details* (I1/Q2/S12). Expert 5 opined that *it's very difficult to get people to change* (I5/Q5/S1). The benefit of EC assessment and ease of use of the system could be emphasised to attract users to adopt BEC Estimator.

Lack of understanding on the importance of sustainability (T3) - The stakeholders may not be aware of the importance of sustainability and EC assessment. Therefore, they may not see the benefits of using the BEC Estimator. *The Lack of understanding of the users might be disadvantageous to make users adopt the system* (I1/Q2/S13). Expert 2 mentioned that *people would like to see a benefit in it if they are to use it* (I2/Q2/S3). Therefore, the importance of EC assessment and ease of using BEC Estimator, need to be conveyed to all stakeholders.

Need to create potential changes to contracts (T4) - *It would require potential changes to subcontracts because currently a subbie just wouldn't be expected to provide this level of detail* (I1/Q2/S8). Mandating EC assessment should be an initiative taken by the government and regulatory bodies to avoid unnecessary issues and confusion that could result.

Stakeholders may be demotivated as it is time consuming (T5) - Stakeholders are required to enter detailed information into BEC Estimator. For example, the fuel quantity or hours of usage of particular plant/equipment used for an activity needs to be entered. Expert 7 highlighted that *the details required by the system demands more work, more time and more resources* (I7/Q2/S6), which result in a *high risk of rejection because* (I7/Q2/S15). If the stakeholders do not maintain such records, it would be time-consuming and an additional effort for stakeholders to use BEC Estimator. Construction stakeholders should prepare themselves and improve their record-keeping and documentation management strategies while embracing digitalisation and being on par with the global trends.

3.5.3 Competitor-related Threats

The threats that resulted due to competitors have been identified under this categorisation. The threats, T6 and T7, have been discussed in this section.

A similar system could be created in future (T6) - Expert 5 opined that *the only other threat you'll have is if somebody else creates the same system, which I don't see to be feasible at this stage due to lack of demand and the mandatory requirements of industry* (I5/Q2/S15). Currently, there is no such system as identified under the strength, S6, and BEC Estimator is one of its kind and it is the only system that captures EC emissions in CSCs using value chain concept and blockchain technology. Hence, it is not a threat in the present day.

Availability of other databases and tools to easily estimate embodied carbon (T7) - There are various EC databases and tools that could be used to easily estimate EC. Expert 7 mentioned that *the consultants who are using the existing methods to make money wouldn't highlight that these methods are inaccurate* (I7/Q2/S16). Therefore, it would be difficult to make stakeholders use BEC Estimator. The accuracy of the BEC Estimator needs to be marketed along with the importance of it to make EC contributors embrace the BEC Estimator.

4 Conclusion

This paper aimed at developing a SWOT analysis for the blockchain prototype system, BEC estimator, which assisted in validating the use and adoptability of BEC Estimator. The strengths and opportunities of BEC Estimator has the ability to mitigate the weaknesses and threats of

BEC Estimator. BEC Estimator uses a supply-chain based value addition method, SCEEM, to estimate EC in construction supply chains accurately. The blockchain system assists in developing an accurate, transparent, more secure, trustworthy and immutable EC estimating system, which is a key contribution to theory and practice. The expert forum, along with the SWOT analysis, provides validity to the prototype system, BEC Estimator. The commercial application could be developed by expanding BEC Estimator while incorporating the opportunities highlighted and mitigating the weaknesses and threats identified by the experts. The application is generalisable in the construction domain to resolve the issues in EC estimating. BEC Estimator is useful for stakeholders in EC estimating, selecting low EC emitting products and decision making.

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Modular Prefabricated Classrooms: A New Zealand Study to Investigate Cost and Time Performance Potential

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Abstract
Modular construction is proposed as a feasible solution for school classrooms construction at a lower cost and shorter period by the Ministry of Education (MOE), New Zealand. However, the traditional construction remains a plausible alternative. This paper aims to review the feasibility of using modular prefabricated classrooms in terms of cost and time performance compared to traditionally constructed ones in New Zealand. Data from construction costs and completion time estimates of a classroom model design was obtained from four prefabrication manufacturers and six traditional contractors to ensure data comparability. The data obtained showed that it is possible to isolate construction method data only from material inputs data as a plausible methodology for comparing modular prefabricated and traditional construction cost and completion time performance henceforth. This methodology was implemented to investigate whether modular prefabricated classrooms could be constructed at a lower cost and completed timelier than the traditional ones, and the cost estimated by the contractors can be implemented in practice. It is concluded that constructing modular prefabricated classrooms, particularly emphasising the construction method, is feasible and holds real potentials to deliver at the originally planned cost and completion time compared to traditionally constructing classrooms in New Zealand.

Keywords: Cost and time, Modular classrooms, New Zealand, Performance, Prefabrication

1 Introduction

Prefabricated construction is considered an innovative construction type where the built elements are manufactured offsite – mostly under a controlled environment and afterwards, the manufactured elements are transported to construction sites for installation (Shahzad et al., 2015; Antillón et al., 2014). The derivative is pre-assembly whereby the manufactured elements can be directly installed as a sub-unit before transportation to construction sites (Wasana et al., 2019). Compared with the traditional construction, prefabricated construction offers more opportunities for higher precision in terms of designing, planning, and constructing (Darlow et al., 2021; Wang et al., 2020). Also, the customisation of prefabricated elements permits mass construction that can be based and relocated easily, and repeatedly constructed elsewhere using the same expertise level (Sutrisna et al., 2019). As a result, numerous benefits such as better cost, time, and quality performance than traditional construction (Arashpour et al., 2018) have been put forward to increase the use of prefabrication for different construction purposes in practice (Mao et al., 2016).

Among these benefits, cost and time savings from prefabricated construction are the most compelling for its adoption and implementation in the construction industry (Shahzad et al., 2014). Reinforcing this position, the growing number of studies that are evaluating the feasibility of prefabricated construction are based on cost and time performance (e.g., Abdul Nabi & El-adaway, 2021; Sutrisna et al., 2019). For instance, cost saving is achieved in prefabricated construction by shifting onsite work cost into offsite manufacturing cost and product transferring cost (Sutrisna et al., 2019). Also, the customisation of elements and process design, plan, installation, transportation, and expertise contribute to time savings and speedy prefabricated construction (Razkenari et al., 2020). Meanwhile, there are different categories of prefabricated construction such as sub-assemblies and elements, panelised construction, modular construction, whole building prefab and hybrid (Hong et al., 2018; Shahzad et al., 2014; Sutrisna et al., 2019). However, the cost and time benefits that are reported in the literature rarely differentiate between the different categories of prefabricated construction (e.g., see Abdul Nabi & El-adaway, 2021). As a result, it may be challenging to establish the feasibility of prefabricated construction in terms of cost and time performance in a country like New Zealand, where the Ministry of Education (MOE) has prescribed the modular prefabricated construction category as a feasible solution to overcome school overcrowding at a lower cost and timelier completion (MOE, 2015).

Despite the benefits of prefabricated construction, modular construction has slowly taken off and the construction stakeholders like everywhere else are undetached from the traditional construction in New Zealand (Chen & Samarasinghe, 2020). Shahzad et al. (2014) established that more prefabrication content potentially increases the cost and time performance in prefabricated construction of commercial buildings and more investigation of the subject in other building types in this country was suggested. With MOE's proposal for modular prefabricated classroom construction on one hand, and stakeholder attachment to traditional construction, the paper explores the scope to compare the performance of both construction types in New Zealand. The aim of this study is to determine whether modular prefabricated classrooms are more feasible in terms of cost and time performance than traditionally constructed ones in New Zealand. The MOE can use the results to decide whether to proceed with modular schools' construction in New Zealand. Also, the results can be used to benchmark the cost and construction duration of modular school's construction among industry practitioners and school development policy makers in New Zealand and elsewhere in Australasia.

2 Literature review

2.1 Categories of prefabricated construction type

Prefabricated construction type can be categorised according to the amount of prefabrication implemented in the built product. Based on multiple sources (e.g. Wasana et al., 2019; Hong et al., 2018; Shahzad et al., 2014), the four categories of prefabricated construction type that are commonly implemented in practice are sub-assemblies and elements (prefabricated building elements and units such as precast columns and beams), panelised construction (pre-nailed trusses, and the precast wall and floor panels), modular construction (modules or pods), and whole building prefab (complete building short of foundations and onsite service connections). The hybrid has been described as fifth category and is the combination of both non-volumetric and volumetric offsite construction elements in the same project (Sutrisna et al., 2019). Regardless of the category, prefabricated construction projects need to be competitive in terms of the cost and time performance be more acceptably implemented in practice.

2.2 Prefabricated construction project cost and time performance

An increasing number of studies are evaluating the cost and time performance of prefabricated construction (Sutrisna et al., 2019; Mao et al., 2016; Li et al., 2017). Also, these studies employ relative evaluation approach by comparing prefabricated and traditional projects performance. Evaluating the performance of an ongoing hospital project, (Antillón et al., 2014) revealed a 6% prefabrication cost premium over the traditional construction of the project, and this is consistent with other (recent) findings irrespective of the project types (Wasana et al., 2019; Sutrisna et al., 2019). As a result, reasons for prefabrication cost premium have been elucidated. Hong et al. (2018) revealed that the materials that constitute prefabricated elements contribute highly to the total prefabrication construction costs. Materials like precast concrete and steel were estimated to contribute 30-55% of the total prefabrication construction cost (Hong et al., 2018). Also, prefabrication construction cost is increased by the manufacturing costs of prefabricated elements, especially those that are used for singular prefabricated project constructed in isolation. For this kind of project, customisation costs that was accrued cannot be spread across as would in the construction of a chain of prefabrication projects (Sutrisna et al., 2019). Mao et al. (2016)'s analysis revealed that prefabricated construction project cost drivers result from assembly, transportation and cast in-situ. Assembly costs comprise of machinery cost, prime cost of installation, jointing cost, built-in fitting and support costs and tower crane expenses. Transportation costs comprise of the cost of transporting raw materials to the prefabrication sites and the prefabricated elements to the construction site (Hong et al., 2018; Mao et al., 2016). Cast in-situ cost refers to the cost effect on the cast in-situ part of prefabrication projects (Mao et al., 2016) since one hundred percent prefabrication is seldom in practice (Hong et al., 2018). The onsite portion (or residual onsite activity) exposes prefabricated construction projects to uncertainties (Sutrisna et al., 2019), and this is one reason for a lesser prefabrication construction project time certainty than traditional construction (Wasana et al., 2019). Particularly, prefabricated project construction time increases with reduced prefabricated content (Wasana et al., 2019). This means that prefabricated project construction time can be reduced by increasing the prefabricated content. For instance, Shahzad et al. (2014) revealed that 74% prefab content can result to 100% or more-time efficiency in light to medium commercial buildings. The prefabricated construction time saved is an opportunity for costs savings (Smith & Rice, 2015) but this remains a research issue. Based on reported literature, it is suggestive that prefabricated projects are still constructed at high costs in comparison with the traditional ones, while the completion time can be reduced by increasing the prefabricated content. However, the factors responsible for the current levels of prefabricated construction project cost and time performance are elucidated and improvement can be achieved as practitioners and researchers continue to consider them in practice.

3 Methodology

Among the categories of prefabricated construction, this paper is focused on modular prefabrication proposed for school construction. However, the feasibility in terms of cost and time performance was yet to be established in comparison with traditionally constructed classrooms by MOE in New Zealand. Comparing modular prefabrication and traditional construction project cost and time performance is often challenged by a lack of comparison basis in research. Also, methods like comparing data obtained from projects with theoretical and industry benchmarks and/or direct comparison of data obtained from unrelated projects directly do not effectively overcome the challenge (Mao et al., 2016; Shahzad et al., 2014). This paper employed a quantitative approach by obtaining estimated cost and time data from prefabrication (4 number) and traditional (6 number) contractors in Auckland, New Zealand.

To prevent incomparable data and depart from the existing data collection approaches at the same time, these contractors were provided with a case study of $78m^2$ Revit model classroom design (Plan shown in Figure 1) in conformity with the teaching space requirement in the country (MOE, 2015). For either type of construction, the contractors were instructed to provide the construction costs and completion time estimates for the Revit model classroom elements on a pro forma. The elements include preliminary & general (P&G), foundation & slab, framing & bracing, roof building wrap and services. Others are wall insulation & lining, doors & windows, cladding and finishes. The prefabricated construction included the cost estimates for transportation and site installation (Mao et al., 2016). With a pro forma, continuous data can be obtained for parametric data testing (Kaur & Kumar, 2015). It allows isolated request for missing data; therefore, it is a flexible means of collecting continuous project data (Shahzad et al., 2014).

Furthermore, the contractors were instructed to provide estimated costs and completion times expended on construction management tasks, and labour and plant inputs. As a result, the scope of comparison was limited to the construction method to ease comparability. The contractors were not asked to provide the estimates of cost and time expended on materials. This is because they operate different supply chain strategies for sourcing materials that are difficult to compare. Obtaining estimated data is akin to how efficiently the contractors can deliver either project construction types. However, contractors' efficiencies can vary, to the detriment of data validity and reliability. Therefore, data obtained were initially compared on the face value and outlier data from any contractor were removed from the analysis to increase data validity and reliability. The methods of analysis that conform with the adopted quantitative methodology were used are as follows. An arithmetic method comprising addition, subtraction and division operations was computed for preliminary analysis of the prefabricated and traditional construction cost and completion time estimates for the Revit model classroom elements. Finally, independent samples t-test was computed to establish whether there is a significant difference between prefabricated and traditional construction using the construction cost and completion time estimates for the Revit model classroom elements.

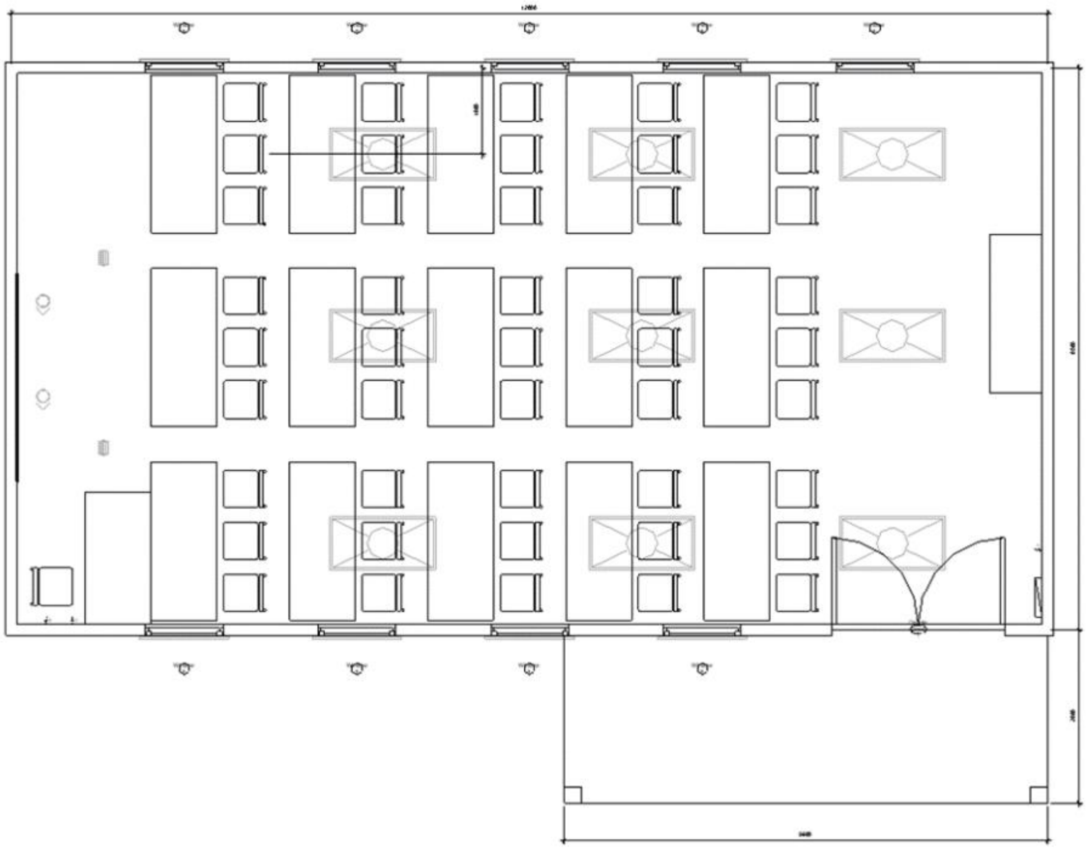

Figure 1: Plan view of the 78m² Classroom

4 Findings

As shown in Tables 1 and 2, four prefabrication manufacturers providers (M1-M4) and six contractors (T1-T6) provided cost estimates for the prefabricated and traditional construction of the 78m² Revit model classroom design on elemental basis respectively as at 2019. For the prefabricated construction, the cost estimates provided by M1 was much higher than those provided by others (M2-M4). Similarly, the cost estimates provided by T2 was much higher than other traditional contractors (T1; T3-T6). High-cost estimates provided by M1 and T2 (Yellow columns in Tables 1 & 2) may be due to the inclusion of material costs used in the construction of the elements. This contradicts the research design to estimate based on construction method only, but it provides an indication of the material cost impact on prefabricated and traditional construction. Regardless, cost estimates by M1 and T2 are outliers and were not used for further analysis. Of the remaining prefabrication contractors (M2-M4), M4 provided the highest total cost estimate (NZ$60,000); the least was provided by M2 (NZ$35,700), and their average was NZ$50,066.67. Also, of the remaining traditional contractors (T1; T3-T6), T1 provided the highest total cost estimate (NZ$128,000); the least was provided by T4 (NZ$80,000), and their average was NZ$97,100.

Table 1: Prefabricated construction cost estimates supplied by different contractors

Prefab elements	M1	M2	M3	M4	Average	Average without M1
Preliminary & General	$ 70,000.00	$ 7,800.00	$ 10,000.00	$ 15,000.00	$ 25,700.00	$ 10,933.33
Foundation & Slab	$ 80,000.00	$ 5,500.00	$ 6,500.00	$ 12,000.00	$ 26,000.00	$ 8,000.00

Framing & Bracing	$ 80,000.00	$ 7,500.00	$ 10,000.00	$ 4,000.00	$ 25,375.00	$ 7,166.67
Roof	$ 60,000.00	$ 1,600.00	$ 6,000.00	$ 3,000.00	$ 17,650.00	$ 3,533.33
Building Wrap	$ 6,000.00	$ 800.00	$ 1,500.00	$ 1,000.00	$ 2,325.00	$ 1,100.00
Services	$ 30,000.00	$ 2,500.00	$ 3,000.00	$ 3,000.00	$ 9,625.00	$ 2,833.33
Wall insulation & lining	$ 10,000.00	$ 600.00	$ 3,000.00	$ 4,000.00	$ 4,400.00	$ 2,533.33
Doors & Windows	$ 6,000.00	$ 800.00	$ 1,000.00	$ 1,000.00	$ 2,200.00	$ 933.33
Cladding	$ 15,000.00	$ 2,400.00	$ 4,000.00	$ 6,000.00	$ 6,850.00	$ 4,133.33
Finishes	$ 15,000.00	$ 1,600.00	$ 2,000.00	$ 4,000.00	$ 5,650.00	$ 2,533.33
Sub-total	**$ 372,000.00**	**$ 31,100.00**	**$ 47,000.00**	**$ 53,000.00**	**$ 125,775.00**	**$ 43,700.00**
Transport	$ 7,000.00	$ 3,000.00	$ 4,500.00	$ 4,000.00	$ 4,625.00	$ 3,833.33
Site installation costs	$ 3,000.00	$ 1,600.00	$ 3,000.00	$ 3,000.00	$ 2,650.00	$ 2,533.33
Total	**$ 382,000.00**	**$ 35,700.00**	**$ 54,500.00**	**$ 60,000.00**	**$ 133,050.00**	**$ 50,066.67**

*Cost data is presented in New Zealand dollars

Table 2: Traditional construction cost estimates supplied by different contractors

Construction elements	T1	T2	T3	T4	T5	T6	Average	Average without T2
P&G	$ 5,000.00	$ 35,000.00	$ 5,000.00	$ 20,000.00	$ 15,000.00	$ 15,000.00	$ 15,833.33	$ 12,000.00
Foundation & Slab	$ 30,000.00	$ 30,000.00	$ 30,000.00	$ 14,000.00	$ 20,000.00	$ 15,000.00	$ 23,166.67	$ 21,800.00
Framing & Bracing	$ 14,000.00	$ 25,000.00	$ 10,000.00	$ 10,000.00	$ 8,000.00	$ 12,000.00	$ 13,166.67	$ 10,800.00
Roof	$ 18,000.00	$ 25,000.00	$ 9,000.00	$ 12,000.00	$ 15,000.00	$ 15,000.00	$ 15,666.67	$ 13,800.00
Building Wrap	$ 3,000.00	$ 3,000.00	$ 3,000.00	$ 3,000.00	$ 2,500.00	$ 1,000.00	$ 2,583.33	$ 2,500.00
Services	$ 6,000.00	$ 20,000.00	$ 6,000.00	$ 3,000.00	$ 4,000.00	$ 3,500.00	$ 7,083.33	$ 4,500.00
Wall insulation & lining	$ 8,000.00	$ 5,000.00	$ 3,000.00	$ 4,000.00	$ 6,000.00	$ 6,500.00	$ 5,416.67	$ 5,500.00
Doors & Windows	$ 9,000.00	$ 25,000.00	$ 2,000.00	$ 2,000.00	$ 2,000.00	$ 2,000.00	$ 7,000.00	$ 3,400.00
Cladding	$ 20,000.00	$ 25,000.00	$ 15,000.00	$ 7,000.00	$ 8,000.00	$ 15,000.00	$ 15,000.00	$ 13,000.00
Finishes	$ 15,000.00	$ 10,000.00	$ 15,000.00	$ 5,000.00	$ 8,000.00	$ 6,000.00	$ 9,833.33	$ 9,800.00
Sub-total	**$ 128,000.00**	**$ 203,000.00**	**$ 98,000.00**	**$ 80,000.00**	**$ 88,500.00**	**$ 91,000.00**	**$ 114,750.00**	$ 97,100.00
Transport	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Site installation costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total	**$ 128,000.00**	**$ 203,000.00**	**$ 98,000.00**	**$ 80,000.00**	**$ 88,500.00**	**$ 91,000.00**	**$ 114,750.00**	$ 97,100.00

*Cost data is presented in New Zealand dollars

Furthermore, as shown in Table 3, the same number of prefabrication and traditional contractors provided the completion time estimates for different elements in the 78m² Revit model classroom design as at 2019. Among the traditional contractors (T1-T6), T2 provided the highest total estimated time to complete the Revit model classroom (75 days); the least was provided by T5 (48 days), and their average was approximately 62 days. Among the prefabrication contractors (M1-M4), M3 provided the highest total estimated time to complete Revit model classroom (64 days); the least was provided by M2 (44 days), and the average was approximately 54 days.

Table 4: Traditional and Prefabricated construction completion time estimates supplied by different contractors

	Traditional Contractors							Prefabrication Contractors				
Constructed elements	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**Average**	**M1**	**M2**	**M3**	**M4**	**Average**
P&G	3	10	3	20	10	10	9.33	7	10	20	25	15.50
Foundation & Slab	7	5	10	10	4	5	6.83	9	5	8	10	8.00
Framing & Bracing	12	15	12	12	8	10	11.50	7	10	10	5	8.00
Roof	8	10	8	8	5	8	7.83	6	3	8	3	5.00
Building Wrap	2	2	3	2	1	2	2.00	2	1	1	1	1.25
Services	2	5	4	2	1	2	2.67	4	3	2	2	2.75
Wall insulation & lining	6	3	6	2	4	5	4.33	2	1	3	2	2.00
Doors & Windows	3	5	3	2	2	2	2.83	1	1	1	1	1.00
Cladding	15	10	6	5	8	5	8.17	3	4	3	5	3.75
Finishes	10	10	5	5	5	5	6.67	2	3	4	3	3.00
Transport	0	0	0	0	0	0		1	1	1	1	1.00
Site installation costs	0	0	0	0	0	0		1	2	3	3	2.25
Total	**68**	**75**	**60**	**68**	**48**	**54**	**62.17**	**45**	**44**	**64**	**61**	**53.50**

*Time data is presented in No. of days

The averages of the total estimated cost and completion time of the prefabricated and traditional construction of the 78m² Revit model classroom design was computed (Table 5) to establish the total estimated cost and completion time differences. As shown in the Table, the total sum of estimated prefabricated construction cost was NZ$50,066.64. This value is 48.43% lesser than the NZ$97,100 total sum estimated for the traditional construction cost. Similarly, the total completion time estimated for the prefabricated construction was approximately 54 days. This value is 13.94% lesser than approximately 62 days of completion time estimated for the traditional construction. It could be seen that differences exist between the total estimated cost and completion time of the prefabricated and traditional construction of the Revit model classroom. The inference is that the prefabricated construction of the Revit model classroom has a lower cost and can be completed timelier than employing traditional construction methods.

Table 5: Averages of the total cost and completion time estimates

Constructed elements	**Average Prefab Cost**	**Average Trad Cost**	**Average Prefab Completion time**	**Average Trad Completion time**
P&G	$ 10,933.33	$ 12,000.00	15.50	9.33
Foundation & Slab	$ 8,000.00	$ 21,800.00	8.00	6.83
Framing & Bracing	$ 7,166.67	$ 10,800.00	8.00	11.50

Roof	$ 3,533.33	$ 13,800.00	5.00	7.83
Building Wrap	$ 1,100.00	$ 2,500.00	1.25	2.00
Services	$ 2,833.33	$ 4,500.00	2.75	2.67
Wall insulation & lining	$ 2,533.33	$ 5,500.00	2.00	4.33
Doors & Windows	$ 933.33	$ 3,400.00	1.00	2.83
Cladding	$ 4,133.33	$ 13,000.00	3.75	8.17
Finishes	$ 2,533.33	$ 9,800.00	3.00	6.67
Sub-total	**$ 43,699.98**	**$ 97,100.00**		
Transport	$ 3,833.33		1.00	0.00
Site installation costs	$ 2,533.33		2.25	0.00
Total	**$ 50,066.64**	**$ 97,100.00**	**53.50**	**62.17**

Given the differences in the estimated total construction cost and completion time of both the modular prefabricated and traditional construction of the Revit model classroom, this paper further investigated whether the differences are significant. In practice, modular prefabricated, and traditional construction are different construction types. Therefore, a significantly different result would indicate that the construction costs and completion time estimates provided by the contractors (T1-T6; M1-M4) reflect the type of construction and are practicable. The independent t-test is used to compare means between two unrelated groups on the same continuous, dependent variable (Laerd, 2018), and was employed. In this paper, the two unrelated groups are modular prefabricated vs traditional construction, while the dependent continuous variable is the estimated construction costs (and completion time) for individual elements in the Revit model classroom. The premise of decision was based on the observed t-value, the degrees of freedom and the statistical significance (p-value) (Laerd, 2018). Following the analysis, the results are presented in Table 6. With $p < .05$, there was a significant difference in the average estimated construction cost of the elements in the Revit model classroom between prefabrication and traditional construction types, $t(75.121) = -4.900$, $p = .000$ (Table 6). Similarly, there was a significant difference in the average estimated completion time of the elements in the Revit model classroom between prefabrication and traditional construction types, $t(91.940) = -2.041$, $p = .044$ (Table 6).

Table 6: Independent Samples Test

Independent Variables		Levene's Test for Equality of Variances		t-test for Equality of Averages		
		F	**Sig**	**t**	**df**	**Sig. (2-tailed)**
Cost estimates of Modular Prefab vs Traditional construction types	Equal variances assumed	18.61	0.000	-4.425	84	0.000
	Equal variances not assumed			-4.900	75.121	0.000
Completion time estimates of Modular Prefab vs Traditional construction types	Equal variances assumed	0.00	0.983	-2.080	106	0.040
	Equal variances not assumed			-2.041	91.940	0.044

5 Discussion of findings

The feasibility of prefabricated construction projects is demonstrated by comparing the estimated construction costs and completion time with traditionally construction ones. Among the categories of prefabricated construction, the modular construction category that has been proposed for school construction in New Zealand was selected for the comparison. Furthermore, comparable data derived from a 78m² Revit model classroom model was obtained from four prefabrication and six traditional contractors in the country. The data was broken down according to the Revit model classroom elements that enabled detailed comparative analysis. However, the data reflected only the construction method encompassing the construction management tasks, and labour and plant inputs. Results from comparing modular prefabricated and traditional construction project have reportedly been poor due to an inconsistent basis comparison (Antillón et al., 2014). In this paper, this problem may have been circumvented by using data reflecting construction method only for comparative analysis. Material inputs only data can also be sourced for such comparative analysis. Therefore, a new methodology whereby construction method data or material inputs data can be isolated to compare modular prefabricated and traditional construction performance may have emerged in this paper.

The comparative analysis using the arithmetic method revealed that the modular prefabricated construction of the Revit model classroom can be low in cost and can be completed in a timelier manner compared to traditional construction. Also, based on the independent t-test analysis, it was demonstrated that the realistic cost of the prefabricated construction of the Revit classroom model design was estimated by the contractors and therefore can be implemented in practice. Notably, this contradicts most literature findings who found otherwise (Wasana et al., 2019; Sutrisna et al., 2019). It should be noted, these studies attributed the higher costs and completion time of prefabricated projects than traditional ones to many reasons such as assembly and transportation of prefabricated elements, and residual onsite activities (Mao et al., 2016). In practice, the Australian and New Zealand construction supply chains work in tandem and Sutrisna et al. (2019)'s reasons for high prefabricated construction project costs can be related to both supply chains. Most prefabricated construction projects in both countries are constructed singularly in isolation and this removes the customisation cost reduction benefits that would accrue to a chain of prefabricated construction projects (Sutrisna et al., 2019). This is expected to change, and improved prefabricated construction cost benefits can be realised when MOE starts to build proposed classrooms to accommodate one hundred thousand students under the National Education Growth Plan (NEGP) in New Zealand (Ardern & Hipkins, 2019). Based on Shahzad et al. (2014)'s study in New Zealand, increasing the prefabrication content of these classrooms will reduce their completion times and ensure they are utilised earlier than traditionally constructed classrooms. However, the shorter construction time demands high upfront cash inflows, about 80% of payment, to fabricate the modules (Wuni et al., 2021).

In addition to the positive cost and time performance potential, studies in other developed countries show that modular classrooms have learning benefits that are relevant for improving academic learning experiences in New Zealand and Australasia. Modular classrooms can be leveraged for research into learning environments to improve pedagogies in Australian higher education (Newton et al., 2020). A Canada study reveals that they can be prototyped for hands-on construction exercise for university students to develop specialised skills (Hegazy et al., 2020). Rizkiyansah et al. (2020) report a strong sustainable modular classroom performance, especially waste reduction in Indonesia. To corroborate, King (2020) reveals that modular classrooms installed with energy efficient measures such as air-source-heat pump generate about 35% lower carbon dioxide emissions than required by current UK regulations. However, modular classroom indoor quality is lowered when in-use with the potential to cause discomfort and health effects to pupils and teachers when the total volatile organic compounds (TVOC) concentration of 200 μg/m3 is exceeded in a Slovakian case (Harčárová, 2020).

6 Conclusion, recommendation, implications

Prefabricated construction has become a paradox in New Zealand. It has been slow to take off because construction stakeholders are undetached from traditional construction, while at the same time, the Ministry of Education (MOE) has proposed it as a solution for school classroom construction to accommodate one hundred thousand students at lower cost and timely completion in the country. Therefore, it became imperative to determine whether modular prefabricated classrooms are more feasible in terms of cost and time performance than traditionally constructed ones in New Zealand. This paper departed from existing comparative analysis methods to ensure data comparability by obtaining data from four prefabrication and six traditional contractors derived from construction costs and completion time estimates of a $78m^2$ Revit model classroom model design. The data obtained showed that it is possible to isolate construction method data only from material inputs data as a plausible methodology for comparing prefabricated and traditional construction cost and completion time performance henceforth. This methodology was implemented to determine that the $78m^2$ Revit modular prefabricated classroom could be constructed at cheaper cost and completed timely compared to the traditional method, and the realistic cost estimated by the contractors can be implemented in practice.

It is concluded that constructing modular prefabricated classrooms, and emphasising on the construction method only, is more feasible at lesser cost and timely completion when compared to constructing traditional classrooms in New Zealand. In terms of implication, it has been demonstrated that estimating the construction cost and completion time of prefabricated construction by isolating construction method data from material inputs data can potentially be done as a realistic approach with reasonable accuracy. In other developed countries like USA and the UK, the potential of modular classrooms has been proven beyond cost and time performance. Modular classrooms can enhance academic research and learning experiences for users in these countries and elsewhere. Academic researchers can undertake fit-for-purpose experimental research using modular classrooms. Students' hands-on-experience of modular classrooms help them to develop specialised construction project management skills that are relevant in practice. In further research, the efficacy of the proposed methodological approach can be further tested using real life data. The MOE can use the findings to decide whether to proceed with modular prefabricated classroom construction in New Zealand. Clients and contractors who may be sceptical about the benefits of prefabricated construction may find this paper as the vehicle to present evidence and potentials that can change their views.

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Constructing pedagogical alignment for a sustainable mindset of future-ready graduates

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Abstract
Increasingly universities are making sustainability a focus for their institutional activities, curricula and student learning. The complexity of addressing epistemology, methodology and pedagogy in education for sustainability has been recognised and a diversity of approaches is emerging. The Central Queensland University has aligned it strategic vision with the United Nations Sustainable Development Goals (SDGs), striving for transformative student learning experiences. The purpose of this paper is to investigate opportunities for integration of the SDGs into construction management learning, teaching and graduate future-ready attributes. This research utilises constructive alignment as pedagogical methodology for a case study design across several units of a construction management masters degree program. The concept of a sustainable mindset, based on values, knowledge and attributes provides the investigative lens. This study seeks to expand education for sustainability in Australian Built Environment programs and to advance constructive alignment as integrative pedagogy for learning and teaching. Findings demonstrate opportunities for SDG integration into unit based learning experiences as well as making SDGs explicit from strategic plan across graduate attributes to specfic unit learning outcomes. Recommendations include a broadening from learning about sustainability content to SDG alignment with student learning experiences and support sustainable mindset development as future-ready graduate attribute.

Keywords
Constructive alignment, built environment education, future-ready graduate, pedagogy, sustainable mindset

1 Introduction

Universities have for the last 30 years demonstrated commitment to sustainability measures and integration into higher education, starting with the international conference of Tailloires, France:

Universities educate most of the people who develop and manage society's institutions. For this reason, universities bear profound responsibilities to increase the awareness, knowledge, technologies, and tools to create an environmentally sustainable future. (Tailloires, p.1,1990)

The Sustainable Development Goals (SDGs) adopted by the United Nations in 2015 represent the most recent and extensive framework for international sustainability implementation across member countries (Figueiró, et al. 2015, Owens, 2017; United Nations, 2015). Sustainability here is based on the definition for Sustainable Development (SD) established through the United Nations World Commission on Environment and Development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). The construction sector internationally, has identified sustainability as the 'great challenge of the 21st century' (Sachs, 2012) and an opportunity to '…improve social, economic and environmental conditions for present and future generations' (Ortiz, Castells, & Sonnemann, 2009, p. 29). Setting measurable goals and targets, the individual SDGs stipulate goals and targets for industry, government and community sectors across biophysical, social and economic systems. For example, SDG 4, which focuses on "Quality Education" and includes targets and indicators for access and participation, early childhood, school, VET, higher education, skills, gender equality, education infrastructure and teacher training (Parkes, Buono & Howaidy, 2017). Across the 17 SDGs, the aim is to advance global sustainable development whilst enhancing local and national long-term performance outcomes (Sachs, 2012; Costanza, Fioramonti, & Kubiszewski, 2016). Over recent years SDG research and implementation in higher education have been increasing internationally with a focus on institutional values, curricula and student learning (Chaleta, et al. 2019; Giesenbauer and Tegeler, 2020; O'Flaherty & Liddy, 2018; Ávila et al., 2017). The research discourse on how to achieve this transition revealed that a "systemic and connected view of sustainability across institutions is required to transform the educational experience of students… a realignment of all activities with a critically reflective paradigm which also supports the construction of more sustainable futures" (Tilbury, 2011, p.2). The notion of the "reflective institution" was successfully demonstrated by Biggs (2001, 2014) in his research and implementation in Australia and Asia of constructive alignment of learning experiences via curricula to institutional values. Constructive alignment is both an institutional strategy as well as an education pedagogy (Biggs, 2014; Fransson & Friberg, 2015; Ruge et al., 2019).

This research utilises constructive alignment as a pedagogical methodology to develop an integrated approach for connecting SDGs with student learning experiences within the institutional framework for expected learning outcomes, skills and attributes for units in a construction management degree program. Linked to the constructive alignment methodology is a sustainable mindset value framework, which focuses on learning for sustainability through knowledge, values and attribute development. The Central Queensland University (CQUni) has aligned its strategic vision with the United Nations Sustainable Development Goals (SDGs) and strives for transformative student learning experiences.

We are committed to embedding sustainable practice in our operations, interactions and relationships, underpinned by the United Nations Sustainable Development Goals… We will produce graduates who have the knowledge, skills and drive to apply global and sustainable thinking to address complex social, economic and environmental challenges (CQU, p.16, 2019).

The purpose of this paper is to investigate opportunities for integration of SDGs as per the institution's strategic plan into learning, teaching and graduates' future-ready attributes to enable their sustainability contributions to industries and communities (Fuertes-Camacho, et al., 2019; Kalutara et al., 2018).

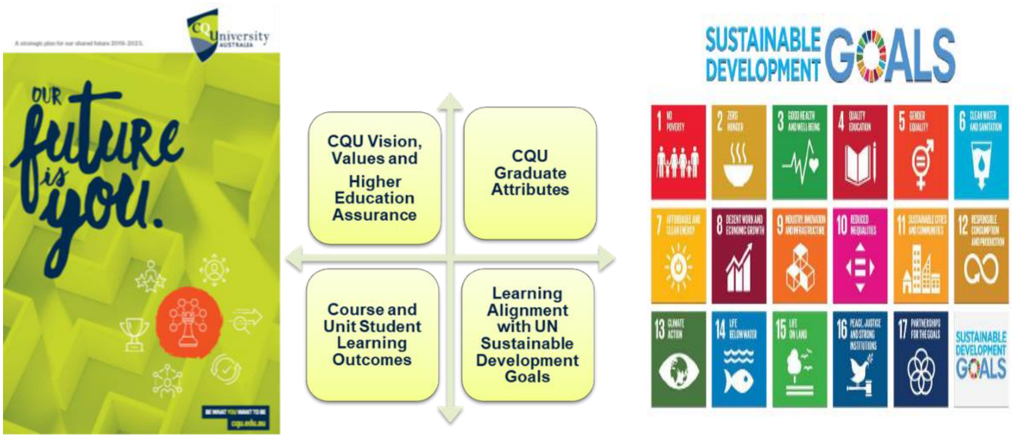

Figure 1. Conceptual diagram for SDG learning alignment opportunities

2 Literature Review

The literature on sustainability integration into higher education learning and teaching has been accepted as providing students and graduates with the knowledge and skill sets necessary to support industries and societies for more sustainable outcomes (Friman, et al., 2018; Holm et al., 2015; Jorge et al., 2015; Lozano, 2010). Research in this field has developed a number of approaches, predominantly addressing SDGs content with a subject or discipline-specific focus only. This opened up opportunities for implementation across educational courses and disciplinary contexts (Cajiao & Burke, 2016, Leal Filho et al., 2019). Many of these initiatives involve university educational developers' expertise for implementation in institutional, faculty, individual course and unit level contexts (McDonald and Stockley, 2008; Baughan, 2015; Leal Filho et al., 2017). Overall, these research trends have expanded the boundaries of education for sustainability from specific subject or context learning towards a student skills and capacity building as a value-based approach.

More recently, these initiatives have been expanded through a shift towards a systemic and broader approach of addressing complex educational contexts (Giesenbauer and Tegeler, 2020, Lozano and Barreiro-Gen, 2019, Sapasi et al., 2020). Examples include sustainability content or specific knowledge focus, usually covering some environmental or material related to the focus of the unit or topic of study (Thomas, 2004). Others emphasise specific SDGs relevant to the course learning, such as SDG 4 on Quality Education embedded in Education degree programs (Ferguson, et al, 2020; Fuertes-Camacho, et al., 2019) or multiple SDGs for across degree or discipline programs (Chaleta, et al. 2019; Ramirez-Mendoza, et al., 2020). However there appears to be an opportunity for research on linking SDGs to the educational pedagogy and practice that supports students to develop the 'knowledge, skills and drive to apply global and sustainable thinking to address complex social, economic and environmental challenge' as aspired in the CQU strategic plan. The literature urges an increased focus on developing a context of competencies for future challenges (Lozano 2006; Leal Filho 2017; Rieckmann 2012; van Weenen 2000; Wiek et al. 2011) and utilising SDGs as opportunity to build a more holistic perspective.

International research findings on curriculum design and course delivery call for more emphasis and detailed focus on '… engaging pedagogies, professional development for instructors, course designers and administrators should give alignment the long over-due attention … so that proper implementation of the CA can be ensured in practice' (Wang et al., 2013, p. 488). CA has expanded from a teaching for learning approach to a teaching and learning management application in institutional settings linking to internal culture and long-term staff commitment for its successful implementation (Borrego & Cutler, 2010). The research gap identified in the extant literature relates in particular to implementation processes from policy to practice and how potential institutional constraints or strength are linked to teaching and learning outcomes targeted through constructive alignment (De La Harpe et al., 2000; Harvey & Kamvounias, 2008).

3 Research Methodology

This qualitative research study utilises constructive alignment (CA) as pedagogical methodology for a case study design across several units of a construction management masters degree program (Biggs, 2014; Boud & Falchikov, 2006).
The first institution-wide implementation of CA was undertaken by Biggs and Tang at the Polytechnic University of Hong Kong (Biggs and Tang, 1999). Since then CA has been implemented extensively internationally, including Australia (Harvey & Kamvounias, 2008; Mills, Tivendale, Chan, & Liu, 2013; Ruge & McCormack, 2017), Asia (Biggs & Tang, 2011; Thota & Whitfield, 2010; Wang, Su, Cheung, Wong, & Kwong, 2013), Europe (Fransson & Friberg, 2015; McMahon & Thakore, 2006), and the USA (Blumberg, 2009; Borrego & Cutler, 2010).

The new focus in this research is on integration of SDGs from institutional strategy to unit level student learning. The concept of sustainable mindset, based on values, knowledge and attributes provides the investigative lens for the integration of SDGs (Kassel et al., 2016; Parkes et al., 2017; Hermes & Rimanoczy, 2018). The concept of the sustainability mindset, advocates for deep learning as a more holistic approach to education for sustainability. It was introduced over a decade ago through Rimanoczy's educational research (2010, 2017). She is the convener of the Principles of Responsible Management Education (PRME) Working Group on the Sustainability Mindset, a UN backed international initiative promoting innovation and a sustainability mindset across a wide range of disciplines.
Sustainability mindset is a way of thinking and being that results from a broad understanding of the ecosystem's manifestations, and an introspective focus on the personal values and the higher self…The Sustainability Mindset is ultimately a lens through which we analyze and interpret information, and make decisions... The mindset is an internal aspect, yet it can be seen in action, in behaviors. Educators can promote innovative and collaborative work on projects to make a difference in the students' community, as a way to create the experiential learning that can be transformative.
(https://www.unprme.org/prme-working-group-on-sustainability-mindset).

A sustainable mindset goes beyond specific technology or prescribed methodology learning, and combines "value, knowledge and competency". This provides opportunities to develop an overarching educational strategy connecting university, course, industry and importantly graduates' future-ready skills outcomes. The three key sustainable mindset dimensions identified by Kassel et al (2016) include "being" or values, "thinking" or knowledge and "doing" or competency (Kassel, Rimanoczy & Mitchell, 2016). Through this methodological approach this research seeks to advances the pedagogy of constructive alignment as framework supporting education for sustainability. The first institution-wide implementation of Constructive Alignment (CA) was undertaken by Biggs and Tang at the Polytechnic University of Hong Kong from 2002. This had the aim of achieving improved and measured student learning outcomes across the university, linked to teaching quality and institutional support and systems (Biggs & Tang, 2011; Fransson & Friberg, 2015; Treleaven & Voola, 2008; Trigwell & Prosser, 2014).

In order to support the qualitative research design and to be able to capture and analyse the educational design development process of CA, the authors utilised the interpretive research lens of sense-making (Colville, Brown, & Pye, 2012; Schwandt, 2005; Weick, 2012). Established in the research fields of management and organisational behaviour, sense-making is about interpreting the institutional narrative and how from this narrative a 'schema for action' of 'what to do next' is developed (Colville et al., 2012; Weick, Sutcliffe, & Obstfeld, 2005). Data sources utilised in this study include institutional strategic planning documents, peer review and assessment development notes and diagrams. The research methodology and design set out below aim to provide a verifiable, adaptive and thereby transferable approach for future planning and design of CA implementations (Gerring, 2006). The initial research involved an iterative process of inductive interpretation of the CA experience and deductive analysis of the institutional CA process and practise (Weick et al., 2005). This sense-making process of analysis allowed the re-interpretation of the CA situational context to explicit knowledge and develop a new framework for implementation.

The literature identifies a number of constraints and barriers faced by educational development initiatives targeting a broader scale of implementation. These include a continuing critique that the SDGs whilst being interdisciplinary are at the same time regarded as vague and lacking practice-focued insights (SDSN, 2016; Spangenberg, 2017). The other major constraint noted in the literature is the lack of institutional engagement and educational training for academics and casual staff for teaching and learning about sustainability (Chaleta, et al. 2019; De La Harpe et al., 2000; Watty, 2003). On the other hand, a key strength for educational development strategies could be the motivation of discipline teams and individual academics, who are supported in their skills development to lead change in close connection with students, institutional stakeholders and employers (Entwistle, 2005; Blumberg, 2009; Mak, et al., 2013).

4 Findings and Discussion

CA implementation processes for learning outcomes in discipline-orientated programmes are faced with complexities. These include active engagement of faculty and discipline management as well as supportive attitudes of relevant internal and external stakeholders (Diseth, et al., 2010; Thota & Whitfield, 2010). The process of degree or discipline-based constructive alignment for student skills development identified several areas of strengths as well as constraints. A key strength of the 'bottom-up' approach is the strong motivation of discipline teams and individual academics, who are leading and implementing change in close connection with students and external industry stakeholders and employers (Blumberg, 2009; Entwistle, 2005; Ruge et al., 2019). This ensures a direct feedback loop and active engagement with students in the semester cycles of monitoring, review, reflection and improvement of CA for assessments and learning activities (Larkin & Richardson, 2013; Trigwell & Prosser, 2014). In this case study the constructive alignment with connections from institutional vision to specific unit learning outcomes was made explicit from the first lecture and reiterated as the learning activities proceed to assessment learning and further supports student learning engagement.

Figure 2. Lecture Week 1 Student Learning Slides showing SDG connection

Table 1. Constructive alignment with SDG integration for student learning outcomes

SDG Integration Case Study Unit: Construction Contract Administration		CQU Strategic Plan & SDG 2019-2023	University Graduate Attributes (GA)	Course Learning Outcomes (CLO)	Degree Unit Learning Outcomes (ULO)
Constructive Alignment engages students in their knowledge, values & skills development					
Unit Learning Outline and Topics	Learning experiences with linkages to SDG and Sustainable Mindset	From unit introduction, SDGs are integrated as relevant to weekly learning topics and activities ranging in depths and complexity			
Student Tutorial Workshops		Student led discussions and research encourage knowledge and attribute development through learning activities with SDG linkages			
Assessment Learning		Constructive alignment of ULO/ CLO/GA through authentic assessment is made explicit to students who recognise how they are building their attributes & sustainable mindset for future careers			
Formative Feedback		Formative feedback for students is supported by constructive alignment of scaffolded learning experiences and continuous development of attributes			
Student Reflection on Learning		Students learn and engage in reflective practice through assignment and learning activities as well as written elements for their professional portfolio based on their knowledge, attributes & values.			

Institutional Peer Review comments were received from the Educational Designer who attended when the constructive alignment of learning and assessment was introduced to students (CQU Peer Review, 22 July 2021). These include:

- Outlined Assignment details – talked about using what they have learned to contribute to the assignment
- Connected the assignment with what they would see in the real world – practical

- Great to mention how it all fitted to the Graduate Attributes and Unit Learning Outcomes
- Students could clearly understand what is expected of them in this assessment
- Good connection to other units that students are studying
- Outlined Assignment details – talked about using what students have learned to contribute to the assignment
- Connected the assignment with what they would see in the real world – practical.
- Talked about Portfolio creation – and how it will benefit them for CV / job application

This study found that the Australian higher educational system with constructive alignment of SDGs for student learning provides opportunity for sustainable mindset integration to support students' development of their worldviews towards sustainable development (Setó-Pamies & Papaoikonomou, 2016). Sustainability mindset through its elements of knowledge, values and attributes links to students' deep learning and a more holistic approach of education for sustainability (Cotton & Alcock, 2012; Dyllick, 2015).

The three key attributes for a sustainability mindset defined by Kassel et al (2016) as "value, knowledge and competency" can take on a distinct meaning in terms of educational development for student learning. First, with awareness of "values" across institutional strategy, faculty culture and individual academics' capabilities, educational developers are able to encourage students to reflect, articulate and connect their values, beliefs and practices to future-ready curricula and student learning experiences. Secondly, enabling academics and educators to connect "knowledge" and thinking from disciplinary fields to institutional policies, procedures and processes. This is important for long term integration of a sustainability mindset throughout university operations and course design, learning and teaching (Naeem & Neal, 2012; Parkes, Buono, & Howaidy, 2017). Thirdly, "building competency" in this case study through constructive alignment for learning as central focus for student learing and development activities. In a broader context the sustainable mindset framework enables connection of future-ready graduate skills and attributes for graduate employability with contributions to community and society at large. The literature calls for educational developers and educators to foster and promote sustainability attributes to influence students' worldviews and their future potential towards more profound sustainability leadership and social change (Dobson, 2007; SetóPamies & Papaoikonomou, 2016).

5 Conclusion

This paper reflects the early stage of a longer term research study with potential for future institutional implementation. It builds on several previous successful projects of constructive alignment in higher education built environment programs in Australia. Findings from this investigative research identified that constructive alignment as educational methodology in conjunction with the sustainable mindset parameters allows the integrate of SDGs from strategic plan to graduate and student learning outcomes (institutional dimension) as well as into individual student learning activities and experiences throughout the unit and degree program (student learning dimensions).

A new framework illustrating this broadened approach indicates potential for increased strategic and operationalised integration of SDG's in higher education learning and teaching.

Further detailed development and data collection is required at the next development stage to refine the implementation process. In addition this study recognises the opportunity for built environment educators in professionalised degree programs to engage in the development of pedagogical strategies and scholarly teaching and learning practice such as constructive alignment for learning outcomes well established in other disciplines. The ultimate focus is on enhancing the students' capacity to develop the 'knowledge, skills and drive to apply global and sustainable thinking to address complex social, economic and environmental challenge' as aspired for in the CQU strategic plan.

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Integral Perspectives Supporting Sustainable Decision Making in Building Projects

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Abstract
Existing project management approaches follow discipline and predominantly linear time and task specific methodologies. These offer limited insights into the decision-making dynamics at key project lifecycle stages. The purpose of this paper is to apply Integral Theory to investigate sustainable decision-making in building projects and develops a new methodology with potential to advance professional practice. Utilising Integral Theory and its four quadrants' perspectives goes beyond the traditional project management parameters and allows to capture the contextual, participatory and temporal dynamics of project interactions. This multi-perspective framework introduces the individual/subjective, individual/objective, collective/inter-subjective and collective/inter-objective roles of project participants involved or influencing sustainable decisions making. The authors have developed a new visualisation of 'scenario windows' to capture key participants interactions at important project lifecycle stages. The concept of scenario windows allows the project mananger to establish sustainability halt points during the building project life cycle and actively engage the project team in the dynamics of multi-perspective decision-making for sustainability outcomes. Findings highlight the importance of increased project management awareness for collaborative and diverse stakeholder involvement and participatory engagement in sustainable decision-making. This research offers an innovative contribution to industry practice and support built environment education and skills development for sustainability.

Keywords
Building education, decision-making dynamics, integral theory perspectives, project management methodology, sustainable decision making

1 Introduction

For several decades now, sustainable development (SD) in the construction sector internationally, has been identified as the 'great challenge of the 21st century' (Sachs & Warner, 1999) and an opportunity to '…improve social, economic and environmental conditions for present and future generations' (Ortiz, Castells, & Sonnemann, 2009, p. 29). This is based on the definition of SD established through the United Nations World Commission on Environment and Development. This identified SD as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987).

Yet, despite industry wide adopted sustainability rating tools such NABERS or Green Star and broader concepts such triple bottom line and corporate social responsibility reporting, to date sustainable development in management of building and construction businesses in Australia has not been addressed with sufficient depth or detail (Huemann& Silvius, 2017). Recent research has identified several barriers that are hindering construction businesses in the adoption and integration of SD practices both within Australia and internationally (Hwang &

Tan, 2012; Parkin, Sommer, & Uren, 2003; Sev, 2009). The international literature notes the increasing gap and growing need to develop a better understanding of sustainable development in practice and longer terms outcomes (Matar, Georgy, & Ibrahim, 2008). With the increasing economic, environmental and social impact of building and construction activities that are becoming evident globally, there is now a growing need for this sector to enhance and adopt sustainable development practices (Chang et al., 2018; Revell & Blackburn, 2007).

Despite the technology performance improvements, it appears that the current approach to sustainability decision-making practice can be improved at the human project management interface in alignment with technology across the project lifecycle (Zanni, Soetanto & Ruikar, 2017). Existing project management approaches follow discipline-based and predominantly linear time and task-specific methodologies. These offer limited insights into the decision-making dynamics at key project lifecycle stages.

The purpose of this paper is to apply Integral Theory to investigate sustainable decision-making in building projects and develops a new methodology with potential to advance building education and professional practice. Utilising Integral Theory involves activating four perspectives on project management decision making, captured through a four-quadrant visual and analytical tool developed by Ken Wilber (2007). This multi-perspective framework is utilised in this research to capture the individual/subjective, individual/objective, collective/inter-subjective and collective/inter-objective roles of project participants shaping sustainable decisions making in a hypothetical building project following a typical project delivery process along design, approval, pre-construction, construction, handover and defects to longer term operation and asset management. This review of the literature and current context has led to the identification of the research questions: How can Integral Theory as a research approach capture the dynamics of sustainable decision making? How can insights gained from Integral Theory multi-perspective lenses enhance sustainable decision-making practice in building project management at key life cycle stages?

2 Literature Review

In relation to sustainable decision making the international literature identifies continuing barriers affecting longer-term sustainable development outcomes. These include: overall variability in sustainability understanding and practice across building industry professions and stakeholders (Khalfan, 2006; Chong et al., 2009), In addition, corporate vision and positive sustainability intentions my not align or reflect corporate processes and practice (Jones et al., 2010). Further issues identified are lack of understanding of how knowledge management and decision-making processes for sustainable development outcomes take place (Mathur et al., 2008; Atkinson, 2008) and limited industry-specific research into the complexity and dynamics of project management processes and practice for sustainability. Through this literature review on theory and practice, the potential for Integral Theory was identified to investigate construction project management processes through its multi-perspective lenses.

2.1 Integral theory for multi-perspective research

The key assumption of Integral Theory is that multiple perspectives, reaching from the individual to the collective and from the subjective to the objective, can be applied to any given subject (Wilber, 2000). The understanding of reality from a singular perspective is valid, yet it tends to be fragmented and biased. Integral Theory has been used in various disciplines such as social welfare (Larkin et al. 2014), arts, criminology, education, environmental philosophy, future studies, medicine, music therapy, politics, psychotherapy and counselling, and sustainable development (Esbjörn-Hargens, 2010; Ingersoll, 2007; Shea & Fritsch, 2014). The

Integral Sustainable Design approach (Roetzel et al., 2017; DeKay et al., 2018) is the first application of Integral Theory to the built environment focused on sustainability.

This research seeks to extend the knowledge and application of Integral Theory to sustainable decision making in building and construction. The theory framework utilises the 'All Quadrant, All Levels (AQAL)' approach for executing multi-perspective analysis. Wilber (2000) highlighted four quadrants as four distinct dimensions of reality (worldviews or paradigms) which consist of individual interiors (Upper Left); individual exteriors (Upper Right); collective interiors (Lower Left); and collective exteriors (Lower Right).

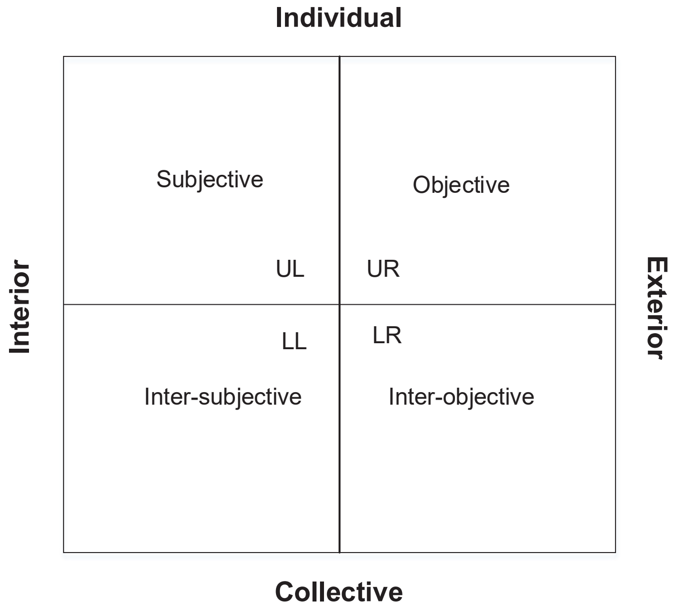

Figure 1 2-Dimensional AQAL Formulation adopted from Wilber (2005)

To apply Wilber's AQAL taxonomy for a construction project following a typical delivery path from design via construction to operation, the authors have chosen four specific lenses, which relate to each of the quadrants. Firstly, individual project or construction managers' personal insights, skills, and role can be captured in the 'subjective- interior' perspective of the Upper Left Quadrant (UL). Secondly, project inputs for example to a National Australian Built Environment Rating System (NABERS) (http://www.nabers.com.au) Energy building rating is industry specific and an objective perspective that relate to Upper Right Quadrant (UR) decision making. Thirdly, the collaborative stakeholder and project team processes can be identified and captured within the project 'interior-collaborative' aspects of the Lower Left Quadrant (LL). Fourthly, the application and integration of external sustainability benchmarks adopted industry wide such as the Green Building Council of Australia's Green Star rating tools shape decision making processes through the 'external – objective' perspective of the Lower Right Quadrant (LR). These four project perspectives can be identified individually through the four Integral Theory perspectives and offer a new opportunity to investigate the dynamics and influences through and across these perspectives on sustainable decision-making in building projects.

3 Research Methodology

Integral Theory has been utilised across many transdisciplinary research investigations, diverse methodologies and resulted in notable contributions to a diversity of fields. These include climate change (Esbjörn-Hargens, 2010), sustainability science (Brown, 2005; Sadick et al., 2020), conceptual modelling and analysis (Bowman, 2012; Stewart, 2008), and discipline-specific design approach (Roetzel et al., 2017). These studies provide evidence that the integral approach can overcomes the limitations of singular epistemological perspectives which are unable to describe the considerations of complex contexts comprehensively. Current sustainable decision-making approaches, provide an additive sustainability evaluation, thereby failing to recognise the interactive and iterative nature of individual life cycle techniques (Dong & Ng, 2016; Tokede et al., 2018).

The methodology for this research investigates Integral Theory and its ability to integrate the experiences and narratives of organisations with the implementations for actions and is followed by the iterative process of meaning-making of the respective data sources. The analysis involved an iterative, reflective and adaptive application of the Integral Theory perspective to transcend the predominantly linear decision-making sequence currently applied in building projects. This qualitative research study investigates sustainability decision making in an illustrative case study context of a typical building project design, construction and operation process with a focus on the critical stages along the project life cycle timeline. This research seeks to address the research questions: How can Integral Theory as a transdisciplinary research approach capture the dynamics of sustainable decision making? How can insights gained from Integral Theory multi-perspective lenses enhance sustainable decision-making practice in building project management? Engaging through this methodology in an exploratory and reflective stance on the process of sustainable decision-making, allows to develop a project management narrative following the key project. In utilising the transdisciplinary approach, the researchers adopted the principles of Lang et al., (2012).

(1) Collaborative problem-framing: The researchers engaged in collaborative, reflective discussions to review and re-interpret the sustainability decision making processes and dynamics identified for the selected case study scenario.
(2) Co-producing solution-oriented and transferrable knowledge: The research has drawn on detailed interviews with Australian project managers and their perception and practice for sustainable development (Ruge, 2019). The authors are emic researchers and educators in building construction, which provides an additional layer of insights and reflexivity to investigate the changing boundaries between theory and practice (Gerring, 2006; Cash et al. 2003).
(3) Re-integrating and applying the produced knowledge: The research involved an iterative process of reflexive and inductive interpretation of the Integral Theory perspective experiences and deductive analysis of the process and practise at play to interrogate the decision-making on a typical construction project delivery from design and construction to delivery for long term asset operation (Mitev & Venters, 2009).

3.1 Research design for individual quadrant analysis

Wilber (2007) highlighted four quadrants as four distinct dimensions of realities (worldviews or paradigms) which consist of Individual Interiors (Upper Left); Individual Exteriors (Upper Right); Collective Interiors (Lower Left); and Collective Exteriors (Lower Right). The following sections illustrate how the AQAL multi-perspectives allow to identify stakeholder views for inclusion into sustainable decision-making in construction projects:

3.1.1 Individual perspectives and values (Upper Left Quadrant)

The Upper Left (UL) quadrant provides an understanding of people's individual experiences (DeKay et al., 2018). It represents all factors that directly influence an individual's experience of the world). It is a map of an individual's subjective experience and covers the entire realm of self and consciousness (Brown & Hewstone, 2005), including the subjective, phenomenal dimension of individual consciousness and entails all experiences, emotions, sensations, perceptions, motivations, intentions and thoughts (Marquis, 2007; DeKay et al., 2018). For this study, the individual views of project managers, whose typical role it is to manage and lead the building project through all contractual stages, are investigated for the upper left (UL) subjective quadrant. Insights and data for this perspective have been drawn from available research studies and personal interviews with construction managers on their individual sustainable development perceptions and practices (Ruge, 2019).

3.1.2 Socio-cultural conventions (Lower Left Quadrant)

The Lower Left (LL) quadrant examines the situated contexts of collective interpretations of culture and worldview (Brown, 2005). These include the shared values, interpersonal relationships, customs, communication, perceptions and ethics amongst the project team members. This study focuses for the LL quadrant on the project team interactions at relevant stages, to investigate the collective basis for project values, expertise and skills that are shaping sustainable decision-making processes. The LL quadrant represents all realms and reasons that directly influence a group's experience of each other and the world.

3.1.3 Objective measures and systems (Upper Right Quadrant)

The Upper Right (UR) quadrant provides an understanding of the objective, measurable parameters and represents the exteriority of individuals (Brown, 2005; Marquis 2007). The UR quadrant relies on scientific measurement and can include measures such as laboratory observations, field research, chemical testing and statistical analysis relating to the physical system and associated responses (Brown & Hewstone, 2005; DeKay, 2018). The UR perspective in this study focuses on industry-specific sustainability measures for buildings, such as the National Australian Built Environment Rating System (NABERS) (http://www.nabers.com.au). NABERS is a quantitative rating tool, which calculates the performance of an existing building (or part of one) on a particular environmental indicator such as Energy, Water or Waste and provides as annual rating performance. The NSW Government, Department of Environment, Climate Change and Water (DECCW) is the supervising entity for the benchmarking and issue of NABERS rating certificates. (http://www.nabers.com.au). The primary purpose is to apply Integral Theory to investigate sustainable decision-making in building projects and develops a new methodology with potential to advance professional practice. This seeks to increase project manager’s awareness for collaborative and diverse stakeholder involvement in sustainable decision-making across the construction project life-cycle.

4 Findings and Discussion

The authors have set up a typical project management timeline and ‘carved' into this timeline four ‘scenario windows’ at key project stages. These project holt points are openings to investigate the sustainable decision-making dynamics utilising the Integral Theory four quadrant perspectives at that specific point in time. These ‘scenario windows’ are positioned along the traditional project lifecycle to make them recognisable and realistic. The top of Figure 2 shows a visual representation of a typical building project lifecycle and captures the linear industry process in terms of sequential project stages over time. The included timeline commences on the left with the project initiation and design, then leads to construction start-up and completion, followed by building operation and eventually redevelopment and re-use for the next building lifecycle. The four-quadrant scenario windows shown in Figure 2 below the timeline, capture some of the interactions and dynamics between individual, collective, subjective and objective influences. Findings for each scenario window are described in more detail below.

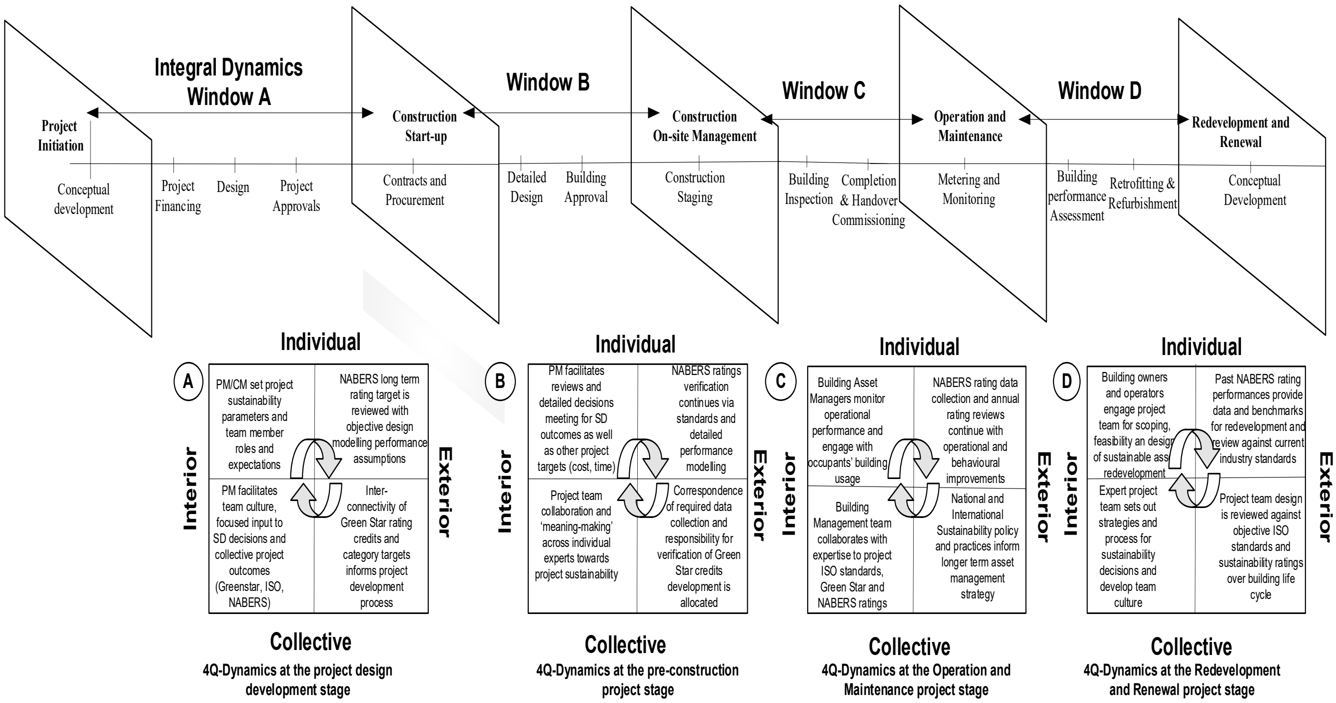

Figure 2. Integral theory 'scenario windows' exploring project sustainability dynamics

4.1 Integral perspectives at project design development stage (Scenario Window A)

The 'Window A' (Figure 2) captures some of the essential interior and exterior as well as individual and collective stakeholder contributions to sustainable decision making at the project start-up stages. The main individual /interior perspective holder (UL) is the Project Manager (PM) or Construction Manager (CM). At this early stage of the project, the people and technical skills and knowledge of this person set the stage for the interdisciplinary engagement amongst project team members and others directly or indirectly involved. The Project Manager's role is to lead, facilitate and communicate project aims, values, targets and processes across all knowledge disciplines and facilitate the project team members' input. For this to take place, the PM is actively engaging with the project team members' inputs, i.e. the collective of individual experts (LL), but also tracking these activities in conjunction with the externally regulated Building Construction Codes and Standards as well as sustainability targets and ratings. In this example, the Australian NABERS and Green Star rating scheme serve as the reference document. These form part of the exterior project parameters and objective standards (UR and LR Quadrants) of the integral connections illustrated in Window A.

4.1.1 Findings for 'Window A –Project Design Development Stage'

A key finding emerging at this point through the Integral Theory Window A is an early dynamic of primary (UL and LL) and secondary sustainable decision-making processes (UR and LR) emerging for subsequent stages. At this design development stage the engagement dynamics are led by the project management process and leadership which informs and develops the team culture, which in turn shapes the individual and collective activities on the left quadrants as these in multiple iterations engage with the right-hand quadrants to establish the sustainability parameters against the external NABERS and Green Star rating tools and integrating these measurable targets into the project design development before construction commencement.

4.2 Integral perspectives at construction start-up stage (Scenario Window B)

A critical stage for embedding sustainability on building projects takes place during the construction start-up phase. Here the 'left side quadrants' of internal project skills and engagement between the project manager/client with the collective views and skills of the project team members and expert consultants need to consolidate their inputs with the 'right side quadrants', where the objective goals and targets via sustainability ratings and a wide range of building construction and engineering standards and codes are cross-checked and verified for the project. The scope of individual trades and engineering services are now documented and combined with the detailed design drawings issued as tender packages for pricing. This stage requires intense focus by expert design team members (LL Quadrant) to achieve alignment of a wide range of sustainability aims and targets, such as Green Star (LR Quadrant) and make these explicit within and across the respective contractual tender packages. The Integral Theory perspectives visualise the potential tensions and power dynamics across the quadrants and within project teams.

4.2.1 Findings for 'Window B – Construction Start-up'

This stage is very interactive and dynamic across and between all quadrants, with the main input and action for sustainability decision making taking place between the Project Team (LL) and their development of solutions in alignment with Green Star credits to achieve targeted outcomes (LR). Here the right-hand side external ratings and targeted outcomes set the benchmarks and trigger iterative reviews of sustainability decision making on the left-hand side quadrants of PM and Project Team to validate left-side (UL, LL) and right-side (UR and LR) quadrant alignment for all trades and building elements detailed at the construction procurement stage. These 'Window B' dynamics continue as bidders on the tenders may provide further options in their submission and continuing to the next phase of on-site construction, potential unforeseen changes or conditions, render additional stimulus for possible amendments of the sustainability scope for building trades and services. The more integrated these processes and dynamics are established and managed, the higher is the likelihood of embedding sustainable decision-making for the crucial next stage of construction and operation of the completed building for its intended uses and users (Sev, 2009).

4.3 Integral theory perspectives at operation and maintenance stage (Window C)

The operation and maintenance phases are significant in terms of sustainability and cover the longest lifecycle stage of a building (Luther et al., 2018). Sustainable decision-making here is dependent on building occupant behaviours, availability of technology-enabled design solutions, and the quality of construction and its performance measurement (Zanni et al. 2017). Building asset or property managers now take over from construction PMs in the UL quadrant. They are tasked to measure, monitor and report on operational performance against the UR and LR targeted ratings. The asset manager also engages with the occupant's building usage, as described in the UL of Window C, in Figure 2. To achieve this objective, asset managers could rely on NABERS rating data collection (and similar sustainability assessments) and annual rating reviews to identify opportunities for resource conservation, as well as develop strategies for behavioural improvements (UR).

4.3.1 Inter-systems and contextual impacts (Lower Right Quadrant)

The Lower Right (LR) quadrant includes the inter-objective perspective of systems, addressing broader aspects of societies such as economic structures, civic resources, habitat and biota. (Marquis, 2007), The LR, therefore, represents an arena of objective descriptions and explanations of how our social, economic, political and ecological system operates and interact (Brown, 2005; Esbjorn-Hargens et al., 2010). For this study, the Australian Green Star rating tool managed by the Green Building Council of Australia has been incorporated into the sustainability decision making scenarios. This national rating environmental tool combines physical, social and environmental aspects of the building life cycle processes through multi-criteria assessment systems across a wide range of sustainability categories. These include Energy, Indoor Environment Quality, Transport, Emissions, Water, Materials, Land Use and Ecology, Management, Innovation. Each category contains a series of criteria that, if complied with, would reduce the environmental impact of a building in that category (GBCA, 2020).

4.3.2 Findings for Scenario Window C – Operation and Maintenance Stage

The Integral Theory perspectives for the operation and maintenance stage identified key sustainability decision-making dynamics around the management of sustainability ratings and data (UR and LR) which plays out from the previous design and construction stage implementations. During this phase, the Asset or Property Manager (UL) takes on the role of the Project Manager and involves a group of engineers or expert sustainability advisors (LL) to assist with the data interpretation, fine-tuning of building services and systems, and where possible, provide behavioural and educational information to engage building-users towards more sustainable decision making, behaviour to enhance the ongoing sustainable building performance.

4.4 Integral perspectives at redevelopment and renewal stages (Scenario Window D)

Sustainable decision options at this stage are diverse and range from retrofitting, refurbishment, repurposing, adaptive re-use, and re-certification. Each of these initiatives is directed at elongating the life of a building and in some cases, improve performance and planning for redevelopment and renewal (Tokede et al., 2018).

4.4.1 Findings for Scenario Window D – Redevelopment and Renewal

In the Window D scenarios of the redevelopment and renewal stages all Integral Theory quadrants are at actively involved. The project sustainable decision-making processes are shaped by the dynamics between how the UR performance-based data for the building in its previous lifecycle is interpreted and engaged with by the LL building management and operational team, which then shapes the decision making by the client-manager or project manager advising the investor or owner (UL), who are also considering the broader trends and future rating tool measures of the LR quadrant to future-proof the next building lifecycle.

4.5 Discussion: Integral theory and practice

The theoretical contribution of this research is to showcase the application of Integral Theory to sustainable decision-making processes across a building project life cycle which has not been done before. This verifies and expands Integral Theory from a conceptual model to its practice focused dimensions and transferability to industry specific contexts.

The findings from each 'scenario window' indicate the shifting dynamics between the different stages of projects, individual and collective roles and inputs (UL and LL quadrants) on the subjective side of the Integral Theory approach, as well as the changing influence of the objective guiding parameters related to sustainability benchmarks of Green Star and longer-term performance ratings such as NABERS (UR and LR quadrants). The implications for embracing Integral Theory and the four quadrant (4Q) multi-perspectives advances the understanding of sustainable decision making. This research offers a practice focused application of Integral Theory, which identified deeper insights into the dynamics of sustainable decision-making in building projects. The Integral Theory application in this study provided an innovative approach to capture sustainability decision making processes at crucial lifecycle stages of a typical mid-sized building project in Australia. It further confirmed that theories and models with multi-dimensional capacities are valuable to investigate sustainable decision making from an individual, corporate, community stakeholder, as well as holistic industry perspectives (De Ruyter & Scholl, 1998; Roetzel et al. 2017). Utilising the four-quadrant perspectives, allowed to capture and make explicit not just on 'what' technical detail is involved but 'how' the engagement and dynamics in the sustainability decision-making processes typically take place.

5 Conclusion

This paper applied Integral Theory to investigate sustainable decision-making in building projects and develops a new methodology with potential to advance professional construction management skills and practice. Utilising Integral Theory and its multi-perspective framework allowed to go beyond the traditional project management parameters and capture the contextual, participatory and temporal dynamics of project interactions at key project life-cycle stages. The authors developed a new visualisation of 'scenario windows' into the interactions shaping sustainable decision making at important project lifecycle stages. The integral theory perspectives presented here offer a new understanding of the complex project dynamics and open up new perceptions towards integrated sustainable decision making for building projects. These insights reach beyond traditional disciplinary boundaries and captured changing levels of participant engagement, not typically recognised in the predominantly linear discipline specific tradition. For project managers these findings point towards increased importance of developing integrative project management skills and practice with explicit and collaborative attributes for sustainability decision making.

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Construction Industry Inclusive Branding: Attracting Non-traditional Talents

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Abstract
The construction industry is facing skills shortages that threaten many companies' sustainability and market competitiveness. In the West, the predominantly male, white industry has begun to recognize the need to reposition its brand image to attract non-traditional talent. This research used image content analysis of corporate websites to explore how effectively the online brands of two of the world's leading construction professional societies are signalling workforce diversity and inclusion. Analysis of the posted images, pictures and videos was conducted by recording the frequency of portrayal of age, gender, and racial diversity. The findings showed the image of the construction industry was portrayed differently by each society. The younger society (A) visually signalled that construction offers a progressive, youthful workplace that embraces gender equity. However, few people of colour were depicted on their website. In contrast, the older society (B) used images that maintain the traditional image of construction as 'stale, male and pale'. The findings were interpreted using the theoretical lenses of signalling, identity fit, and social belonging theories. Recommendations are made for increased attention to ensuring the construction industry's brand image attracts greater gender and racial diversity to counteract the widespread skills shortage.

Keywords
Diversity and inclusion, Industry image, Attraction, Age, Gender, Race, Minorities

1 Introduction

While most industries are affected by global skills shortages, the construction industry is of particular concern due its strong contribution to national GDP. A recent survey of construction activity in 64 global markets found 65.6% were experiencing skills shortages (Turner and Townsend, 2019). In the U.K. alone, 20,000 more new construction recruits were required to deliver the country's planned building projects for 2020 (Royal Institution of Chartered Surveyors (RICS), 2019). In response to the talent crunch (Korn Ferry, 2018), many companies are attempting to recruit from a more diverse labour pool (Bell, 2011). Beyond the benefit of addressing pressing skills shortfalls, greater diversity also provides commercial benefits through producing more creative thinking and problem-solving, improved customer satisfaction, significant performance gains, and increased competitive advantage (Richard, 2000; Hunt, Layton and Prince, 2015). Improving construction workforce diversity also addresses social injustice and advances the United Nation's (2021) aim of creating equity for all people.

In order to become attractive to more diverse non-traditional labour pools (Avery and McKay, 2006), the construction industry requires a radical shift away from its traditional image of dirty, dangerous, macho, and white-dominated (Poon, Rowlinson, Koh and Deng, 2014). In the UK, only 12% (1 in 8) of the construction workforce is female (Keir, 2019), and even less are from ethnic minority groups (2.4% or 1 in 40 workers) (Abouen, Ahmed, Worrall, Baldry and Pathmeswaran, 2008). This latter statistic is of concern since black and minority ethnic (BAME) 18-24-year-olds make up 19% of the British working-age population (Office for National Statistics, 2011). To attract a more diverse workforce (Tosti, 2019), the construction industry requires a rebranding effort (Sargent, 2020) to create a new inclusive industry brand image.

One effective way that industries can rapidly convey their brand image is through developing attractive, inclusive corporate websites which provide online accessibility to a broad audience of students, potential employees and the public (Bal and Sharik, 2019). Professional societies like the Australian Institute of Project Management, Engineers Australia, the Chartered Institute of Building, and the Royal Institution of Chartered Surveyors represent the construction industry to school leavers and young professionals searching for career opportunities. In order to develop and communicate a positive employment value proposition (Sánchez-Hernández, González-López, Buenadicha-Mateos and Tato-Jiménez, 2019) to attract minority groups, these professional bodies could adopt best practices from the branding and marketing communications literature. Research shows that when underrepresented groups see others of the same identity portrayed on organisational websites, they experience a sense of 'perceived fit', imagining themselves as belonging socially and being able to succeed in that setting (Chapman, Uggerslev, Carroll, Piasentin and Jones, 2005; Hartley and Morphew, 2008).

To date, scant research attention has been paid to how the construction industry conveys its brand image to a global internet audience. Despite the importance of talent aquisition in the construction industry, no known research has been conducted to understand industry branding as a tool for attracting more diverse talent. Drawing on the marketing literature and adopting the lenses of signalling, identity fit and social belonging theories, this study aims to identify whether the industry brand images portrayed on the websites of the two leading international construction professional bodies (identified as Society A and B) are likely to attract non-traditional members of the labour market, namely, women and racial minority groups.

2 Literature Review and Theoretical Model

2.1 Industry Brand Image

The terms 'industry brand' and 'industry image' are often used interchangeably. Studies related to the keyword 'industry brand' are limited in the literature, with only two papers found. One study concerned the rail industry's employer brand, finding that the rail industry lacked a clear brand position **(**Wallace, Lings and Cameron, 2012**).** The other study explored the magazine industry's brand (Sacks, 2014), revealing that the advent of digitisation and multiple new communication platforms has meant that the magazine industry no longer has a clear brand identity. More research has been conducted on 'industry image'. Industry image is defined as "a set of associations that is firmly anchored, condensed, and evaluated in the minds of people concerning a group of companies, which, from the point of view of an individual, supplies the same customer groups with the same technologies for the fulfilment of the same customer needs" (Burmann, Schaefer and Maloney, 2008, p.159).

Industry image includes two important attributes (Keller, 1993). Firstly, functional attributes such as, good prospects on the job market, rapid growth and guaranteed future, international, high degree of job security, social responsibility, high wage increases, high starting salary, and good balance between professional and private life. Secondly, symbolic attributes such as employees who are cheerful, reliable, authentic, have high standing among friends and acquaintances, enterprising, and employees are 'like me' (Burmann et al., 2008**).** The attractiveness of an employer to job seekers is influenced by their previous work experience in a particular industry sector (Wilden, Gudergan and Lings, 2010), so it is important that, the industry brand is positive and well-developed. Research on industry branding remains in its infancy (Edwards, 2010) and there has not yet been any consideration of the role of industry brand image in the construction literature.

2.2 Signalling Theory

Proposed by Michael Spence (1973), signalling theory is based on the job-market signalling model from economics, which view signals as possessing information content. The theory is fundamentally concerned with reducing information asymmetry between two parties (individuals or organisations) (Spence, 2002). The theory is useful for describing behaviour when two parties have access to different information. Typically, one party, the sender, must choose whether and how to communicate (or signal) that information, and the other party, the receiver, must choose how to interpret the signal. Signalling theory involves four key aspects: the signaller, the signal, the receiver and the feedback. Signalling theory has been used to understand employer branding (Wallace, Lings and Cameron, 2012; Wilden, Gudergan and Lings, 2010). For the purpose of this study, signalling theory will be used to explore the role of industry brand image in signalling diversity and inclusion to appeal to minority groups. It is proposed that **t**he industry's brand image will need to signal an attractive employment proposition of inclusivity if diverse individuals are to be attracted to careers in the construction industry (Ehrhart and Ziegert, 2005).

2.3 Identity, Fit and Social Belonging Theories

Identity-related constructs are known to positively influence job choice decisions, and can be used to attract members of diverse labour market groups (Chrobot-Mason and Thomas, 2002). The symbolic attributes of a brand image can be designed to convey that employees in this particular industry are 'like me' (Burmann et al., 2008**)** and therefore signal a perceived match or 'good fit' (Kristoff-Brown and Bilsberry, 2013). The symbolic attributes conveyed in images of different categories of employees that are portrayed on corporate websites can be used to send an overt visual (or sometimes subliminal) signal to the viewer about their level of 'fit' with the organisation and/or industry (Bal and Sharik, 2019). In the case of gender, age and race, a young female and/or non-Caucasian viewer will perceive there is a 'good fit' if they see web images of construction professionals who have diverse identities like their own. Such signals are likely to convey the promise of 'social belonging', the perception of social connectedness in and fitting in socially (Walton and Cohen 2007; Tellhed, Bäckström and Björklund, 2017), which is recognised as a basic human need (Baumeister and Leary, 1995).

3 Research Method

3.1 Sample

The sample selection criterion for this study was corporate websites of leading international professional bodies in the construction industry. After consultation with two industry experts (one in the UK and one in Australia), two professional societies (A and B) were selected. The experts considered these two to be the world's preeminent professional bodies in terms of size, reputation and impact. Although the two societies originated in the UK and are headquartered there, they both have a strong global presence in the Europe, Asia and the Asia-Pacific region. Together, the two societies have a combined membership of over 180,000 members in over 100 countries.

3.2 Data Collection and Analysis

Secondary data was collected in January - February 2020 from the websites of the two societies in the form of images and videos displayed there. Since the identity of an organisation can be defined through its documents (Owen, 2014; Prior, 2003), it is contended that the brand identities of these two organisations are conveyed by the images on their webpages. The characteristics of individuals portrayed in the website images were recorded, noting gender (male or female), race (based on physical features and skin tone: Caucasian i.e., white skin or non-Caucasian, i.e., non-white skin) and career stage/age (early-career, aged 18-39; mid-career aged 40-49; and late-career, aged 50+ years). Career-stage/age was estimated by taking multiple observable features into account; including appearance of skin (smooth and supple versus wrinkled), body shape, clothing style, hair style and colour. To minimize subjectivity in interpretations and to ensure consistency in the analysis of results, the characteristics of individuals (portrayed gender, race and career stage) were coded separately, then compared and discussed by the first two authors. For each website, the images on the homepage of the site were analysed (first-level links). Then, each clickable link or tab on that page was followed (for example; a link to 'About Us' or 'News & Insight' or 'Events') and all images on that second-level link were also analysed. All links on the website were followed to ensure that all images on the website were analysed. Sometimes this meant that images at up to seven-level links were noted. When a link on the website directed the user to a third-party link (e.g., to a website of an external industry training provider or a blog managed by another organization), data collection stopped at this point and images on the third-party webpage were not recorded.

4 Results

4.1 Gender Diversity

Content analysis of the images on the 2 professional societies' websites revealed that there was a disparity between them in terms of the visual representation of genders (see Table 1). Society A signaled greater gender inclusion: 52% of all individuals depicted were male and 48% were female. The almost equal gender proportions were very different from the results obtained for Society B where only 1 in 4 images on their website portrayed females.

Table 1. Image portrayal of males and females

Professional society	Males	Females
A	126 (52%)	117 (48%)
B	96 (72%)	36 (28%)

4.2 Age/Career Stage Diversity

Content analysis of estimated age of the individuals in the images revealed further disparities in how different age groups were represented. Most (45%) of the individuals (both male and female) represented in the images on Society A's website were in the early stages of their career (aged 18-39) followed closely 40% in their mid-career stage (aged 50-49); with a relatively low proportion (15%) in their late career (aged 50+). This pattern of age and career stage portrayal was consistent for both genders on Society A's website (see Table 2).

Table 2. Image portrayal of males and females at different career stages

	Males			Females		
Society	***Early career***	***Mid career***	***Late career***	***Early career***	***Mid career***	***Late career***
A	50 (20.5%)	48 (19.7%)	28 (11.5%)	60 (24.6%)	49 (20.2%)	8 (3%)
B	27 (20.4%)	27 (20.4%)	42 (31.8%)	9 (7%)	21 (16%)	6 (5%)

As shown in Table 2 above, there were evident gender differences in career stage/age portrayal between the two societies. On Society A's website, people estimated to be in their early-careers made up the most frequently displayed images for both genders (M=20.5%; F=24.6%), followed closely by mid-career portrayals (M=19.7%; F=20.2%). Society A's results contrasted with the age/career stage of the individuals portrayed on Society B's website, where the largest proportion of individuals were either in their mid-career (36.4%) or late-career (36.8%) stages. Only 27.4% of Society B's images portrayed people estimated to be in the early career stage. For males, the majority of individuals on Society B's website were in their late-career stage (31.8% of overall images), in contrast to its female images, where mid-career images (16% overall) dominated.

4.3 Racial Diversity

When examining the racial diversity of the individuals represented on both professional societies' websites, the results showed that individuals of non-Caucasian appearance were in the minority (see Table 3). Of all the individuals portrayed on Society A's website, 90% were of Caucasian appearance. Society B's website showed similar results, where 89% of all individuals were of Caucasian appearance. Only a very small proportion of individuals portrayed were of non-Caucasian appearance (Society A, 10%; Society B, 11%).

Table 3. Image portrayal of races

Society	Caucasian	Non-Caucasian
A	219 (90%)	24 (10%)
B	118 (89%)	14 (11%)

5 Discussion

The findings of this study suggest that the world's leading construction professional societies have made some advances in modernizing their brand, but they still have some way to go in creating an inclusive brand image. In terms of gender, both professional societies are presenting an *aspirational* portrayal of gender participation in the construction workforce, since current female participation rates in the UK stand at only 1 in 8 employees (Keir, 2019). Society B's website images portray a 1:4 female to male ratio. However, Society A is more ambitious in its aspirations, portraying a near equal proportion of females and males in their webpage images. Interpreted through the lenses of Signaling theory and the Identity, Fit and Social Belonging theories, it appears that Society A is overtly signaling (Spence, 2002) that it aspires to achieve gender equity in the industry by conveying that females equally belong and fit (Kristoff-Brown and Bilsberry, 2013) in their organization. Both professional societies have made progress in portraying that women belong in the wider construction industry.

In terms of age diversity, Society A portrays an image of construction as a vibrant, youthful industry. Their website sends signals (Spence, 2002) about belonging (Tellhed et al., 2017): i.e., that young, early career individuals of both genders are welcome in the industry. This portrayal suggests that Society A's marketing strategy is aimed at attracting the future generation of workers, i.e., students searching the internet for information on careers in construction, or young professionals seeking an early career change. In contrast, Society B shows a bias towards presenting people more established in their profession (i.e., late-career males and mid-career females), which possibly reflects its membership profile. However, it is also possible that the proportion of older male images on the website of Society B has been skewed by a historical timeline displayed prominently on their website with portraits of important members spanning across three centuries. Due to the social norms of the times, the images from the 19^{th} Century were male and mostly old. Whilst no doubt the timeline was intended to signal the solid historical standing of this austere professional body, it could also be perceived as reinforcing the entrenched image of the construction industry as a rather staid, unprogressive, old, white male domain. The signals sent by the images on Society B's website are unlikely to appeal to high school students or to young people searching the internet for exciting career options. They are less likely to perceive Bal and Sharik's (2019) 'good fit' or to believe that they 'belong' (Walton and Cohen 2007; Tellhed et al., 2017) in the construction industry portrayed by Society B.

The situation with regard to the portrayal of race on both societies' websites is more problematic. Although many construction companies have expressed an interest in increasing the racial diversity of their workforce (Turner and Townsend, 2020), the findings of this study show that this intention has yet to be enacted by the industry's leading professional societies. Despite the racial diversity in many of their memberships' countries, it appears that individuals of diverse heritage are not being adequately represented on the websites of either of these two international construction bodies. Although the proportion of non-Caucasians represented in their web images is slightly higher than the current representation in the British construction industry (Chaudhry, 2014), the low representation on their websites fails to present an aspirational, inclusive image to signal to people of diverse racial backgrounds to feel that they fit and socially belong. The sparse depiction suggests that these two societies' website marketing strategies are not yet focused on increasing cultural diversity. This omission represents a liability since research has shown that companies with executive teams with high cultural diversity are one third more likely to produce industry-leading performance (McKinsey, 2018). This current study's findings suggest that the construction industry is failing to reap the potential profitability benefits of racialdiversity. Since both these construction professional societies are prominent in non-Caucasian countries in South Asia and Asia-Pacific, in terms of signaling theory (Spence, 2002) the relative lack of non-white images conveys a rather exclusive British/Euro-centric focus. Interpreted through the lenses of Identity, Fit and Social Belonging theories, this lack of racially diverse images is likely to convey the message that people of colour do not fit or belong in construction (Walton and Cohen 2007; Tellhed et al., 2017) since they are unable to see people like themselves represented there **(**Burmann et al., 2008**).**

5.1 Limitations and Future Research Directions

Although this research has produced a new understanding of the construction industry's current brand image as presented on two of its leading professional societies' websites, the study has several limitations. First, the study examined the websites of only two professional societies.

However, these bodies were selected after consultation with subject matter experts who advised that they were the major professional bodies recognised in the UK, Europe, South Asia and in Asia Pacific. Future research could include professional societies from North America and other geographical regions to compare the industry's brand image across a broader range of countries. Second, this study looked at the diversity and inclusiveness of the construction industry's brand image only in terms of gender, age, and race. Future studies could explore other diversity categories such as social class, disability, religion or sexual orientation. Third, although the first two authors compared and discussed the career-stage of each facial image, it is possible that some judgement calls were not accurate. Finally, as this study has focused on diversity and inclusion in only one particular industry (construction), these findings may not be generalisable to other industries. Nevertheless, researchers may find it useful to employ this novel method of website image content analysis to explore diversity issues in other industry sectors.

6 Conclusion

The findings of this web image content analysis study suggest that the two leading construction professional bodies are portraying differing images of the construction industry. Society A appears to be actively appealing to the upcoming generation in terms of depicting an image of construction as a young workforce where both males and females equally belong. This organisation is showing awareness that gender equity is valued by the youngest-born generation, Gen Z. However it seems unaware that this generation also values equitable representation of all minorities, including racial groups (Scholz and Rennig, 2019). Similarly, the older, more history-focused professional society, Society B also seems to be unaware of the importance of racial diversity and inclusion in the workplace. In respect to gender, age and race, this more austere organisation is less aspirational in its marketing, representing the traditional status quo by upholding the image of the construction industry as an old, white, male club (Chaudhry, 2014). Although one of the two leading professional societies has made substantial progress in terms of its attractiveness to women, there is still more work both these societies can do to positively rebrand the image of the construction industry as more diverse and inclusive. Both would benefit from advice from the branding literature and from marketing professionals on how to revamp their web presence to include more racially diverse images as signals to improve the perceived fit and social belonging of under-represented minorities.

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Reconstruction Technologies: A Study over the Effects of Construction Technologies on Post-Disaster Housing Recovery

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Abstract
Post-disaster housing recovery is a complicated process. Successful housing recovery depends on the relationships between several factors, such as resources, new structures, cost and material type. Housing recovery may take several years to complete. The process is often classified into three major stages including emergency sheltering (a tent, host family or etc.), transitional sheltering and the permanent housing. A two stage recovery process also can be defined by extending sheltering (the first stage) and by advancing the third stage through rapid construction, which will have several benefits. This scenario can be more achievable today than before because of advancements in related technologies, such as new structural systems, integrated transportation systems, and the progress in dealing with non-technological factors. Some features in the structural systems and construction technologies can lead to rapid construction and result in improvements in the post-disaster housing process. This paper aims to evaluate the potential of four new structural technologies for rapid housing reconstruction. The structural systems are then compared based on their construction time and other factors which are notable in post-disaster construction. The main purpose of the paper will be to show how these new construction technologies might be useful in post disaster situations.

Keywords
Post-Disaster Housing, Rapid Construction, Construction Technologies, Emergency Shelters, Reconstruction.

1 Introduction

Shelters are an emergency need in the aftermath of a disaster, they provide the survivors with their most basic needs. After this stage the process of recovery should start quickly and this is depended on quick decision making over several related factors. Some of these critical factors include the place to rebuild houses (relocation issues, land tenure, accessibility, liveability, future hazards and…), how to build (construction methods and technologies, materials, human resources, design and…) and financial issues (Johnson and Lizarralde 2012).

Quarantelli (1995) has defined four main stages for housing recovery, which consist of emergency sheltering, temporary sheltering, temporary housing and permanent housing which are usually summarized into 3 stages. 'Emergency sheltering' is used during the height of the emergency and in the immediate aftermath; it may be as simple as a plastic sheeting, staying at a neighbours' house, or in a mass shelter, such as stadiums or urban shelters built for war or cyclone. In the 'temporary housing' stage, families are able to restore their daily activities, such as school, work, food preparation, and other social functions, however, in a temporary place, such as a small prefabricated house or a rented apartment. 'Permanent housing' is the final stage in housing recovery, when families have replaced their pre-disaster housing conditions with a long-term solution, similar to past, or of better quality (Johnson and Lizarralde 2012).

Among these stages, the permanent housing is a critical and time-consuming stage in the post-disaster recovery process, and according to the Florida Division of Emergency Management (FEMA) it may take up to 5 years to be completed (FEMA 2005).

Accelerating the permanent housing process can enhance the quality of recovery by reducing the consequences of living in inappropriate spaces. One of the most important reasons for providing a quick recovery is to prevent the unsafe rebuilding of the houses by the affected people or their self-resettlement in the disaster prone areas which will replicate the previous vulnerability. The desired quick recovery would be result of a complicated post-disaster management between interconnected influencing factors; among these factors which consist of social, economic, environmental and other determinatives, the role of construction systems and related technologies is also of high importance (Celentano et al. 2018).

The significance of this research is rooted in the harmful consequences of post-disaster housing prolongation on the affected people and the capabilities of rapid construction on reducing them. New structural technologies suitable for rapid construction, can be used in the two stage reconstruction scenarios and result in remarkable improvements in the recovery process. According to Davis and Alexander (2016) pre-plans for recovery and rapid construction technologies are essential for the two stage recovery and searching within the literature reveals that, there are very few researches done over this correlation. This research gap has led to lack of novel solutions in post-disaster construction. The novelty of this study is in comparing some rapid construction technologies in the context of post-disaster construction.

During last decades a lot of rapid affordable housing concepts has been introduced and implemented worldwide which have been successful or not. Some of the main characteristics needed for these concepts to be more successful are discussed in the next part.

2 Post-Disaster Housing Characteristics

In this section, some of the previous findings of post-disaster housing researches and practices are reviewed briefly in order to extract the criteria for evaluation of related developing technologies. There is an apparent emphasis on the importance of considering the survivors or affected people and communities as the main stakeholders of the reconstruction process. The success of a post-disaster reconstruction project is mostly depended on being accepted and executed by the community (Davis and Alexander 2016, Charlesworth 2014, Barenstein and Leemann 2013).

2.1 Main Requirements

2.1.1 Costs

Post-disaster housing resourcing and costs have been always a critical issue and depending to the location and country can be a demanding parameter, especially, where it meets annual inflation or the increase in overall construction cost as a consequence of the disaster (De Silva 2012).

Recent large scale disasters have shown the importance of the availability of proper and adequate resources, such as building materials and construction practitioners, and its effects on the results of the reconstruction process (Chang et al. 2012).

The international organizations and governments in many countries are capable of contributing limited budgets on post-disaster humanitarian housing projects. Therefore, as we see in practice, there is a clear gap between the tendencies and solutions presented by the innovators and the possibilities at society in an extensive emergency (Charlesworth 2014).

2.1.2 Participation Capability

Housing reconstruction success is depended on involving the users in the design phase and the construction process. In other words, building systems and technologies more capable of users' participation in the construction process has a higher chance of leading to a successful housing recovery. Researches show that collaborative participation can solve complex, time consuming problems such as budget planning and so on(Charlesworth and Ahmad 2015).
Innes and Booher (2004) believe that participation should be considered as a collaborative interaction and it should incorporate citizens, organized interests, profit-making and non-profit organizations, decision-makers and public administrators in a system in which all components are interacting and influencing the others and all are acting independently at the same time.

2.1.3 Construction Time

Permanent housing as mentioned before is a time consuming process that can take up to five years to be completed (FEMA 2005). Reviving livelihoods which is an important part of post-disaster recovery is depended on the housing reconstruction timeframe. Comparing 7 determining factors, Tas et al (2010) indicates the time as the most determining/restricting problem in the design and construction of post-disaster permanent housing through the studies over an earthquake in turkey (see figure 1).

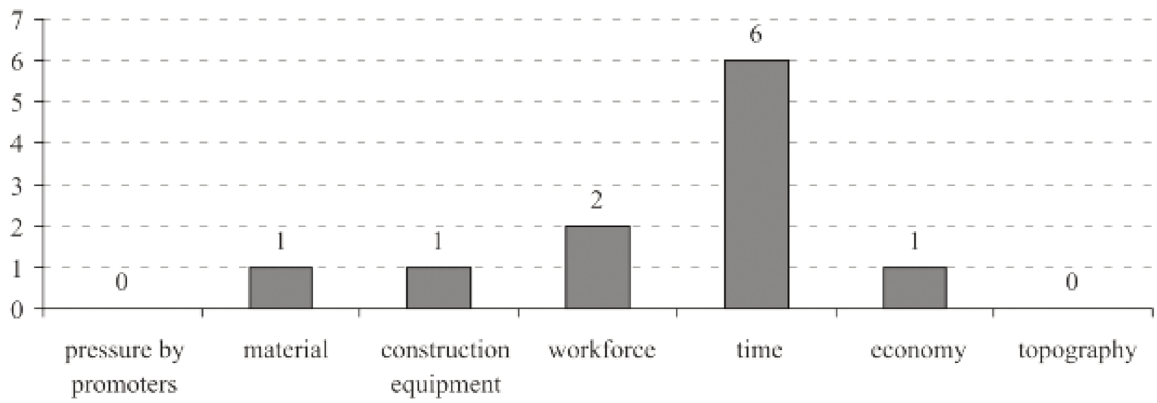

Figure 1. Ranking of the influential factors in permanent housing.
Source: Case study of Kocaeli earthquake in Turkey (Tas et al. 2010)

There are also important advantages caused by shortening of the construction time, such as decreasing the extra expenses caused by inflation and changes in materials and workforce costs (Gunawardena 2014).

2.1.4 Logistics

The success rate in logistic operations in a post-disaster situation has significant influence on decreasing the negative social and economic impacts in humanitarian activities, and on the quality of care as well. The logistics are also a significant part of every sheltering and housing process (Bastos et al. 2014).
In order to have a successful rebuild after disasters, the self-reliance of the community should be considered as an important factor. Utilizing vernacular materials, facilities and local means of building houses as well as noticing the local contextual features have been repeatedly

emphasized within the literature (Oxfam 2003)

2.1.5 Design (Functional and Cultural Acceptance)

Cultural issues and the design acceptance of post-disaster housing projects have been under debate for a long time. Inappropriateness of design is rooted in various factors such as misunderstanding of local needs by executive agencies which may lead to beneficiaries' refusal of inhabiting the new houses, making changes in them or selling their components. Inappropriateness appears in the size and form of houses, spatial design, interior design of the houses and the surroundings, material usage and infrastructural plans. In most cases the importance of consultation with beneficiaries is recognized by the agencies but it is not sufficient and hence, reconstruction project failures are likely to continue despite spending huge amounts in budget and time (Ahmed 2011).

2.1.6 Liveability

In a study on post-disaster done by the Humanitarian Practice Network, housing is defined as "the process of providing permanent dwellings and the related physical, social and administrative infrastructures". Houses are built as the result of this process, while their design and materials as well as their function vary among different cultures. The definition emphasizes on liveability and the local context as significant parts of the housing process expressing a human-centred approach (Barakat 2003). In other words as Charlesworth and Ahmed (2015) have indicated, the most effectiveness of housing recovery process is not achieved unless it includes the community requirements and makes appropriate connections to infrastructures and services which leads to the creation of true livelihoods.

2.1.7 Resilience

Post-disaster housing recovery shouldn't be summarized in replacing the destroyed house. Instead, as evident in the literature, it should lead to a safer and more over, a more resilient house which doesn't simply recreate the vulnerable condition which existed before the disaster, and provides an opportunity to build back better (Charlesworth and Ahmed 2015).
In case of the success in Building Back Better which leads to a more resilient community, a sense of security is resulted which stems from the fact that the buildings and community are safer than before. In such community, a new normal stage appears that includes higher readiness for confronting future disasters with buildings being more capable to cope future threats. Future-proofed communities in this scope are the result of considering the recovery process as an opportunity for building back better (Mannakkara et al. 2019).

2.1.8 Environmental Effects

Climate change is increasing natural disaster rates and the built environment considering both construction industries and buildings' energy consumption are responsible for the biggest part of CO_2 emissions which is the main reason of the climate change (Ritchie and Roser 2017). As mentioned before, post-disaster housing is an opportunity to build back better, so, it can be an opportunity to reduce the environmental footprints of the buildings, from using sustainable materials to reducing energy consumption and carbon footprint.

2.2 Recent Rapid Construction Technologies

In this section, four structural technologies which are mostly developed in the last decade, are classified and compared. They are selected because they are illustrations of the main types of new rapid construction technologies. The criteria for choosing these technologies (among over 15 other technologies studied), is their simplicity, costs, ease of transportation and construction

time (all of them can be used for completing a house in less than 10 days). These criteria are extracted from post-disaster housing characteristics in the previous part.
According to Nadeem et al. (2021), the rapid and economic construction by prefabricated modular steel structures can be the solution for addressing the growing need for affordable housing. This category is chosen because of the remarkable features such as fast installation, ease of transportation, high precision and strength which are explained in the next part. Another one of the recent technologies capable of building shelters and houses in a limited time is 3D printing. Previous researches show that 3D printed structures have the potential to be used broadly in post-disaster construction. This may be more achievable in near future (Gregory et al. 2016, Dancel 2019). The third structural system chosen in this research is cast-in-place concrete structures with integrated formwork. Concrete is one of the most used materials in construction. This fact is rooted in the strength of it, the ability to get different shapes, high availability and low cost. There are new types of concrete with various components making them stronger, lighter and eco-friendly (Ogundipe et al. 2021). And the last technologies to be discussed are composite and hybrid structural systems. Composition of expanded polystyrene (EPS) and concrete coating can be a notable option for rapid construction and affordable housing (Sulong et al. 2019).
This selection does not cover all of the new structural technologies and it is more focused on structures built from steel and concrete materials.

2.2.1 Modular Prefabricated Structures

Modular and prefabricated structures are useful concepts broadly used in construction. The extensive substantial characteristics of modular structures allow for rapid construction through off-site construction. Modular structures can include all components of a building such as stairs, lift shafts, rooms, corridors, services and façades. The mass production of these modules has valuable advantages of higher quality and lower price. The shape and size of modules can be different and just limited to transportation facilities. Due to incorporating the façade and interior components to modules, the on-site work is minimized. The modules have the ability of being detached and reused in other places. Modular structures can reduce the construction time by 50 percent compared to on-site construction technics and this makes the building habitable sooner (Lawson et al. 2012).
Recently Vectorminima, a new Canadian company has developed a highly-optimized volumetric structural solution that minimizes material, manpower and setup time, both in the fabrication plant and on the jobsite. The new structural system with commercial name of Metaloq is a Cold Formed Steel (CFS) module framing system (Fig. 2 left).

Figure 2. Metaloq modular framing system by Vectorminima.
Source: Metaloq system (Ryder 2021)

The remarkable features of this modular framing system include innovative connections (resulting in fast and simple installation), high precision, minor shipping space, low weight (60-80 kg/m^2), building in height (up to 10 stories), integrating mechanical, electrical, and plumbing (MEP) connections into the units and using recycled steel (Ryder 2021).By prefabrication and mass production of the modular structures, a large number of houses can be built and installed in a relatively short time and this can accelerate the process of reviving livelihoods in the affected communities.

2.2.2 3D Printed Structures

The first 3D printer was invented in 1984 and since then, 3D printing has become one of the fastest growing technologies in many industries. Since 2014, the real revolution in construction industry has started and by printing the first house, a new chapter in construction technologies has begun (Hager et al. 2016).

Early research and development in 3D printing for construction have been under way since 1995. Around 2000, Behrokh Khoshnevis's team at USC Vertibi began to work on building scale 3D printing of cementitious and ceramic pastes, encompassing and exploring automated integration of modular reinforcement, built-in plumbing and electrical services, within one continuous build process. The elimination of formworks was one of the major benefits resulted by the development of 3D printers (Sanjayan and Nematollahi 2019).

In recent years, 3D printing technologies have been tested for construction of buildings, bridges and architectural forms. In 2018, the Italian company Wasp printed a small house using raw soil, straw, lime and some natural waste materials from rice without using cement. The importance of the project was in using large proportion of materials from the site and almost zero environmental impacts. The company is working on another sustainable habitat project called Tecla since 2019 which is the first house to be entirely 3D printed using locally sourced clay (Stevens 2021).

Figure 3. 3D printed structure using local resources.
Source: TECLA sustainable habitat project by WASP (Stevens 2021).

2.2.3 Cast-in-place Concrete Structures

There are various methods for building on-site bearing concrete walls which provide both structural and dividing walls (in terms of separation and space creation) at the same time. These methods include shotcrete and cast in place technics like traditional formwork technics, ICF technology, Moladi formworks technology and so on.

Figure 4. A cast-in-place structural system. Source: Moladi formwork (Otieno 2021)

Cast-in-place concrete can be economically feasible. Much of the cost factor is related to the depth of the structure. Shotcrete is a good option when wall sections range in thickness from 6 to 12 in. Both of these options are usually cost-effective. Thicker sections of concrete walls require traditional concrete forming to maintain the cost-effectiveness (Woodson 2012). Cast-in-place concrete requires formwork to define its shape during the curing process. The most common materials used for formwork include plywood and milled lumber, metal formworks, and plastic formworks (Kubba 2010). Moladi formworks are reusable (up to 50 times) and they can be recycled after that. In this system, lightweight panels are configured into a mould which forms a house of any size and the concrete is placed at once. The thickness of smooth walls created in this method are 10 or 15 centimetres (Otieno 2021).

2.2.4 Composite and Hybrid structures

Generally, a composite structural system is not a new concept (for example steel-concrete composites have been used for decades) but in the recent years a light-weight composite system including EPS with cementitious coating has been developed for rapid construction that has shown remarkable advantages (Fig. 5 left).

Figure 5. Left: SABS system, an innovative EPS composite structure. Right: hybrid Timber Frame (HTF) modular structure. Source: Strata International Group, Inc. (SABS 2021) and Hybrid timber wall system (Casagrande 2021)

SABS is a composite building system that uses EPS as the core material for all of the structural elements. The EPS is then sprayed with a composite coating made up of a specific mixture of sand, cement, glass fiber and additives which together, create a structural shell that meets all related testing protocols (SABS 2021). Containing about 98% air, EPS also presents excellent insulating and shock absorbing features (Sulong et al. 2019).
In another innovative modular structure project, a recent research by Casagrande et al. (2021) at National Research Council of Italy has developed a new timber construction system called "Hybrid Timber Frame" (HTF). The system combines cross laminated timber (CLT) and an innovative connection system which has been specifically developed to increase the speed of assembling and dismantling of walls. This connection system is preinstalled at the four corners of the panel and, during the assembling phases, it simply requires to be bolted to the foundations without additional screws or nails. The innovative anchoring system, enables each wall module to be removed and re-used in a different location with few on-site operations (Fig. 5 right).

3 Research Methodology

This study is based on an extensive literature review on two main categories. The first category is post-disaster construction characteristics and requirements. The second one is recent innovative structural systems compatible with the first part. The selected technologies are also capable of being used in rapid construction and this feature makes them suitable for a specific two stage model of housing recovery.

The main approach in this research is evaluating the potentials of different structural systems for being used in post-disaster circumstances. This is done by making comparisons based on the data provided by the structural manufacturers and making a conclusion through logical reasoning. In the next step the information is classified and presented in a table and the data is analyzed.

The structural systems are compared based on seven quantitative and qualitative factors including main materials, laborers, construction time, logistic features, design capabilities, environmental considerations and other distinct features. Some features such as liveability and resilience are defined in connection with the context, location and infrastructures, therefore, the structures alone cannot be compared based of them.

4 Findings and Discussion

In this section, four structural systems introduced in the second section are compared based on their major features, and the results are shown in table 1. Metaloq modular frames are capable of reducing the costs by 25 percent due to short installation time and using less steel and ironwork compared to conventional steel structures. 3D printers also have the potential to make remarkable savings by autonomous construction, this can reduce the costs to near zero when using local soil as the main part of mortar. Moladi plastic formworks are capable of reducing the costs by 30% in comparison with traditional brick and mortar methods (Ryder 2021; Stevens 2021; Otieno 2021).
In terms of construction time and manpower, Each Metaloq module is assembled in two hours by skilled workers and connected to the other modules in 18 minutes, which includes only the structure and not walls. Moladi formworks are simple applicable solutions for developing countries with less cost and higher strength compared to traditional walls. This has become a handy method that can give an acceptable result in a short time using simple laborers. Gaia 3D

printed house was built in ten days and the more recent Tecla project was printed in 200 hours. However there have been better records in 3D printing concrete industry, for example the BOD 2 printer by COBOD Company has the potential of printing 100 cm per second which is equivalent to printing 10 tons of concrete per hour (Ryder 2021; Stevens 2021; Otieno 2021; Williams 2021).

In order to build a 45 m^2 space in two days using Moladi formworks, six to ten people are needed. 3D printers need few operators, and the Metaloq modular frames has decreased the need for ironworkers by using an innovative connection at structure joints, so that they are installed quickly using simple tools and few workers. 3D printers almost eliminate the need for participation of survivors and local people, except in concepts like the Tecla project which relies on local materials that can be delivered and sorted by people. 3D printers are capable of building various forms and this can meet the users' needs in future (Ryder 2021; Stevens 2021; Otieno 2021).

Although steel industry has a significant carbon footprint, Metaloq modular frames minimize the steel use and they have been made by recycled steel, so they are affecting the environment less than other steel frames. Cast-in-place concrete structures and most 3D printed structures are based on cement which is also one of the main sources of carbon emissions, but, in concepts like Tecla, the carbon foot print is near zero thanks to the sustainable mortar made from soil and bio-materials derived from rice cultivation waste. However, it seems to be designed as a basic home for poor countries which form a large part of the world population and it doesn't fit the needs of urban people in developed countries.

In terms of logistics and transportation, all four technologies have remarkable advantages. Despite conventional modular houses, Metaloq structural elements are transported in pieces and not boxes, which allows for more of them to be fitted in a container. In 3D printing technologies, by delivering the printer facilities and using local materials the need for transportation facilities is minimized and in Moladi system, the lightweight formworks can be delivered easily and reused several times.

Table 1. Comparing housing capability of four different structural systems

Features	Metaloq system (Modular Prefabricated steel Structure)	WASP 3D, TECLA project (3D Printed Structure)	Moladi formworks (Cast in place concrete)	SABS composite building system
Main materials	Steel profiles and wood/ drywall	Mortar (based on soil)	Concrete and reinforcement	EPS and special concrete coating
Laborers	4 skilled workers	2 skilled workers/ operators	6-10 simple workers	4 skilled workers
Construction Time	2 hours (one module of structure only)	10 days (Walls)	2 days (Walls)	1 days (Walls)
Logistic features	The most compact form of Modular structures	Reusable printer facilities and Local materials	Light and reusable Plastic formworks	Very light main material
Design Capabilities	Dependent on the module design	Free forms	Dependent on the formwork shapes	Varity of plans No limits
Environmental Considerations	Reducing steel amount Using recycled steel	Sustainable local materials	Reusing and recycling plastic formwork	Fully recyclable
Distinct feature	Multi-story construction (up to 10)	Using local soil as main material	Simple technology	Light, strong Easy to build

Source: Data in the table is approximate and retrieved from the producers' websites (Kubba 2010, Ryder 2021, Stevens 2021, SABS 2021)

The main advantages of modular structures include prefabrication, quick installation and land-saving resulted by multi-story construction. Modular structures also benefit from the offsite construction in a controlled environment that has advantages including the higher quality, higher efficiency, higher safety and less wastage (Kolo et al. 2014). In 3D printed structures the autonomous construction, low costs and the variety of forms are notable advantages (Sanjayan and Nematollahi 2019). In cast-in-place structures, the simplicity of the process and materials, the fast construction and the high strength of the structure are remarkable points. And finally, in coated EPS composite structures, the light weight and resistant material, capable of shaping different forms in a short time is the remarkable point.

5 Conclusion

According to the literature, several factors are influential in the success of post-disaster housing projects. From decision making on where and how to rebuild, to financial management and social issues. In this complicated context, structural advancements can help to reduce the construction time as well as construction costs, and to improve the other features described as the characteristics of an acceptable and successful post-disaster housing. Four structural systems with high capabilities in post-disaster construction are compared in this paper based on the main features required for a successful housing recovery.

The research shows that the comparison between structures is complicated and this is rooted in the different characteristics of each structural system which makes it suitable for different circumstances. Moreover, the 3D printed structures are still in basic levels of their progress and some of major built samples are in fact prototypes and will be more efficient after further developments. The findings also show that each structural technology has unique features making it suitable to meet some parts of post-disaster housing needs, from time and cost savings to land use reduction and environmental considerations. Comprehensive knowledge of such technologies may help governments, people and organizations practicing in post-disaster construction to make appropriate decisions in accordance with peoples' needs. In this approach technologies are looked as a means of creating people-centred solutions for reconstruction.

There have been limitations in this study, including insufficient information in some features of the mentioned technologies, different and far locations of each technology origins and the Covid-19 pandemic which limited site observations and in-person data collection.

Further research can be done in comparing the structural systems based on their function in different disaster types and also their compatibility with different regions of the world. The capabilities of new structural systems in addressing design acceptance issues is also a potential subject for further research.

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The Impact of New International Waste Policies on the Australian Construction and Demolition Waste Stream

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Abstract
The launch of new waste policies by developing nations that ban waste import from other countries has put pressure on the waste management and recovery sector in Australia. Hence, the Australian state and territory governments have started to find solutions to mitigate its impact. However, the process to obtain such solutions need to be informed and backed by the industry key stakeholders' outlook. Therefore, this study aims to find out how various stakeholders perceive the impact of new waste policies and corresponding solutions. A cross-sectional (online) survey of a purposive sample of C&D waste management stakeholders operating in different Australian jurisdictions was conducted from June to September 2019. The results that are based on 132 collected responses showed that a majority of participants opined that the new policies have a positive impact on the Australian industry in the long run. The participants indicated that developing a domestic market for C&D waste is the best response to the new changes. Besides, the study presents open-ended responses on the nature of new policies impact on the Australian waste management and resource recovery sector. Lastly, the study provides a set of mitigating strategies extracted from academic sources to resolve the issues arising from implementing these policies. It is expected that the findings of this study assist policymakers and authorities in local agencies and government departments with providing the best solutions to the potential issues. Such findings would contribute to developing sound policies that do not negatively affect the key stakeholders.

Keywords
C&D waste management, environmental protection, government, regulations, recycling.

1. Introduction

The construction industry in Australia has grown significantly in the past two due to population growth, migration, and expansion in the tertiary education industry. The growing population has necessitated extensive property development, better public transport, and improved infrastructure. The range of construction activities involves businesses engaged in the construction of residential and non-residential buildings, engineering structures, and associated trades and services (ABS, 2006). The industry is identified as the fourth largest contributor to Australian growth domestic product (Trading Economics, 2018); with more than 1 million employees working in the industry. Unsurprisingly, this construction quantity brings about a considerable quantity of construction and demolition (C&D) waste. In 2017-18, approximately 27 Mt of C&D waste was generated in the Australian construction industry, accounting for 44% of the total core waste generated in Australia (NWR, 2020). Due to the massive worldwide construction, the management of such waste materials has become a priority in many developed and developing countries as their mismanagement are found to have inflicted environmental, social and financial consequences (Shooshtarian et al., 2019a).

1.1. Literature Review

One of the issues that have a mixed impact on Australia's waste and resource recovery system is the introduction of a new waste policy enforced by foreign countries such as China's National Sword Policy' and 'Green Fence 2013' (Earley, 2013, Carr et al., 2019), that aim to ban the import of certain foreign waste materials, with a strict level of contamination, to benefit the national policy environment (Healy, 2018). China has long been the main end-market for recycling materials for developed countries such as Australia. It is reported that the import of recyclables partially has fuelled China's economic boom. In 2016 alone, China imported the US $18 bn of recyclables (Ritchie, 2018). This policy's new restrictions have presented challenges for the waste industry (Shooshtarian et al., 2019b). The waste producers can no longer avoid landfill levies or recovery operation fees by shipping waste overseas. Although this policy only focuses on certain types of metals, textiles, plastic and not all C&D waste, the announced level of acceptable contamination is a real hurdle to exporting C&D waste from Australia. Some Australian organisations have claimed that the ban diminishes the ability of material recovery facility (MRF) operators to market sorted recyclables, and consequently stockpiling, and more landfilling will likely occur (Senate Environment and Communications References Committee, 2018).

At the same time, this new policy comes with some advantages for Australia's waste recovery industry. In a series of interviews with experts at Melbourne Law School, University of Melbourne (Leggatt, 2018), it was stated that '*for too long we have looked elsewhere to deal with our waste problems*' and "*it's probably a little bit overplayed in some parts of the media, but I also think that it's a long-term issue that needs to be addressed*". While interim solutions such as considering other waste destinations (e.g. Vietnam, Thailand, India, and Malaysia) on the government's radar, it seems that other strategies have to be pursued for the long term.

The effective mitigation of this issue through sustainable solutions presents an opportunity to shift Australia's perspective from simply passing the issue of waste on through overseas waste recovery operators. This change also triggers a conceptual shift from linear waste management approach to a circular economy of waste resources. Previous studies have adopted contingency theory to build circular economy and resource efficiency (Lahti et al., 2018, Kortmann and Piller, 2016). This theory assists decision makers in understanding the management challenges associated with implementing the circular economy. Notably, it conceptualises the need for structural adaptation through a realignment to fit with the new conditions.

From this new perspective, further analysis of the waste recovery regulatory framework, investment in infrastructure, and domestic market development would be beneficial. Several submissions to Senate Environment and Communications References Committee, 2018 inquiry stated that there had been a preference to ship unprocessed waste overseas rather than incurring waste recovery operation fees and landfill levies. Relevant organisations such as the National Waste and Recycling Industry Council suggest that there must be immediate, short, medium and long terms responses to this issue (Waste Management Review, 2018); in the immediate term, for instance, two large Australian states, namely New South Wales (NSW) and Victoria committed to AU $47 m and $13 m financial support, respectively. For the medium-term, the federal parliament passed legislation banning the export of unprocessed waste overseas via the Recycling and Waste Reduction Act 2020 (Downes and Read, 2020).

1.2. Aim of the study

Given the pressure of such policies on the waste recycling industry in Australia, this research study explores the key stakeholders' perception of the impact and to identify the best approach to tackle this issue. The study also informed a larger research project entitled *'A National Economic Approach to Improved Management of Construction and Demolition Waste'*, conducted at RMIT University and supported by Australia Sustainable Built Environment National Research Centre. This project endeavours to foster a holistic national approach to address C&D waste issues.

2. Methodology

Surveys are considered an appropriate data collection method to obtain information from primary sources using well-planned questionnaires and are widely used by researchers within the construction management domain. In this study, an online questionnaire survey was considered the most appropriate modality for the same reasons as Saez et al. (2013), that they are an efficient and flexible approach that ensures participant confidentiality. In addition, conducting questionnaires online is now the most common delivery method, which means participants are familiar with the approach and more likely to respond

2.1.Data collection

A cross-sectional survey of a purposive sample of stakeholders of C&D waste management operating in different jurisdictions of Australia was conducted from June to September 2019. According to the Australian National Statement on Ethical Conduct in Human Research (Australian Research Council, 2007) and RMIT University Human Ethics Committee instructions and requirements, recruitment was executed. The project industry partners including the Waste Management and Resource Recovery Association of Australia (WMRR) and the SBEnrc assisted with the recruitment process by providing their network contact details. WMRR's members consist of businesses and experts who are engaged in recycling and waste management activities. SBEnrc members include experts from government, industry and academia who are involved in issues around the management of the built environment notably C&D waste management. The former organisation is the industry partner of the project presented in this paper, and the latter funded the research project. Since the project study aimed to capture responses from a wider range of stakeholders, therefore, in order to increase the potential response rate, one of the main selection criterion used was an adequate experience in dealing with the management of waste in Australia. Email communication was the method of recruitment. An email, including the online link to the survey and the project's information sheet, was sent to a list of participants compiled by the research team that included 250 individuals with relevant experience in the waste management and resource recovery sector. The list consisted of members of the two organisations as well as other experts separately identified by researchers. The research team sent a reminder email to those who did not respond to the first round of the survey. Participation in this study was voluntary and a completed survey implied informed consent.

The target population consisted of the main stakeholders of C&D waste management including design, construction and resource recovery industries, and government organisations officials with experience in waste management. To recruit participants, the research team considered different approaches. Firstly, the researchers circulated the questionnaire survey link to their network. Secondly, the recipients were asked to forward the link to others with C&D waste interest and experience. Thirdly, two industry associations, namely The Waste Management and Resource Recovery Association of Australia and the Sustainable Built Environment National Research Centre, were approached to use their network to spread the word. According to Qualtrics records, the six questions presented above took 5 minutes to complete on average. In total, 132 survey responses received from which only 84 had an acceptable response level (more than 70%) were considered.

2.2.Data analysis

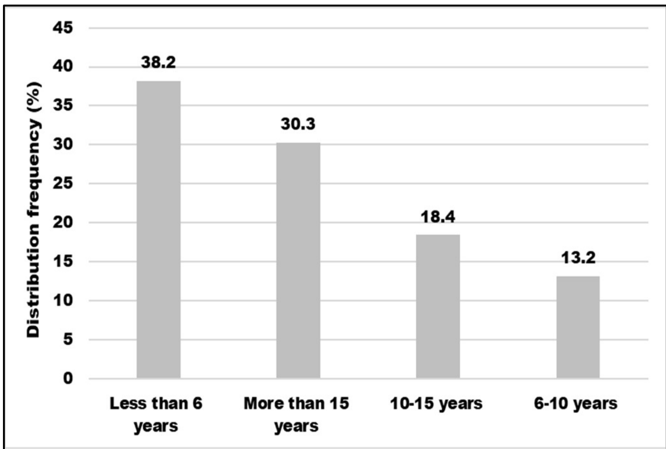
In total, 132 responses (53% response rate) were received and recorded in the Qualtrics database. After screening the responses, the data from the survey were analysed. Descriptive statistical techniques were applied to explore the participants' demographic details and their opinion on C&D waste issues and opportunities (Holcomb, 2016). For the quantitative data, frequency distributions were examined to compare different categories of responses received from participants. For qualitative data, a thematic analysis (Braun and Clarke, 2006) of responses on the impact of new policies on the Australian C&D waste management sector. NVivo V.11 was used to conduct a thematic analysis of participants' qualitative responses.

3. Findings

The results of the survey are presented below in three parts: the profile of participants, the impact of new waste policies on new C&D waste and the responses to the changes caused by new waste policies.

3.1.Profile of participants

The participants' profile, including the industry and geographical zone in which they performed their main activities and the length of their experience, was explored. The sample size represents the major stakeholders with direct involvement in the construction material end of life management: around 60% of the participants belonged to the construction (24%), waste recovery (20%), and landfilling (15%) sectors, the three sectors that are most affected by C&D waste regulations and policies. The responses also approximately align with the number of employees in each of these sectors. As expected, the study sample consisted of experts based in the four Australian major states (i.e., Victoria, NSW, Queensland, and Western Australia) that deal with the C&D waste management challenges the most and have a higher population and thus more construction activities. Around 44% of participants had less than six years of experience working in waste management, whilst fewer than 30% worked in the industry for more than 15 years.



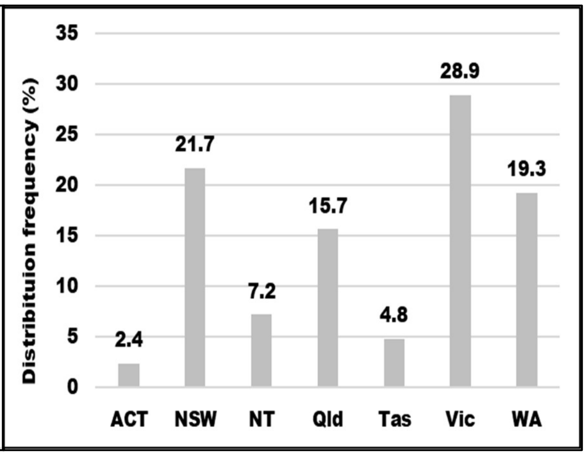


Figure 1. Left: summary of participants' experience; Right: frequency distribution of the main location(s) of their activities

3.2.The impact of new waste policies

The results showed that only 23.5% of respondents believed that this policy could negatively impact the waste management and resource recovery sector (Figure 2). Table 1 presents the qualitative responses from the participants for this question. According to the responses, about 55% of the participants surveyed opined that the imposition of restrictions on the Australian C&D waste could be beneficial to various industry and country as a whole.

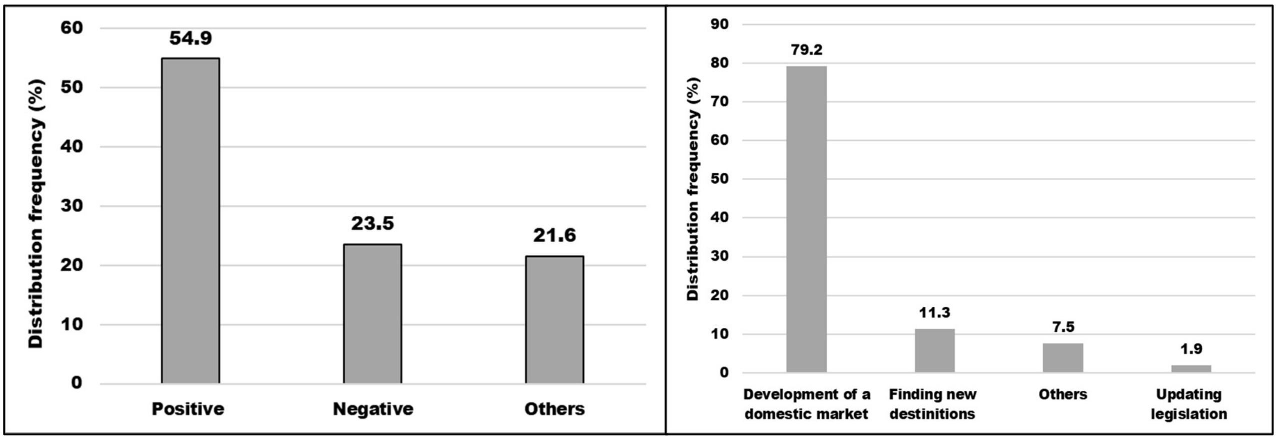


Figure 2. Left: frequency of responses to the impact of new waste policies on the Australia C&D waste management system; Right: the frequency distribution of participants responses to mitigation strategies

3.3.Response to new waste policies

Participants were also given choices to express their opinion on the best approach to respond to these restrictions. An overwhelming majority (79.2%) of the participants had "development of a domestic market" among their responses (Figure 1). Understandably the lowest frequency belonged to "finding new destinations" implying the maturity in the perceptions of those involved in the C&D waste management about the sustainable approach in managing C&D waste.

Table 1. A summary of selected participants' qualitative responses to support the three key categories

Category	Example quotes (open-ended responses)
Negative impact	• *In the short term, it is forcing a lot of materials into landfill. It is resulting in recyclables being landfilled. Now contaminated waste will be disposed of in Australia, earlier it was too easy for lazy Australian companies* • *What are we doing with it now?* • *Raises issues that may not be correct* • *Highlights the challenges in the waste industry* • *We can no longer recycle the cardboard boxes (builders packaging from ovens, dishwashers, tile boxes etc) that is sorted from mixed C&D waste as it had dust/sand on it so is not acceptable to bale and recycle anymore.*
No impact	• *Unlikely to have a significant impact on actual recovery given the bulk of C&D recycling occurs locally, however it may undermine confidence in recycling overall* • *Plastics, timbre and other materials recovered have a lower value* • *No C&D waste was ever being exported in NSW.* • *Because Australian leaders have already started to support new investments in the recycling* industry

Positive impact	• *We can act locally and create jobs - its an opportunity for the industry. Resource recovery is getting the attention it deserves* • *It will force change locally and drive investment in recycling infrastructure* • *It's forcing us to confront this issue and be more sustainable* • *We need to invest here in Australia* • *The China Sword highlights opportunities to increase local recycling to provide jobs and investment and minimise the impacts of transporting waste (in other words, minimise reliance on overseas markets). C&D recycling is generally done locally, so the C&D sector could leverage positive messaging about 'opportunities for local recycling.'* • *It forces Australia to develop new industries, promotes employment* • *Waste materials must now be sorted at source prior to transporting to MRFs* • *This forces more collaboration in recycling techniques* • *We need to be developing methods to manage these products locally (and regionally) not just metro areas* • *It forces us to act.* • *Cause we must deal with instead of closing our eyes* • *Forces others to take waste issues seriously* • *Positive (long term) as products look to use Australian recycling within Australia* • *Has motivated us to take responsibility* • *Enforces Australia to manage its own waste* • *Forces Australia to acknowledge and catch up with reuse/recycling initiatives already established elsewhere.* • *Because it will force development of local reprocessing rather than relying on other countries to sort through our waste* • *Enforces local market and adaptive activities to deal with the waste internally* • *Forces the issues to be addressed* • *Because it means we are forced to develop an economy and mature industry around integrated waste management not just a basic logistics companies* • *Australia will need to reuse its own recovered materials* • *We have to do something about the rate of production of waste, rather than just shipping it abroad for someone else to deal with* • *We are stuck with it, now we might create jobs and uses here* • *We need to invest here in Australia* • *It will promote increases in our own local recycling efforts.*

4. Discussion

Based on the qualitative responses, survey participants favour C&D waste market development, making Australia independent of other countries' policy changes, generating new jobs, and shaping a circular economy. However, developing a thriving market for these resources hinges on several factors. These factors are determined by extensive analysis of relevant literature, findings from the survey published before (Shooshtarian et al., 2020a) and are informed by application of contingency theory. As depicted in Figure 2, these factors include supportive regulations, extended producer responsibility (EPR), optimised supply chain, sustainable procurement (SP), investments in technology and infrastructure, and research and development. Figure 3 summarises these influential factors.

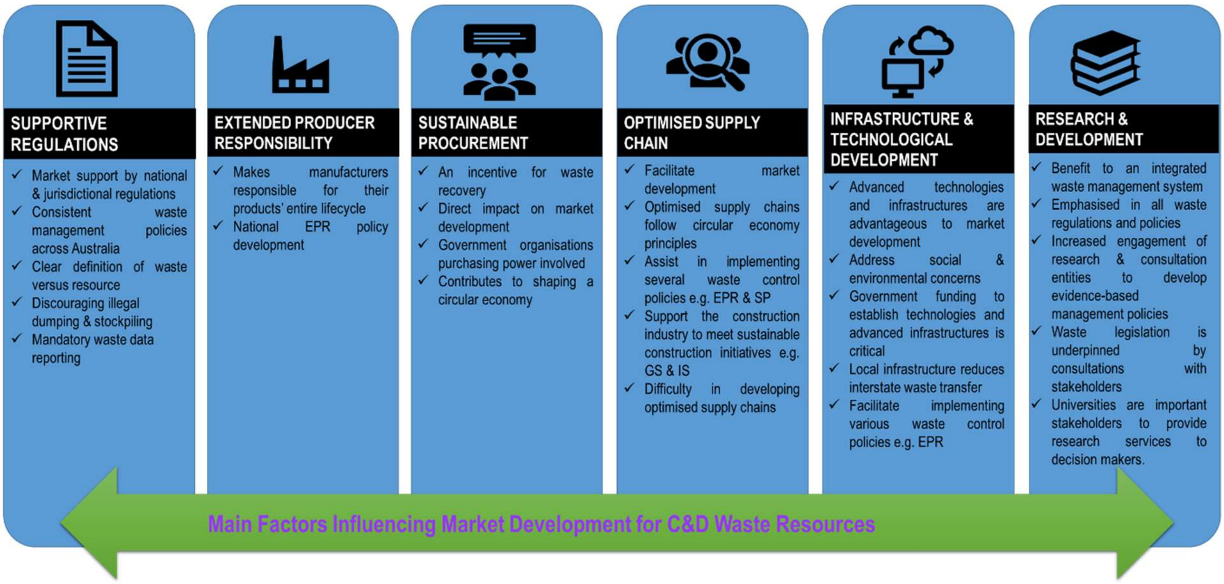


Figure 3. Structural changes required to develop market for C&D waste resources.

4.1.Regulations

Federal and state waste regulatory frameworks should support domestic market development to promote resource efficiency and a circular economy. Notably, regulatory support should facilitate consistent waste management policies throughout Australia, clarify when waste becomes a source and is not liable for landfill levy, discourage illegal dumping and stockpiling activities, and mandate consistent waste data reporting. The approach to taking advantage of a landfill levy is not straightforward due to varying factors in the effective management of waste. While a landfill levy is the best economic driver in some circumstances, it can act as a disincentive in other circumstances. In the literature, conflicting results are reported in response to a landfill levy (Shooshtarian et al., 2020b), both in domestic and international contexts.

4.2. Extended producer responsibility

EPR is a strong motivator for establishing a marketplace for C&D waste materials. This scheme is a policy instrument that eventually reduces waste disposal and is long adopted in countries for different waste streams (Hanisch, 2000). Technically, EPR makes manufacturers responsible (financially and/or physically) for their products' entire lifecycle including design, manufacture, recycling, and final disposal (OECD, 2016). However, EPR policy development and implementation, particularly for C&D waste, is still at an early stage in Australia (Shooshtarian et al., 2021). It is recommended that these schemes are implemented nationally because many of the potential participants work across Australian jurisdictions.

4.3. Sustainable procurement

SP policies provide an incentive for further waste recovery. SP's implementation has a great impact on the flourishing of the waste materials market. In response to China's new waste policy, the Minister of Agriculture, Water and the Environment committed to supporting the increased use of recycled materials in the goods procured by government organisations and collaborating with the industry on creating new markets for recycled materials. In Australia, the reuse of recycled materials is strongly encouraged under Ecologically Sustainable Development (ESD) and SP programs. This policy has also emphasised applying a circular economy's principles to efficient use of national resources.

4.4.Optimised supply chain

An optimised supply chain in the waste and resource recovery sector facilitates waste market development. The effective supply chain follows circular economy's principles and the industrial ecology (symbiosis) concept. Optimised supply chain aid with implementing EPR policy, ensuring the sustainable provision of stockfeed for waste recovery facilities and motivates an alignment between the industry practices and green construction programs such as Green Star (GS) and Infrastructure Sustainability (IS) tools (Shooshtarian et al., 2019b). Creating a supply chain is not a straightforward task, as it involves numerous actors, each playing their part in the delivery of supply chain objectives. In Australia, a decade's worth of effort towards creating an effective supply chain has limited success. NSW is the leading state in building a supply chain system for domestic waste. In 2009, this state established an organisation called the Australian Industrial Ecology Network to promote the concept of industrial ecology and identify the opportunities to link waste producers and waste consumers. In 2012, the Department of Agriculture, Water and the Environment released a guideline on the supply chain of C&D waste materials. This document primarily aims to promote industrial ecology in the C&D waste stream and secondarily showcase successful C&D waste trades in Australia.

4.5. Investments in infrastructure and technological development

Waste recovery technology advances and infrastructure development are advantageous to domestic market development. Building modern and efficient facilities addresses public social and environmental concerns and provides better services to the waste and resource recovery sector through economies of scale. Government funding to improve waste and resource facilities and effective law enforcement provides an impetus for further waste recovery activities and diminishes the reliance on waste export. An increase in the number of local infrastructures frees waste producers and collectors from the interstate waste transfer. Technically, many waste minimisation practices and strategies, such as EPR and the proximity principle, depending on the availability of technologically advanced local infrastructures. Several waste management strategies in Australia have highlighted the need to keep pace with technology changes for smarter and more efficient waste management. New technologies, such as Building Information Modelling (BIM), Blockchain, Geographical Information Systems (GIS) and online marketplaces can be helpful

4.6. Research and development

An integrated waste management system benefits from R&D. Almost every single strategy, policy, action plan and regulation on waste management in Australia has highlighted the role of R&D alongside encouragement and enforcement for effective development and implementation of waste-related programs (Shooshtarian et al., 2020c). As authorities' realisation of R&D benefits increases more research and consultation entities are engaged to develop evidence-based C&D waste management policies. The Australian legislation process is underpinned by consultations with key stakeholders who are affected by developing regulations. Consultation drafts calling for submissions from industry, authorities, researchers, and the public are a bridge that fill the gap between regulation and R&D. Universities are important players in providing research services to decision-makers, regulatory authorities, industry and broader communities (Calvo et al., 2014).

5. Conclusions

The paper aimed to determine how various stakeholders perceive the impact of new waste policies in developing countries on the Australian waste management and resource recovery sector, notably in the C&D waste stream. The research findings showed that most participants opined that the new policy positively impact the Australian industry in the long run, and the development of domestic end-markets for C&D waste is the best response to the new resultant changes. The paper also discussed the key factors contributing to developing the C&D waste management market. It is expected that the findings of this study assist policymakers and authorities in local agencies and government departments with providing the best solutions to the potential issues. Responses to these changes should be reflected in new policies that also consider affected stakeholders. Future research themes include working with relevant stakeholders to develop domestic markets for C&D waste, investigating the success of national and state government initiatives in supporting waste recovery industry to respond to new conditions and studying the feasibility of harmonisation of waste efforts across Australian territories and states.

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Industry-enabled Work Integrated Learning through Certificate of Practice Program

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Abstract
The introduction of Work Integrated Learning (WIL), although well documented throughout the Built Environment sector has been found challenging by some universities to adopt. Unbeknownst, WIL activities were actively being employed at a particular school of the built environment. It took some time for the school to recognise that to be the case. The reason being was that these activities were forthcoming from industry-led initiatives and did not fall under any structured WIL course or program conducted by the school. The lessons gained from this experience has led to the creation of a Certificate of Practice as a means for students to engage more with industry engagement by receiving a document with tangible benefits in addition to their degree. Although yet to be fully launched, the COP has gained considerable interest within the university. This case study will demonstrate events that have actually taken place and compare these against recommendations that have been published from research. This paper highlights the contributions of industry practitioners who have given their time and a sense of genuine care for students who are pursuing a profession that is similar to their own. Their overall agenda is one of 'giving back' to an industry that has provided for them over the years.

Keywords
Built Environment, Construction Program, CPD, Higher Learning Institution, WIL.

1 Introduction

In response to Government demand-driven funding, Construction Management programs are being urged to adopt a pedagogy to ensure students are 'job ready'. Work Integrated Learning (WIL) is a means for universities to articulate to students via a variety of learning methods, industry practices to develop their skill sets (Jones et al., 2019). In brief, WIL turns Theory into Practice. In response, a Certificate of Practice (COP) program via WIL is being introduced within a popular undergraduate Construction Management program in Western Sydney. This paper will report on the key highlights of this COP program. This initiative will offer a WIL focus within the curricula, which is lacking in most construction undergraduate programs. The proposed COP has been designed to demonstrate student learning outcomes within an industry-focused setting. To do so, students could undertake Continuous Professional Development (CPD) activities whilst networking with industry leaders and become active within various professional institutions that are relevant to the construction industry.

Through this COP program, undergraduate construction students would be able to develop practical skills from the day they start their degree. Like health and law, which have specific practice-based learning, construction undergraduate programs should also create this change of culture from the traditional approach to practice-based construction education. Such a move will not only provide future industry-ready graduates, but also exposure to wide-ranging industry opportunities for students and addressing of difficulties in seeking employment due to gender, culture, and lack of local contacts. The next section reports on the literature findings around WIL and CPD.

2 Literature Review

Continuous Professional Development (CPD) has not been commonly adopted by construction management undergraduate students. However, it can provide many benefits. Hamilton (2018) stated that employers greatly value students who show initiative and self-development. Students who are studying construction management courses and work at the same time may not gain the benefits of potential synergy between the two (Forsythe, 2012). Therefore, CPD is a significant form of experiential and lifelong learning (O'Brocta et al., 2012). Students can have control over their learning process and learning outcomes.

Different studies show how CPD can be an effective form of learning for professionals. Herbert and Rainford (2014) conducted action research within a case study to develop a model of CPD for teachers. The study highlighted the issues that emerged during the conduct of the research as well as the advantages of using this approach and gained insight within the natural context of the case study. Peleman et al. (2018) found that CPD can be effective for the quality of pedagogical practices in early childhood education and care. They stressed that the active engagement of practitioners and peer exchanges within a tested framework is the most effective approach. Holmes (2013) used action research to explore how a learning community through an online method can support the CPD of school teachers. Aspects of the online community such as trust, mutual respect, and shared value are required in this context.

O'Brocta et al. (2012) investigated the development of a CPD process for pharmacy students. Based on feedback from students and academics, they found that the CPD program is feasible and valuable for the students' lifelong learning. Hamilton (2018) distinguished between two types of CPD learning for law students, which are self-directed learning and self-regulated learning. In self-directed learning, students take control of all the processes of learning from identifying the goals of learning to evaluate learning outcomes. While self-regulated learning includes aspects of proactive learning where students use different processes of self-directed learning.

Previous research works on WIL in construction-related courses are summarised in Table 1. As the literature review summary shows, most of the studies discuss the importance of integrating WIL into construction education. Some studies focus on specific topics related to this integration such as student performance, student quality of life, nature of the industry, the attitude of employers, and online WIL. However, there is a lack of studies on the application of practice-based education through COP and similar programs. According to Hardie and Saha (2015), universities systems often do not regard external work experience for students as a high priority. They emphasised the need for student industry experience to be evaluated and recorded in a manner that recognizes its worth to the industry. Therefore, this research attempts to contribute to the literature on how CPD can be applied for effective and integrated learning for undergraduate construction management students. This research aims to evaluate the recently introduced COP program for undergraduate construction program in one of the higher learning institutions in Western Sydney. The research will offer lessons learned and future directions for the application of such programs to wider practice.

Table 1: Summary of literature review on WIL in construction programs

Study	Purpose	Method / Context	Key Findings
Bronkhorst (2013)	To assist with the preparation of civil engineering students for the workplace.	Activity Theory and case study / South Africa.	Knowledge and practice divide. The institution policy has a role in reducing the gap.
Mills, McLaughlin, and Davis (2011)	To investigate the attitude of employers toward assessing internships.	Pilot interviews with employers followed by focus group / Australia.	Many employer organisations expressed considerable goodwill towards collaborative education with universities. The study discussed some issues or challenges of WIL associated with the project-based nature of the industry.
Williamson (2008)	To understand the performance of WIL in the architecture program.	Assessment of reports provided by students and employers / Queensland University of Technology, Australia.	Agreement between students and employer regarding the major work experience areas. There is some misunderstanding of the program's aims by some participants. Students are positive about the program.
Simmons et al. (2010)	To investigate how the practical skills of construction management and nursing are embedded into an online portfolio platform.	Analysis of competencies from different accreditation / New Castle University, Australia.	Skills and competencies acquired at university and during WIL can be integrated to enable students to graduate as professionals in their respective disciplines. Student ethical practice, team communication, and occupation health and safety practice are developed.
Hardie and Saha (2015)	To understand how the construction industry culture and practice may present a resourcing challenge for academic designing WIL program.	Records of 360 student outcomes over seven years / Western Sydney University, Australia.	WIL in construction management has an ill-defined impact on academic performance. Its impact on construction management students is yet to be determined.
Mutereko and Wedekind (2016)	The complications of WIL may affect student throughput. To evaluate new construction programs without WIL.	In-depth interviews / University of Technology, South Africa.	WIL, in its current form, does not make graduates work-ready. Employers use it either to get extra cheap labour or as a recruitment process.
Forsythe (2012)	Students in construction management often work and study concurrently. To highlight the benefits of the potential synergy between the two.	Literature review.	The 'work ready graduates' is difficult to achieve in reality. The paper proposes a means of enabling WIL via a structured student-industry network.
Gillett-Swan and Grant-Smith (2018)	To study the impact of WIL on student quality of life.	A conceptual model called WIL wellbeing is presented to identify the impact of WIL beyond the learning context.	The model emphasises the importance of nurturing a combination of individual coping strategies, formal policy, and informal institutional support.
Quinn et al. (2019)	To evaluate the implementation of site visits through online (virtual) WIL for students undertaking fully online courses.	Business processes modelled using a swimlane diagram plus feedback from some students.	The implementation of virtual tours and activities, blended with independent face-to-face site visits and assessment, forms an authentic, supported, and constructively aligned WIL experience for students.

3 Research Methodology

Case study research methodology is utilised in this research. According to Yin (2013), a case study is an empirical inquiry that investigates a contemporary phenomenon within a real-life context, where the boundaries between phenomenon and context are not evident. It offers description, exploration, and/or explanation based on the facts, experience, and perspectives of case study actors. In selecting particular cases, Eisenhardt (1989) states that it makes sense to choose cases in which the purpose is 'transparently observable.' According to Dyer and Wilkins (1991), the essence of case study research is the careful study of a single case that leads researchers to see novel theoretical versions. Hence, this study opted for a single case study. Accordingly, a Certificate of Practice (COP) program via WIL that is to be introduced within a popular undergraduate Construction Management program in Western Sydney University (WSU) was subjected to this case study. The data collection included observations and peer feedback that was analysed qualitatively. The next section presents and discusses the findings and reports on the background, design, and key features of this case study.

4 Findings and Discussion

This section will report the key findings from the case study.

4.1 Case study background and design

The Building and Construction Management programs at WSU commenced in the early 1990s. They have always had a compulsory work component. Our location in Western Sydney, which is possibly the largest construction market in the country, has enabled students to find a broad range of work experience while they study. The nominal amount has always been set at 1200 hours of learning experience compiled throughout the course. Among the acceptable work categories are:

1 Design

Design, drafting, documentation, specification writing, and preparing tender packages

2 Construction

Builder's labourers, tradesmen, foremen supervisors, and quality control

3 Commercial Management

Contract administration, businesses administration, sales, marketing, and cost control

4 Estimating

Quantity surveying, estimating, tendering. quotations, feasibility studies, and pricing variations

5 Project Management

Construction planning, project management, property development, progress reporting, and works scheduling

6 Building Materials

Sales, purchasing, stores, and stock control

7 Miscellaneous

Material testing, research, local government building departments, tutoring, client or third party inspection, and supervision

By chance, a group of industry professionals, members of the Australian Institute of Building created a special group with the sole purpose of providing learning opportunities to students. The group comprised a number of disciplines, architects, builders, project managers, engineers, quantity surveyors, certifiers, and members of the university. They met socially once a month for a breakfast meeting, sponsored by a different member either at their office or at a local café. An agenda was established, and dates were set for site visits, social gatherings for networking, an 'office crawl' allowing students a first-hand encounter of workplace environments, BBQ with the Boss, mentoring, placement, and potential guest lectures. The benefits gained by this initiative have left a lasting legacy of collaboration with industry partners and other institutes such as NOVUS from the CIOB.

Exploring all of the opportunities available, WSU undertook the task to establish an online system that was able to record students' activities such as the 1200 hours of work experience. A number of available programs were investigated that were ultimately deemed not suitable without major adjustments. The decision was made to utilise and modify an existing platform developed by the university for the sole purpose of WIL named Alpha. The resultant outcome is a Certificate of Practice (COP).

Whilst the 1200 hours of work experience is a requirement for graduation, the COP is a means to assist students in achieving their industry experience. This is particularly beneficial for international students. The COP program is an elective, resulting in a transcript of the student's experience plus a certificate that can be used to demonstrate their personal engagement with industry activities. Peer-reviewed comments from industry practitioners have been favourable when questioned if they would employ a graduate with a combined COP and degree over a graduate who has not undertaken a COP.

Government agencies have also welcomed the program.

The design of the COP program that is subjected to this case study research has three specific features capturing the above seven categories.

1. **Transferable.** This segment of learning will concentrate on the student's personal development. Regardless of the student's career choices, students can independently design the most appropriate learning that will assist them with their career to become leaders in their field. Modules will concentrate on emotional intelligence, self-confidence, presentation, and cultural awareness for example.

2. **Workplace.** These skills are designed to prepare students for their initial workplace encounters. They will prepare students with the basic knowledge and requirements employers are looking for. Modules will include induction training, site visits, guest lectures, social networking events, mental health awareness, and others.

3. **Practice.** These skills are to prepare students for professional life. These modules are usually undertaken in the final years of their degree. Students will be exposed to opportunities to develop their own sense of professional and ethical behaviour. Modules in this category may include, mental health first aid, work experience, mentoring, active engagement with industry student groups (e.g. CIOB, AIB, AIQS, AIBS, RICS).

4.2 Industry-enabled WIL Components Identified in the Case Study

The COP program will record and maintain students' continuous development and learning. The reordering of industry-related activities and COP components will be conducted through the Alpha platform. The COP components, which were designed through established industry partnerships, include guest lectures, site excursions, shadowing of academics, research opportunities, job opportunities, and others. Furthermore, the COP enables Recognition of

Prior Learning (RPL) for those students who have successfully completed an approved apprenticeship program and/or an approved cadetship program with an established firm. Students are able to commence their CPD journey by logging onto the Alpha system. The system will initially explain how to navigate the platform and accumulate their required ‘points’. Students are then directed to online learning modules. Initially, students will commence a number of mandatory Transferable skill set modules followed by modules of their choosing. Advisors are on hand to assist if required. On completion of their minimum Transferable requirement (points), students are eligible to use their RPL and/or points earned completing the Workplace and Practice modules. Screenshots of the workflow within the Alpha system are shown in Figure 1.

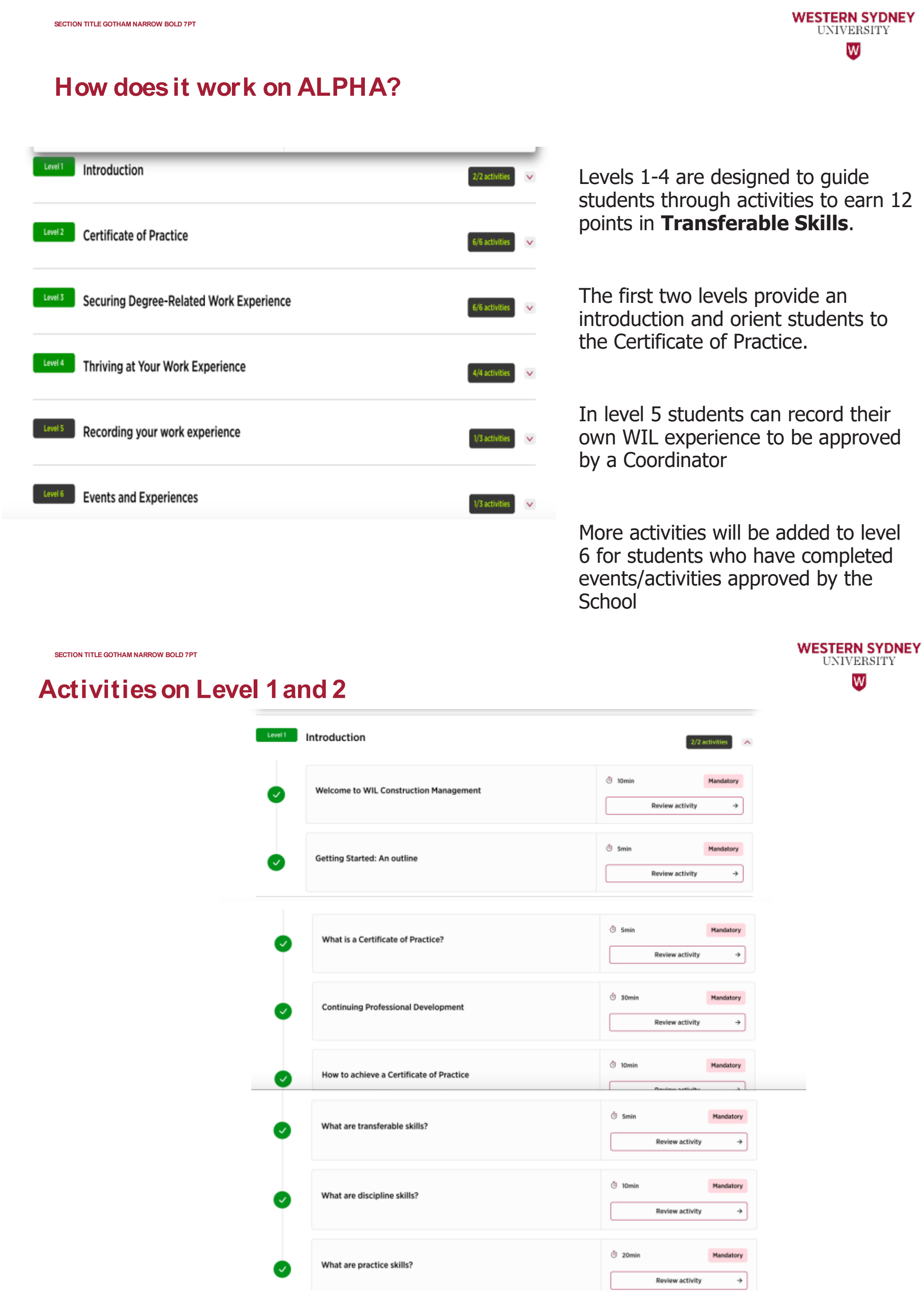

Figure 1: Example of Alpha system workflow.

5 Conclusion

This paper highlights, and based on the literature review, that CPD has not been common among construction management courses. The unique approach proposed for the construction management undergraduate program that is studied in this paper offers a shift in culture from the traditional approach of WIL to practice-based construction education. In doing so, key stakeholder engagement across faculties, government, and industry are important. The COP will be a digital transcript of the students' learning gained during their degree. Furthermore, the Alpha system as shown in the case study could track additional CPD points earned after graduation, creating a digital Curriculum Vitae (CV) with badges for completion.

Hence, this approach will have a significant impact on both the construction management higher education and also similar practice-based undergraduate degree programs. A limitation of this research is that this system has not been fully implemented. Therefore, the system's effectiveness in enabling COP is yet to be determined.

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The Link between Internal Business Integration and Financial Performance

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Abstract
The construction supply chain is complex. Existing research evaluating productivity and performance measurement and management (PMM) at a company financial performance level is scant. This paper aims to address this problem by proposing an approach to manage and measure business performance. This paper reviews the PMM, supply chain and operational management literature, and proposes an approach to measure and enhance business performance through the integration of strategy, process and information. The current literature is fragmented, lacks uniformity and has no agreed theory as to what and how to integrate a business to deliver financial results. A new paradigm of linking the 'bonding ingredients' within the three compound constructs of strategy, process and information directly to financial performance, has the potential to transform construction management. These compound constructs should be tested in further research to validate the proposition that, embedding and aligning these constructs, will directly impact financial performance, unifying the current fragmented literature and modernising measurement and management in the 21st century. This paper proposes a novel integration approach which has the potential to increase productivity in the construction industry through better resource allocation, whilst concurrently attracting and retaining employees who are engaged and challenged.

Keywords
business internal integration, business performance management, construction productivity, construction supply chain, financial performance.

1 Introduction

Contemporary business performance measurement and management (PMM) is rooted in a bygone era. The Ford-Taylor origins of modern manufacturing ideas and, by extension, it is argued the entire foundation for modern Western business management, still permeates current operational management philosophies (Evans and Holmes, 2016). In a similar vein, it can be argued that the advent of the quality movement is not mutually exclusive from the Ford-Taylor management milieu (Koskela, 2003, Koskela and Ballard, 2012). After World War II, as manufacturing around the globe accelerated (as did competition), quality management became an additional tool to build better products cheaply (Beckford, 2009). Whilst the early Ford-Taylor concepts produced greater volume of product, the need for better, more reliable and robust products demanded by the marketplace saw the start of the quality movement (Crowley, 1998, Beckford, 2009). Increasing globalisation of supply chains heightened this competitive environment, and the now widely known Japanese quality techniques form part of the manufacturing story. Together with the new tools of Lean, Six Sigma and Theory of Constraints (Looy, 2014) these ideas have extended their influence into business process thinking (Beckford, 2009, Looy, 2014, Schmiedel *et al.*, 2014, Brocke and Rosemann, 2015). As a result, we have a current Western management tradition that is more than a century old: Ford-Taylor gave us the task focused production line; quality helped make the business more efficient and reliable; and, together with supply chain management, whose roots also lie in manufacturing, the entire business management approach is based on sequenced activities, siloed functional specialisations with a quality movement attempting to optimise them.

2 Literature Review

A systematic literature review was conducted as described by Danilova (2018). This review sought to answer the following research questions:

1) What are key internal integration constructs?
2) How do these integration constructs impact financial performance?

Peer reviewed articles, industry reports and conference papers published from 1995 onwards were reviewed. The articles were selected based on the following criteria: Chang et al. (2016) advise that it was in the mid 1990s that the first empirical research began to appear on supply chain integration. The mid 1990s is also true for cross-functional processes (Looy, 2014); the linkage between shareholder and customer values (Bourguignon, 2005) and finally, supply chain management in the construction sector (Segerstedt and Olofsson, 2010).

2.1 The engineering and construction sector

Engineering and construction companies operate in complex commercial landscapes. Globally, the sector underperforms, with low profit margins and both schedule and budget overruns (Yeo and Ning, 2002). Some of these problems are persistent and seem not to be known to top management, with little research on how to close this performance gap (Hjelmbrekke *et al.*, 2017). One reason the construction sector faces financial performance challenges is the nature of its supply chain. The unique nature of construction projects, being temporary and comprised of numerous players seeking to maximise the opportunity to earn money, creates a bespoke supply chain for each project (Arantes *et al.*, 2015). A construction company may come together with a mix of other companies for one project, disband at project completion, and then come together with a different mix of companies for the next project (Briscoe and Dainty, 2005). This project cycle repeats and the high fragmentation in the industry presents a significant barrier to integrating companies into a unified supply chain (Cheng *et al.*, 2010). Unlike companies in the process based sector, such as manufacturing, project based companies have not developed a suite of standard templates, processes and technology interfaces, instead, they are comprised of fragmented and self-interested players, with no uniformity of purpose or linkages (Behera *et al.*, 2015). The network of sub-contractors and suppliers within the construction sector creates layers of complexity and additional risk (Arantes *et al.*, 2015) and the unique temporary project nature of the industry means the transposition of supply chain practices from other sectors is not necessarily transferable to construction (Fernie and Tennant, 2013).

Supply chains are the interconnectedness of various functions and businesses to deliver a product or service when and where it is needed. Mentzer *et al.* (2001) succinctly capture this in their definition:

> … the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole. (Mentzer *et al.*, 2001, p. 18)

This definition highlights two critical elements: the first is the coordination across traditional business functions within an individual company and, secondly, the purpose of improving long-term performance. Given the fragmentation of construction supply chains through the multitude of entities within them and given that the industry is challenged by poor performance issues, the ability to improve supply chain performance has the potential to improve long-term business performance. However, the integration mechanisms for a product supply chain, are not necessarily relevant in a construction supply chain (Tennant and Fernie, 2013). With the construction supply chain being highly bespoke for each project, comprised of self-interested players, with few mechanisms or incentives to create linkages across the various companies, the ability to create an external supply chain of meaningful value is severely limited (Fernie and Thorpe, 2007). The idea that a single construction company can control other members of an extended, external supply chain has been deemed unrealistic (Fernie and Tennant, 2013). Therefore, with this external fragmented supply chain being of limited value that can be optimised to contribute to shareholder value requires investigation of the: "… strategic coordination of the focus on the tactics across these business functions…". This paper focuses on the internal integration elements due to the construction sector's limited ability to integrate externally as a result of the fragmented nature of the industry (Demirkesen and Ozorhon, 2017).

2.2 Business integration

The idea of coordination has been studied in research dating back to the 1930s, as described by Emery (2009). The seminal work of Lawrence and Lorsch (1967) compared types of performance and their relationship to cross-functional coordination and found empirical evidence that higher performing companies had greater levels of interdepartmental coordination. The concepts of coordination have been articulated as the collaboration and coordination of information, processes and behaviour within a firm and, together, described as 'internal integration' (Chang *et al.*, 2016). Internal integration is within a firms boundaries and across functional areas (Richey *et al.*, 2010). Internal integration is also referred to as cross-functional, inter-functional or inter-departmental integration and is an area of research that is still emerging (Swink and Schoenherr, 2015). With the ideas of integration extending back to the 1930s, and the concept of supply chain management being used since the 1980s, it seems counterintuitive that internal integration is an area of research that is still deemed as emerging. The reason for this is that integration has no universally agreed definition (Turkulainen and Ketokivi, 2012). It is viewed through a range of lenses which bias the definition towards that particular expertise or field of practice (Berente *et al.*, 2009, Danese and Bortolotti, 2014). These disparate lenses are a result of the fact that management of a supply chain extends across multiple parties and functions, as Chen and Paulraj (2004, p. 120) explain: "A number of fields such as purchasing and supply, logistics and transportation, operations management, marketing, organizational theory, management information systems, and strategic management have contributed to the explosion of SCM literature."

This "melting pot of various disciplines" (Soni and Kodali, 2013, p. 263) has influenced the definition and led to a range of views and frameworks based on the disparate backgrounds and views of practitioners, researchers and consultants, leading to fragmented research and the lack of clear definitional constructs from which to base a supply chain management framework on (Chen and Paulraj, 2004, Soni and Kodali, 2013). However, a significant reason is that:

> The failure to anchor SCI [supply chain integration] as a research concept has led to a situation where several related and overlapping definitions of SCI battle for acceptance. Disarray surrounds the meanings and theoretical identities of behaviors

that appear to constitute a continuum of interaction: coordination, cooperation, collaboration, and integration. (Autry *et al.*, 2014).

These various views of integration are at odds with its original intent to deliver a competitive advantage through greater coordination, and it is for this reason that internal integration continues to be poorly understood with research remaining incomplete (Turkulainen *et al.*, 2017). Bringing the focus of internal integration back to the original intent, there is a need to focus integration research specifically on how it relates to performance (Swink and Schoenherr, 2015). Therefore, this paper defines internal integration as: a unified approach within an organisation that coordinates and collaborates across all functions and departments to enact the organisations strategy. Having established the intent of integration to produce a competitive advantage and thus, greater performance, performance is the next area for discussion.

2.3 Business performance

Competitive advantage, by definition, is to position a company to win more work and secure revenue. How effectively a company delivers this work to generate a profit, is a reflection of its financial performance. The literature discusses 'performance' across three dimensions: operational, financial and strategic (Chang *et al.*, 2016). Often, these ideas are rolled-up and referred to as 'firm performance' or 'business performance' without clearly articulating what 'performance' actually means (Turkulainen and Ketokivi, 2012). It is argued that discussions of operational or strategic performance are distracting. All entities, regardless of their profit or not-for-profit status, must be able to use their capital and assets in the most effective way possible through operational and strategic delivery. Operational performance or strategic performance are not, in themselves, the goal of the entity. The entity's goal is to deliver maximum value in the most effective financial way possible (Sridharan *et al.*, 2005) and "The reality is that the ultimate goal of any company is to make a sustained return for their shareholders." (Skipworth *et al.*, 2015). Sridharan et.al (2005, p. 314) underline what for-profit companies are to do: "Firm value maximization or shareholder wealth maximization is the primary goal of management." Much of the literature treats operational and strategic performance in isolation, as if the investigation of these two intermediary dimensions makes a difference to a company's performance results unilaterally, without considering how they affect financial outcomes. This leads the literature to examine integration in a myopic manner, with disparate and varied goals. These varied goals contribute to the fragmentation, lack of uniformity and confusion as to what performance actually is, just as it has befallen integration (cf. section 2.2). Without a single uniform goal, studies continue to produce ambiguous and inconsistent findings (Maiga, 2016). This research sees the uniform and ultimate goal of any entity as being responsible for the greatest financial return possible for the invested capital, that is, the greatest financial performance. In this paper, all reference to performance is referring to company financial performance.

2.4 Approaches to the analysis of integration performance

In an organisation, the aim of integration is to deliver competitive advantage to produce better firm performance. However, only a very few studies use financial data in their analysis of firm performance. Instead, the majority of studies use subjective measures. Analysis of financial performance should be carried out with financial data, not through perception (Swink and Schoenherr, 2015). The lack of progress in achieving internal integration has been hindered by not having empirical studies containing financial metrics that justify integration by revealing the costs and benefits attributed to it (Enz and Lambert, 2015). Swink and Schoenherr (2015) look to understand the levels of internal integration through primary data and the impact on financial performance through secondary, financial data. That is, the only measure of financial performance is financial performance. So the advancement in the use of objective financial data to measure performance achieved through internal integration, seems to only now be appearing. A selection of studies related to internal integration from the mid-90s found only five out of the 38 studies used objective, financial data in their financial analysis. There are four key findings that arose from existing research: (1) many studies focus on the operational, intermediate level measurement of integration, but not the business level, financial impact; (2) there is a lack of objective (financial) data in the analysis of financial performance (none in construction); (3) a very strong bias towards studies in manufacturing; and (4) the paucity of studies of integration in construction. Studies on integration are still nascent, particularly on how internal integration impacts financial performance. The four key findings will be addressed in the following sections: firstly, a discussion of the historical approach to the study of business internal integration. Second, a review of the key internal integration construct themes. Third, examination of these key themes and what they consist of.

2.5 Internal integration constructs

Integration is classified into three areas: internal, supplier and customer (Radhakrishnan *et al.*, 2013). Supplier and customer are deemed 'external' elements of integration. A company has limited influence on the external elements of integration but they have 100% influence of their own internal elements, and this is particularly true for construction companies (cf. section 2.1). Further, many papers find that companies must first integrate internally in order to have successful external integration (Flynn *et al.*, 2010, Maiga, 2016). This paper examines internal integration constructs with particular focus on what these constructs are, how they are implemented, and the intended goal or outcome of the implementation.

2.6 Major frameworks used to investigate internal integration

Each of the various disciplines that have sought to understand internal integration have done so through various frameworks. The two chief historical influences in examining internal integration have been configuration theory and contingency theory which focus on organisational alignment (Powell, 1992). They are founded on the seminal works from Mintzberg (1973, 1979); Miller and Frisesen (1984); Chandler (1962); and Lawrence and Lorsch (1967). Configuration and contingency theorists examine the alignment of the organisational structure and strategy to the environment. These two frameworks were the main focus of organisational research until this focus shifted to competitive strategy with the release of Porter's (1980) seminal work, which then prompted a large body of similar empirical studies (Powell, 1992). Whilst the organisational alignment and the competitive strategy approaches both focus on financial performance, they do so from two different views. The importance of this distinction lies in the body of research that has progressed from these two views. With both interested in financial performance, but from two different perspectives, the interaction between the two required further investigation, as White (1986) noted. Research to date does not appear to have resolved the intersection of these two approaches. It seems that the lack of a clear, single and uniform approach to integration is to blame, with the recent reviews by Autry et al. (2014) and Frankel and Mollenkopf (2015) conclusive in their assessments of this dilemma. This has led to studies taking a number of approaches, some looking at competitive strategy, some looking at contingency, others looking at configuration some using a combination.

Internal integration research has progressed along a trajectory. Throughout, all research on internal integration has led to mixed results. It has, however, spurred the use of a range approaches in attempts to understand integration and its effect on performance. These approaches, amongst others, have included: positional advantage theory, information processing theory, systems approach, conflict theory, and organisation control theory. A major reason for the non-unanimous findings is due to this "wide variety of operationalisations" across studies (Danese and Bortolotti, 2014). However, these 'wide variety of operationalisations' have produced abundant findings on, mostly, the intermediate or mediating effects of integration on performance. This is useful, as it has identified numerous constructs, and combinations of constructs, that give insight into the complexity and breadth of internal integration factors.

So far research has provided insights into what produces operational improvements. However, the proof that these insights have translated into financial performance remains scarce. Nor is there unified agreement on what and how the factors integrate, and the body of knowledge remains largely product focussed. Little operations management research is focused on the construction sector, even less on the financial performance impact on construction companies.

2.7 Principal construct themes of internal integration

The inconclusive findings on how internal integration affects the financial performance of entities has highlighted the numerous approaches to investigating internal integration which, in turn, has produced a large quantity of constructs of internal integration and three major themes. These three themes are discussed in the following sections.

2.7.1 Process

The overwhelming construct theme in studies is process. This is not surprising, as processes link activities and have been validated both conceptually and empirically with delivering a competitive advantage (Chang *et al.*, 2016). Business processes have gone through an evolution, particularly over the past 30 years, and it is accepted that they tie different parts of a business together to achieve an outcome (Smart *et al.*, 2009, Looy, 2014, Margherita, 2014). As processes are cross-functional, integrating inputs across various business departments, they are a central part of internal integration, and have been termed 'business process integration' (Berente *et al.*, 2009). The desired outcome of this process integration flow is the execution of the firm's strategy (van der Aalst *et al.*, 2016, Prieto and de Carvalho, 2018); the flows are, mostly, information (Berente *et al.*, 2009). So a business process integrates, cross-functionally, by handling and transforming information to achieve the business strategy. With business processes integrating various cross-functional departments, there is a need to not only implement and run these processes, but to maintain them. The fact that changes inevitably occur, newer technology provides for optimisation, strategies are changed, and cross functional boundaries must be coordinated, means a business process owner is required (Wong *et al.*, 2012, Looy, 2014). As processes exist to deliver outputs that go towards the goal of the business strategy, strategy is the next theme.

2.7.2 Strategy

Strategy sets the business direction. A business needs a strategy on which to focus its resources to deliver the financial outcomes that are expected (Pertusa-Ortega *et al.*, 2010). Integrating business functions through processes aligns these resources to the business strategy and allows this strategy to be executed creating a competitive advantage (Smart *et al.*, 2009, Foerstl *et al.*, 2013). Research on whether strategy should be focussed on shareholders or on customers forms part of the literature. This debate, whilst important to understand the operationalisation of strategy is not, it is argued, that most important thing. This paper sees that the business strategy itself, to be the lightning rod which internal integration is built around in order to deliver financial performance. Therefore, a business must clearly understand what its strategy is, and why, and that internal integration processes are put in place to deliver this strategy (Wong *et* *al.*, 2012). Understanding what the business strategy is requires, firstly, formulating a strategy. Once formulated, the strategy needs to be cascaded down throughout the business, for business units and functions to build their own strategies in order to support the overall business strategy (Kathuria *et al.*, 2007). This vertical pillar of strategy requires horizontal processes to allow them to be integrated across the span of the business and prevent vertical silos - therefore, delivering both vertical and horizontal integration (Prieto and de Carvalho, 2018). Ultimately, poor business performance is often caused by failure to align processes with strategy (Wong *et al.*, 2012). With the various vertical pillars in the business creating their own supporting strategies, and processes creating the horizontal linkages, top management's support at both the vertical and the horizontal levels is necessary for successful strategy execution (Wong *et al.*, 2012, Behera *et al.*, 2015, Skipworth *et al.*, 2015). To provide this support, channels of communication are necessary. Top management support of open communications influences employees behaviour to meet the strategic intent of a business (Skipworth *et al.*, 2015). Communication is the act, information is what is communicated in the act. Communication is human engagement (Pagell, 2004, Verghese, 2017), information, as it relates to this study of internal integration, is the data that flows in a process (Berente *et al.*, 2009, Smart *et al.*, 2009). The relationship between information and processes is highlighted as a prominent theme in the literature. This theme of information is addressed in the next section.

2.7.3 Information

Information flows and business process are inseparable. This, together with the horizontal distribution of activities and resources across a firm, explains why the bulk of process flows are information (Berente *et al.*, 2009). The vertical and horizontal channels in firms create a myriad of information flows and the ability to integrate these flows facilitates the processing and correct distribution of information; leading to greater levels of internal integration (Swink and Schoenherr, 2015) and better firm performance (Zelt *et al.*, 2018). A crucial feature of information is its usability. The quantity of information in itself, is not important, it only becomes of benefit to a process when it is in a form that can be used (Zelt *et al.*, 2018). This concept is mentioned throughout the literature, particularly centred on discussions of uncertainty and equivocality (Turkulainen *et al.*, 2017). Uncertainty arises through lack of information. Equivocality relates to information that is ambiguous. By having complete information available, formatted for decision making, mitigates uncertainty and equivocality, allowing processes to proceed unhindered (Berente *et al.*, 2009, Zelt *et al.*, 2018). As the cross-functional nature of process spans means that a number of business functions will be involved, the issue of bounded reality features in the literature. Bounded reality is the trait of being biased due to a particular functional view which can impact decision making (Swink and Schoenherr, 2015). The ability to break away from bounded reality to make decisions that benefit the strategy, and not just self-interest, is reliant on shared information (Swink and Schoenherr, 2015). The importance of information sharing is examined in many studies, however, whilst an enabler of integration, it is the usability of the information that is the lowest common denominator. Information must be usable or it is, by definition, not able to be consumed within the process and the process breaks down (Zelt *et al.*, 2018). If it breaks down, it cannot support strategy execution thus impacting financial performance. Whilst technical advancement has allowed for greater integration, it is the integration of information, rather than the technology platform or system *per se*, that produces business process integration (Berente *et al.*, 2009, Leendert Aalbers and Dolfsma, 2015, van der Aalst *et al.*, 2016).

These three principal themes are the constructs that form the bedrock of internal integration. Contained within these constructs, are four key bonding ingredients:

a. Process: process owner

b. Strategy: top management support and communication
c. Information: usability

It is best to view these four 'bonding ingredients' not as separate constructs, but as integral parts of the same construct - like two sides of the same coin. This may go towards explaining why, when the myriad of constructs from the literature are examined in isolation, studies do not yield consistent results. In order to address this line of thought, the discussion will proceed on the following basis: first, internal integration exists to deliver financial performance. Second, the three key constructs for financial performance are: strategy, which is delivered through processes, which in turn consist of information. Three, the constructs of strategy, process and information are comprised of four 'bonding ingredients', which make each construct whole.

2.8 Construct theme components – the 'bonding ingredients'

2.8.1 Process owner

As processes span across the horizontal within a business, and time brings change, it is necessary to appoint an owner to monitor and maintain processes (Weitlaner and Kohlbacher, 2014). Whilst processes are established to link the various parts of a business, this is not enough to deliver the strategic value that they are established for. The value from a process is its ability to align and pass information across functional boundaries, transforming it to deliver the business strategy (Turkulainen and Ketokivi, 2012). This boundary spanning is seen as a critical element, because although individual functional areas can adopt and implement processes, internal integration requires integrating, horizontally, across these individual functional processes (Smart *et al.*, 2009). This integration across all horizontal processes fits within an owners domain; so process owners require the authority to facilitate and manage the full process path (Smart *et al.*, 2009). At this point, it is of significance to highlight that not all processes are equal. Therefore, whilst alluded to in the literature but not explicitly stated, this paper puts forward that it is a part of a process owners role to determine and triage which processes are raised, owned and managed, and which are not (Berente *et al.*, 2009, Smart *et al.*, 2009, Wong *et al.*, 2012, Tang *et al.*, 2013). In order to support this owner, there is a requirement that staff actually executing a process are committed to the process, thus allowing the process owner to be successful in delivering boundary spanning, integrated results. In large part, this was found to be through two elements: (1) staff assessments linked to mutual process objectives (Emery, 2009); and (2) the use of mutual goals and metrics (Richey *et al.*, 2010, Li *et al.*, 2015, van Der Weshuizen and West, 2016).

2.8.2 Top management support

Determining the business strategy and its implementation across a business needs top management. The formulation of the strategy alone is not enough, it then needs to be executed. This requires the business to know what the strategy is, so the component parts of the business can align their resources and efforts towards this execution (Wong *et al.*, 2012). One of the issues identified in the literature, is winning and maintaining the support of the various business units and functions (Enz and Lambert, 2015). As has been established, there are a range of challenges to overcome in order to unify a business towards a single strategic goal, including bounded reality and different goals and motives, therefore, top management has a role to play to overcome these challenges (Wong *et al.*, 2012, Swink and Schoenherr, 2015). One way top management can facilitate removing these barriers is by involving middle management in strategy formulation. Middle managers can contribute valuable insights into strategy and, importantly, as they are the ones that must implement, their involvement in building the strategy gives them a greater commitment to see that implementation is successful (Wong *et al.*, 2012, Prieto and de Carvalho, 2018). Top management must also facilitate deconfliction of different business unit and functional goals. As the business units and functions will (should) create their own strategies to align with the overarching business strategy (Kathuria *et al.*, 2007), it is important to not let these strategies operate in silos. Senior management can facilitate process owners to achieve integration by setting an expectation for business units and functions to work collaboratively on cross-functional process integration (Wong *et al.*, 2012, Weitlaner and Kohlbacher, 2014, Skipworth *et al.*, 2015, Prieto and de Carvalho, 2018). In the same way, top management can assist with conflict resolution, by setting the rules and expectations in areas of misalignment (Emery, 2009, Wong *et al.*, 2012).

2.8.3 Communication

With expectations set by top management, the integration of processes is reliant on effective communication. Communication is often discussed in the integration literature but it is done so, largely, as a restatement without any detail as to how it contributes to performance outcomes. So it is necessary to look outside of the integration literature to studies of communication. To this end, communicating with employees is identified as a critical success factor by enabling information transfer (Jacobs *et al.*, 2016). Aligning individual employee goals to the goals of the organisation is a task of internal communication and the responsibility of management (Tkalac Verčič *et al.*, 2012). This alignment can be facilitated by management support for open communication. It must also include top management engaging with middle management. Top management must create a flow of communication and strategy messaging both down and across the company. It is through management communication that employees are able to receive the broader context as to how and why their work efforts contributes to company goals. Studies show that communicating effectively with employees results in greater engagement and better work performance (Jacobs *et al.*, 2016, Zdenko *et al.*, 2019). Importantly for internal integration, greater employee engagement also means that employees increase their information sharing (Tkalac Verčič *et al.*, 2012). This is critical, as information suffers from uncertainty and equivocality. With greater sharing of information, the uncertainty and equivocality of information is reduced, leading to greater organisational effectiveness (Riley *et al.*, 2016, Verghese, 2017). Two studies conducted by Leendert Aalbers and Dolfsma (2015) suggested that greater boundary spanning information transfer is beneficial and that such transfer is enhanced when it is supported by managers who shape, or influence, communications towards the organisations benefit.

2.8.4 Information usability

Sharing information through processes is not enough to produce internal integration. Information must be usable, that is, it must arrive in full at the time it is required, in a format that can be applied at the particular point in the process it is needed. The usability of information is deemed to have four traits: accessibility, timeliness, transparency and granularity (Berente *et al.*, 2009). These traits are required to mitigate or remove uncertainty, equivocality and bounded reality. In order to address uncertainty, more information is required, however, increased information has the potential to introduce greater equivocality, so information handling and processing needs to be efficient, reducing multiple touch points and ensuring that the information itself is applicable, clear and able to be interpreted immediately by the recipient (Berente *et al.*, 2009, Zelt *et al.*, 2018). Bounded reality can impede decisions that are in the best interest of the process and thus, the strategy (Luo *et al.*, 2006, Tang *et al.*, 2013, Swink and Schoenherr, 2015). Information that can assist in facilitating decisions that are in the best interest of the process addresses the issue of bounded reality. As processes are largely information flows, and information suffers from uncertainty and equivocality, information that has the four traits of accessibility, timeliness, transparency and granularity, allows processes to deliver the business strategy through internal integration. From Berente et al. (2009) the traits are defined as having the following characteristics:

a. Accessibility: is available at any point in the process by those who require it, therefore, it needs to be a single source of truth.
b. Timeliness: information is available at the correct time in a process to allow it to be processed - not arriving too early or late.
c. Transparency: the information, as it passes across steps in a process, arrives at each step in the format that is applicable to that step and cannot be misinterpreted.
d. Granularity: the information contains a sufficient level of detail, at its particular step, to make using that information possible and applicable.

Information that is usable flows across processes and supports strategy execution.

3 Discussion

This review has highlighted that current business management philosophies are rooted in a by-gone era. It identified that supply chain operations extend across an inter and intra-company continuum, with inter-company alignment having value adding potential for construction companies. The paper has established that previous studies examined internal integration mostly from a product and manufacturing focus. The various focal points from functional disciplines, practitioners, academics and consultants has led to diverse and disparate views of integration with no unified definition, theory or approach. As a consequence, study results are often in conflict, and confusion as to how, what and why to integrate remain. Many of these studies report that internal integration has a positive effect on firm performance. However, like internal integration, it does not have a uniform definition. It commonly refers to the effectiveness of internal operational activities, rather than the ultimate financial performance of a company. No studies were identified of internal integration research and financial performance in construction companies. By examining constructs across the literature, this review has found that three construct themes emerge: process, strategy and information. These themes consist of four 'bonding ingredients': process owners, top management support, communication and information usability. This paper has identified from the literature, that the ultimate goal of a company is to deliver positive financial performance. Therefore, this paper considers company level financial performance as the necessary focus for which internal integration should be centred around, with strategy being delivered through processes which, in turn, consist of information. Such an integration model delivers company PMM by measuring company financial performance that is directly attributable to these compound integration constructs of process, strategy and information.

4 Conclusion

This paper proposes an approach that puts firm-level measurement and management first, subsequently driving the alignment of the constituent parts of the business. Given the vast quantities of literature that have examined process based industries and their intermediate, operational performance, this paper examines an industry sector that has not been absorbed into this historical operating phenomenon. By examining the engineering and construction sector, this paper shows how a perpetually complex industry can act as the catalyst to a new way to measure and manage performance in companies. Given the construction and engineering sector has complexity traits that have not, and cannot, be solved through the old, process industry ways of measurement and management, it presents the potential of this new novel approach. This paper recommends further research to examine the correlations of the identified compound constructs with financial performance, and to assess the levels of impacts of these constructs on financial performance.

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Case Study: Using Gamification to Teach Construction Management Concepts and Content

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Abstract
The need for industry-aligned learning is a consistent demand from construction organisations. Gamification (Game-based learning) can offer such an alignment. By using games as a medium to deliver course content, gamification allows students to acquire knowledge and skills in a new learning experience that is fascinating, personalised, interactive, and entertaining to achieve the purpose of real-time teaching. As a result, an increasing number of educators have adopted gamification in various disciplines in the tertiary sector to enhance learning and teaching. However, the understanding of using gamification within construction management education is still lacking. This paper will discuss the application of gamification within construction management education through a case study within a leading Australian university. The case study incorporates the Merit Game and relevant organisational/business management content into an undergraduate construction management program. The selected case study will report documentation analysis using two years of data and student reflection papers with observations on using this gamification technique. Overall, students reported receiving a positive learning experience with higher-order learning outcomes while further identifying good practices incorporated into future delivery programs. In addition, industry advisory boards, accreditation bodies, and program graduates found it valuable in a small sample. The case study findings will inform construction management programs on selecting and delivering gamification successfully in higher education institutions.

Keywords
Game-based learning, Construction management, Higher education, Project simulation, Tertiary instruction.

1 Introduction

Construction organisations have consistently demanded more industry-relevant learning from Built Environment programs. Although academics have implemented many approaches in their teaching, such as inviting construction professionals for guest lectures, engaging in internships, using industry case studies and utilising construction simulation software. However, it is still not enough to meet the needs of the industry. Gamification (Game-based learning) could provide another solution for this problem.

Gamification has been described as enhancing learning by motivating the student to facilitate experiences and improving behavioural outcomes. Gamification has developed rapidly in higher education worldwide in the last decades, and the gamification structure and process have taken different forms in applications to achieve this end. An increasing number of educators have adopted gamification in various disciplines in the tertiary sector to enhance learning and teaching (Gómez-Carrasco et al., 2019; Swacha, 2021; Rutledge et al., 2018; Tan et al., 2018). However, the understanding of using gamification within construction management education is still lacking.

This paper aims to discuss the application of gamification within construction management education and analyse the effect of gamification on the teaching and learning of construction management undergraduate students through a case study within a leading Australian university. The exploration of this online simulation is timely as COVID-19 has caused much content to be delivered via the internet.

2 Literature Review

Peer-reviewed journal articles were not plentiful in learning gamification or its derivatives, hampering this topics' analysis (Huang & Hew 2018; Huang et al. 2019). However, the number of research articles has been growing (Hamari et al. 2014). Furthermore, the first study investigating how gamification affects students' skills, academic achievement and satisfaction in a higher education active learning situation occurred in 2021 by Murillo-Zamorano et al.

A value assessment of learning gamification should include a) student learning transitioning from passive to active learning, b) intense skills development c) introduction of intrinsic motivation. (Murillo-Zamorano et al. 2021). Each helps add to the student's body of knowledge differently but makes them more industry ready. Gamification of challenging exercises outperform learning outcomes as compared to traditional in-person classroom training and online training. Most notably, games effectively engage students and make them active participants in their education process. Among education scholars, this is one form of Rich Environments for Active Learning (REAL) (Winn 2009).

In learning situations, students decide their level of engagement. However, factors such as camaraderie and competition can promote participation. In addition, a colleague who needs help can trigger a more vigorous learning effort. Additionally, engaging learning encourages autonomy and focus on learning. Games that afford students a primary role and placing the teacher as a guide and interpreter can increase learning intensity (Bonwell & Eison 1991).

According to Huotari and Hamari's conceptualisation (2012), gamification is composed of three fundamental parts: 1) the implemented motivational affordances, 2) the resulting psychological outcomes, and 3) the further behavioural outcomes. The learning process has different phases. According to Boss-Ostendorf and Senft (2018), the sequence is:

1. Recognition of the benefits
2. Gathering an overview
3. Collecting learning material in a structured form
4. Dealing with the material. Repeating the findings
5. Getting feedback
6. Self-organised learning

Gamification appears to be multiple positive effects on student learning. Several empirical studies, such as Tsay et al. (2018) and Diaz-Ramirez (2020), conclude that gamification assessments improve student outcomes. Better performance, more substantial learning outcomes, and higher average scores produce lower failure rates (Subhash & Cudney 2018). However, minimal research examined the effects on the enjoyment of the learning experience or the impact of participating in an international competition well-known among peers, teachers, and potential employers.

Valuable is the professional who ably works in multifaceted teams and environments. Their contribution across subjects is a solid value for their employer. Organisations that desire previous learning should emphasise integrated frameworks which apply to many specialisations (Muduli & Pandya 2018). Student understanding acquired or enhanced during matriculation should be 1) vocabulary, 2) conceptual frameworks, 3) iterative thinking skills and 4) writing. These four focuses are valuable in the construction workplace (Stevens & Day 2019).

A measurement scale of learning games' effectiveness is not available at present (Murillo-Zamorano et al. 2021). Nevertheless, this paper's chosen assessment frameworks may have obvious value for teachers in selecting a suitable simulation for their student cohort. Without an accepted measurement system, those games marketed well may provide less teaching value than others, and student learning will suffer.

Points, badges and leader boards (PBL) are the most consistent motivational feedback recognitions used in gamified learning (Buckley et al. 2018). Future professionals will be expected to master many abilities such as working in groups, listening carefully to others' opinions, motivating self-learning, applying knowledge in practice, analysing, and synthesising information (Murillo-Zamorano et al. 2021). However, there is still a lack of literature exploring the effect of learning and employability of learning technical abilities such as labour demand forecasting, bonus effect on performance, assessment of potential employee profiles, or trade-offs between direct labour and subcontract-oriented project production.

3 Research Methodology

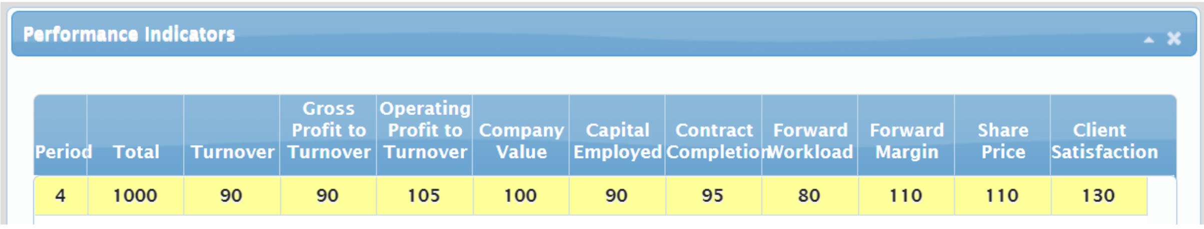
A case study approach is adopted in this research and the use of the Merit Game software in an international competition by Western Sydney University (WSU) is taken as the case. The researchers utilised three credible frameworks to analyse data and observations. The study collected the most recent two years of weekly competition results and after-competition student reflection papers. See Tables 1, 2 & 3 for the assessment of the game structure and software used in the CIOB GSC simulation.

This CIOB GSC international competition utilised Merit Game software. This simulation approaches this construction game as a direct labour prime contractor. Western Sydney University (WSU) competed in the 2020 and 2021 CIOB GSC. WSU mentor and student participants were from its construction management (CM) program. This program is comprised of three disciplines: 1) construction management, 2) building design, 3) construction technology, and student teams were drawn from all these areas. Each of the two years, student applications for team membership were higher than the slots available. Students were selected for three teams in each of the last two years. The CM student cohort was offered an advanced standing credit in a self-selected unit upon completing the CIOB GSC as an incentive for applying.

The CIOB GSC scenario for each student is as a board member for a prime construction contractor employing direct labour that is publicly held. The challenge encompassed six specialised management areas.: a) Financial b) Overhead c) Estimating d) Bidding e) Personnel and f) Construction. Teams are typically comprised of 4 students and assigned two of these areas to master. Each member is additionally responsible for adding their perspectives in the decision-making process for unassigned areas.

Four screenshots for further understanding of the MERIT Game are provided (refer to Figure 1 -4). Each represents a partial but not complete example of the myriad of decisions to be made. What is not shown are several additional input screens and more than 30 reports that contain essential information.

Each team's decisions were scored on their effects on ten areas: Turnover, Gross Profit to Turnover, Operating Profit to Turnover, Company Value, Capital Employed, Contract Completion, Forward Workload, Forward Margin, Share Price, and Client Satisfaction. Each outcome was weighted with the most 62.5% higher than the lowest. The ten areas prompted participants to think about holistic factors that possess long-term value: instead of a short-term focus, such as profit. As an example, Customer Satisfaction is weighted at 130 and Turnover at 80 in relative terms. See Figure 1.

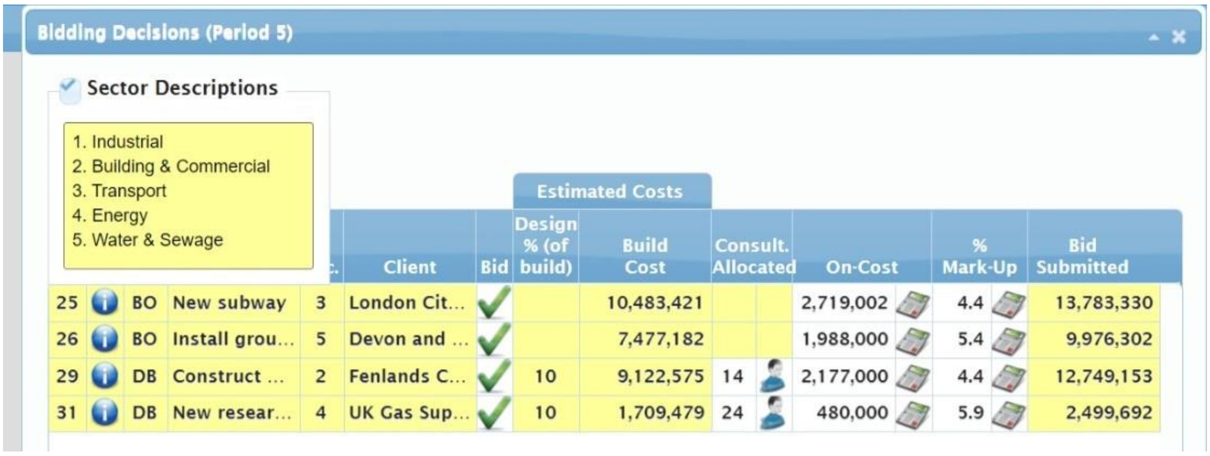


Performance Indicators

Period	Total	Turnover	Gross Profit to Turnover	Operating Profit to Turnover	Company Value	Capital Employed	Contract Completion	Forward Workload	Forward Margin	Share Price	Client Satisfaction
4	1000	90	90	105	100	90	95	80	110	110	130

Figure 1. Score sheet showing the assessment of individual components.

Work acquisition is a critical activity for a construction firm. Tendering or bidding work is the method used. So, project selection ("go/no-go") pricing and costing decision-making is a learning activity in this part. See Figure 2.



Bidding Decisions (Period 5)

Sector Descriptions

1. Industrial
2. Building & Commercial
3. Transport
4. Energy
5. Water & Sewage

				:	Client	Bid	Design % (of build)	Build Cost	Consult. Allocated	On-Cost	% Mark-Up	Bid Submitted
25		BO	New subway	3	London Cit...			10,483,421		2,719,002	4.4	13,783,330
26		BO	Install grou...	5	Devon and ...			7,477,182		1,988,000	5.4	9,976,302
29		DB	Construct ...	2	Fenlands C...		10	9,122,575	14	2,177,000	4.4	12,749,153
31		DB	New resear...	4	UK Gas Sup...		10	1,709,479	24	480,000	5.9	2,499,692

Figure 2. Bidding and Costing Decision Summary Sheet

The firm employs direct labour but can utilise other production methods such as subcontractors for constructing its projects. We share the summary sheet showing previous periods information and one team's decisions, including the cost of jobsite amenities

On-Going Jobs

Job	Last Period: Labour On Site Total	Own	Sub	Site Cost Paid	This Period: Job Status	Planned Labour	Labour Allocation Total	Own	Sub	Own Labour Transfers From ILP	New	To ILP	Paid Off	Site Cost Allocation
6	49	49	0	513,033	In Second Per...	74	79	79	0	0	30	0	0	819,000
10	23	23	0	371,220	In Second Per...	39	43	43	0	0	20	0	0	688,000
14	0	0	0		In First Period	13	13	13	0	13	0	0	0	228,000
16	0	0	0		In First Period	92	96	96	0	12	84	0	0	786,000
18	0	0	0		In First Period	18	19	19	0	3	16	0	0	179,000

Figure 3. Labour Staffing and Jobsite Amenities Decision Making Summary

Teams discussed and selected project managers to lead each project. A profile is offered on each candidate. Students were exposed to a great variation in professional credentials and experience, including personal characteristics. See Figure 4.

Job	Description	Sector	Last Period Proj. Mgr.	This Period Proj. Mgr.	% Bonus
6	Construct daycare facilities	Building & Comm...	38	38	15
10	New water treatment plant g...	Water & Sewage	2	2	15
14	New Cafe/bar facilities in loc...	Building & Comm...	0	4	15
16	Jetty extension	Transport	0	43	15
18	Car plant access road	Transport	0	1	15

Figure 4. Project Manager Selection and Bonus Payment Determination Summary

The researchers analysed student reflection papers submitted after the competition closed in 2020 and 2021. The section headings prompted students to consider the competition both in parts and in whole. See Figure 1.

Boss-Ostendorf and Senft (2018) assert that there are six gamification learning phases. We make the following conclusions from observations and reflection papers. See also Table 2.

1. *Recognition of the benefits* – During the expression of interest process, the student cohort was informed of the competition and its international stature. The CIOB organisation and GSC is well known through0ut the school. In addition, the business of construction is a prominent topic in many units. This subject appears to be attractive to entrepreneurially minded students. We did re-emphasise these benefits in the interview process.
2. *Gathering an overview* – during the interview process and our training period, the mentors emphasised the primary components of the Merit Game simulation. This allowed students not to be overwhelmed by the 560-page instruction slides, multiple input screens and the scoring outcomes.
3. *Collecting learning material in a structured form* - We created training session material and presented it to students before sharing the lengthy Merit Game instruction material. It numbered approximately slides.
4. *Dealing with the material. Repeating the findings* - Our four-week trialling period with the Merit Game software gave students no risk exposure. In this period, each entry was

scored and returned in approximately 10 minutes. Each week in meetings, the individual multiple trialling attempts were discussed.

5. *Getting feedback* – the mentors offered tips and insights to individuals and their teams to advance their understanding. The system, both in trialling and in competition, gave scores and multiple reports of performance. It even publishes an external audit flagging positive and negative decisions. The researchers have counted more than 30 reports published by the decision for each game entry made.
6. *Self-organised learning.* The students were given a schedule of activities each week and for the entire GSC. The crucial deliverables were decisions in the areas they were assigned. Additionally, they were expected to be knowledgeable and add to the discussion of unassigned areas. Students were free and expected to organise their time to meet those deadlines. Most of the students work while in school, and so, their self-organised learning was further refined.

Table 1. Boss-Ostendorf and Senft (2018) Gamification Learning Phases

Gamification Learning Phase	CIOB GSC Characteristics Exhibited
1. Recognition of the benefits	Expression of Interest (EOI) and Initial Interview ask for each student's reasons for applying for the competition.
2. Gathering an overview	EOI and Interview communicate an overview. Once a team member, students read 560 pages of instruction slides.
3. Collecting learning material in a structured form	560 pages of instruction slides were structured for clear understanding. Trialing of software over four weeks provides an integrated understanding.
4. Dealing with the material. Repeating the findings	Mentors provide an updated spreadsheet with recent outcomes to start the following week's critical calculations and decision-making.
5. Getting feedback	Weekly game score and company audit report provide feedback. Team discussions further refine lessons learnt and next steps
6. Self-organised learning	Students have weekly 2-hour team meetings. All other time is theirs. Peer pressure to have review and calculation done before the weekly meeting

Huotari and Hamari's (2012) framework is shown in Table 2's analysis of three sources of information from the 2020 and 2021 CIOB GSC. They were a) Mentors' Observations, b) Student Reflection Papers and c) Game Score Results. The comments column is a collation from this paper's three researchers.

Table 2. Huotari and Hamari's (2012) conceptualisations applied to the CIOB GSC

Concept	Mentors' Observations	Student Reflection Papers	Game Score Results	Comments
Implemented motivational affordances	-International competition motivates students and their mentors. -Advance Standing in a Selected Unit	"A Challenge" "Unique Thinking Space" "Beneficial to enter"	Team ranking was cause for interest in the 4 a.m. weekly leader board release	International competitions have an explicit prestige and employability value for ambitious students
Resulting psychological outcomes	-More Confidence in their knowledge of the Construction Industry	"Improved thinking skills" "Increased understanding of organisational metrics" "Better team engagement skills"	Externally competitive spirit is an emotion that is fully engaged. Some students were energised, while others were demotivated by it	Self-reported outcomes
Further behavioural outcomes	-Unclear, however, listed on CVs for employment	"Gained confidence" "Improved time management skills" "Better on my follow-up"	Students note in their reflections increased confidence	During COVID and afterwards, contact between students and mentors is minimal

Additionally, other university academics shared their perception of the school's partners about the Merit Game unit. These third parties are enthusiastic without adverse comments. Teaching construction business aspects are welcomed and advancing the thinking about trade-offs all decisions have. Additionally, building service graduates comment positively about it alignment with labour-intensive contracting issues.

4 Findings and Discussion

This paper's analysis suggests that the CIOB GSC and the Merit Game simulation are valuable additions supporting tertiary CM programs. The Merit Game software simulation is a tailored approach for student learning. Initial group discussions prompt each team member to understand and self-assign a decision-making area. Each area is different in the kind of analysis and interpretation needed.

Learning games are typically structured with a shorter cycle than traditional assessments. For example, class-based games may require weekly input, while a typical construction program's test schedule will commonly be three times over a 14-week semester. The CIOB GSC's weekly cycle included learning tasks such as downloading and analysing the previous week's results, followed by initial decisions for the next week with discussion and final inputs with the team. The trialling period's cycle was the same. Weekly team meetings discussing various experiment strategies, attempts, and results were faster than a typical unit's assessment cycle. This shorter rotation with its task deadline may lead to learned intensity. From the researchers' experience, this more profound and sustained task focus is aligned with industry reality.

Gamification introduces a construction industry reality: competition. There is competition in for-profit businesses internally and externally. Internally it manifests itself in promotions and bonus determination. Although it may be counterproductive to the organisation's goals, it is a reality. Externally, companies compete again each other. It is the reality in the CM environment. For example, there are limited projects in which companies vie and increasing a firm win rate decreases its competitors' success ratio.

In an educational-learning game, students can assess their passion for competing against others. Some may find it exhilarating and others less so, even demotivating. This is a timeless lesson on which students may reflect. Part of our analysis includes student reflection papers.

Students' knowledge of significant concepts grew from the first week to the last week of the Merit Game competition. This growth of knowledge includes of themselves and their preferences. The researchers endeavoured to make each week slightly different, although the team's ranking was still the main focus.

Working in multidisciplinary teams seeking integrated solutions on a deadline basis prompts unusual reactions from each member. This student response to challenging problems is partly an expression of learning styles. In addition, these reactions can add to a student's self-awareness.

The Merit Game uses a leader board as part of its motivation approach with students. All teams are ranked, and a leader board is publicly communicated to CIOB members and social media. From the mentor's observations of the groups, the higher the ranking each week, the more energised each group is, while lower-ranked teams are less so.

4.1 Outcome-Based Learning Contributions of the Game

Program learning outcomes (PLO) are one of a few primary reasons to introduce a university unit. The selection of any learning simulation should support the same. Contained in Table 3 are the researcher assessments of the CIOB GSC and its Merit Game in support of the Western Sydney University Program Learning Outcomes.

Table 3. Bachelor of Construction Management Studies Program Learning Outcomes comparison to the CIOB GSC Simulation (Source: Western Sydney University)

Program Learning Outcomes (PLO)	**Assured, Developed or Introduced**	**CIOB GSC Dynamics**
1. Demonstrate the broad range of skills and knowledge needed to manage people, construction processes and products	Introduced	Student interactions with their team are witnessed and managed by the mentor during weekly discussions and decision meetings. Determining the best decision after a lengthy engagement process gives students an understanding of iterative thinking. Students were immersed in many processes involved in governing a labour-intensive construction contracting firm. This was a 10-week engagement that reaffirms good and poor decision-making processes. In addition, students were exposed to team dynamics and engagement.
2. Perform competently at a professional level in the building industry, in one or more of the following roles: Construction Managers, Project Managers, Building Supervisors, Estimators, Quantity Surveyors and Building Researchers.	Developed	Students are assigned individual roles in their team but are challenged to review and recommend decisions in other Merit Game areas. Skills such as labour forecasting, financial projection, and bid modelling help in the roles specified in the PLO. Competency in this game is measured against an international field via weekly rankings. WSU student teams placed in the top half of all competitors
3. Develop specialised skills in CM and encompass the degree of complexity involved in planning, design, construction and operation of large-scale residential, commercial and public projects.	Developed	The Merit Game focus is on a large-scale company acquiring and constructing a portfolio of projects. Most projects are non-residential, spanning energy, transportation, building & commercial, water and industrial Labour management and designer selection are critical decisions. Separate risk and complexity levels affect each project. Therefore, a strategy and process must be developed.
4. Communicate effectively through reading, listening, speaking and writing in academic, community, industry, financial, and environmental contexts.	Assured	The intensity of the communication is increased due to weekly deadlines and competitive emotions. Teams interact through speaking, listening and sharing calculations. Much reading is needed since there is a 560-page game. An industry setting is the learning context with a full range of academic skills challenged. Much reading, speaking and listening in a team during the game phase with a reflection report requirement afterwards
5. Conduct research and contribute to the development of innovative procurement methods and construction techniques for future application in the industry.	Introduced	Teams must develop a holistic strategy and process of designer subcontractors and project managers selection. Other challenges include company resource management - shared labour, home office personnel and funds. Procurement of design consulting firms as part of the game with potential design, i.e. savings and risk exposure
6. Adapt quickly to the rapid evolution of the industry environment.	Developed	Customer satisfaction, direct labour management, and designer hiring are relatively new variables. The game prompts teams to develop a system to address each issue. Students were exposed to issues surrounding 1) increased complexity and 2) large publicly held construction contracting firms

Comments from outside academics who taught the Merit Game in 2020 in a construction education unit (not the CIOB GSC competition) were unanimously positive. This seems to demonstrate value across countries and international institutions. Additionally, their statements appear to state the industry's perception of the game explicitly. Groups that shared their thoughts with the academics were IABs, Accreditation Bodies (non-CIOB) and past program graduates. This cross-section appears to represent the diversity of the industry.

5 Conclusion

Written and observed evidence from CM students, university academics, IABs, accreditation bodies, and CM program graduates reflect enthusiasm for both the CIOB GSC and Merit-Game-based units internationally.

Learning games are an established method of teaching and learning. The integration with the internet has enhanced their flexibility and value. As a result, more vendors offer them, and teachers can be a source. The Merit Game was established more than three decades ago and has been a valuable contributor to CM programs internationally. The CIOB has been a continuous sponsor of an international CM competition using the Merit Game simulation.

Construction organisations appear to want employee technical and collaborative skills that help teams work efficiently and flexibly on multiple tasks. Tertiary educators cannot ignore this trend. One solution may be team-centric teaching and learning games structured to stress each skill.

This research adds knowledge of gamification in the Construction Management discipline by understanding its application. The views and perceptions of industry advisory board (IAB), accreditation bodies, and CM program graduates were critical to consider. This paper is timely as the COVID pandemic has prompted academics to seek well-tested online delivery methods of engaging content.

Further research is needed to quantify gamification effects on student learning. Additionally, more studies concerning gaps in present CM learning games and content will assist further improve offerings.

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Exploring the Grit Personality in a Construction Management Program

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Abstract
Construction organisations appear to place a high value on graduates who possess what has been recently labelled as the Grit personality in their hiring. Grit is defined as a combination of passion and perseverance. This paper explores this personality characteristic and its utility in an undergraduate construction management program. Currently, Grit is a popular subject amoung educational researchers and appears to be a valuable trait for the student and the employer. Many studies have predicted long-term success in a career, but it does not significantly improve academic success. This paper is a beginning examination of the possibility of growing the Grit personality and awareness of its utility in construction management students.

The data collection began in mid-2021, making the sample size small but growing. The researchers measured Grit with a well-accepted instrument via an anonymous survey. We have taken a starting sample, and it is a snapshot of the effect of academic and employment intensity. The results conclude that there is no significant effect regardless of employment intensity and study hours while matriculating through a construction management program.

This paper proposes developing a teaching and assessment approach for increasing Grit in a construction management program. The researchers also recommend that discipline leaders continue to build a culture that promotes a passion for construction with a personal commitment to excellent work. This readily connects to the industry's desire for "gritty" minded graduates.

Keywords
Construction Career, Built Environment Success, Building Contracting, Infrastructure Employment.

1. Introduction

The construction industry has endorsed an informal model for many years of what has been recently labelled as Grit. The market has consistently hired graduates who exhibit "character" or "stick-to-itiveness" in their work habits. A majority of construction professionals appear to value this more than academic achievement. This paper attempts to explore this personality characteristic and seeks to answer what a university construction management program may do to strengthen this personality characteristic.

There has been perennial interest in personal qualities other than cognitive ability that determine success, including self-control, Grit, growth mindset, and many others (Duckworth and Yeager, 2015). For example, Duckworth and Yeager illustrated Grit's seemingly strong character with numerous narratives from situations such as military academies, spelling bee competitions and mathematics courses. "We hypothesise that grit is essential to high achievement evolved during interviews with professionals in investment banking, painting, journalism, academia and law… whose sustained commitment to their ambitions was exceptional" (Duckworth et al., 2007). Golding et al. (2018) echo this sentiment by stating that Grit is one of the most important predictors of long-term success. However, as a uniform construct, it is not correlated to higher academic performance; instead, it consists of two non-cognitive characteristics that unequally relate to achievement.

The literature has shown that long-term success can be predicted for higher grit scores, such as in a construction career. Construction firms have actively hired gritty students. They appear to label its character. In our review, however, this quality is lightly studied in the construction management education literature. In construction management, measuring this valued attribute may help quantify the desirability of a program's graduates.

Thinking further about the role of university programs to produce more valued graduates as perceived by employers, we explore how a construction management program might develop the grittiness of students during their matriculation.

2. Literature Review

While cognitive and non-cognitive factors are implicated in student achievement, non-cognitive factors are salient due to their potential malleability through education and intervention (Duckworth and Yeager, 2015). Non-cognitive factors include attitudes, behaviours, motivation, and emotion, which play an essential role in a student's academic success. Student academic performance is improved by increasing non-cognitive skills such as self-motivation, disciplined behaviour, study skills, and goal setting (Lee and Stankov, 2018). The importance of non-cognitive factors is further highlighted by research that has found that academic discipline (a non-cognitive factor) mediates the relationship between high school and university academic achievement. This suggests that non-cognitive factors are critical for continued success in higher education (Komarraju et al., 2013). Another non-cognitive factor that has received research attention in recent years is Grit, conceptualised as perseverance and passion for long-term goals (Duckworth et al., 2007).

2.1 Defining Grit

Grit tends to strive towards a long-term goal with sustained effort and enthusiasm (Von Culin et al., 2014). As a personality trait, Grit is composed of two related but distinct qualities: consistency of interest (CI) and perseverance of effort (PE) (Duckworth et al., 2007). While these two qualities are differentially related to academic achievement and participation in activities, empirical evidence suggests that combining the two qualities is more highly predictive of success in challenging tasks (Duckworth and Quinn, 2009). When a gritty individual pursues a goal, they do so repeatedly despite setbacks or challenges (Duckworth and Gross, 2014). Such individuals display discipline, commitment, determination, and enthusiasm for their goal. Therefore, it is not surprising that Grit is theorised to be one reason why students of similar ability levels experience differing levels of success (Duckworth and Gross, 2014).

Grit is one ingredient for the long-term achievement of goals while being more productive. It is theorised to be linked with long-term academic success (Kirchgasier, 2018). However, empirical research linking Grit with increases in academic achievement is mixed. For example, Strayhorn (2013) found that Grit was positively related to college grades in a sample of African

American males attending predominantly white colleges. In contrast, the relationship between Grit and cognitive abilities, such as college qualification tests and cumulative grade point average, is not significant, meaning Grit does not determine aptitudes or abilities (Choi, Myers and Louis, 2016).

However, measuring Grit appears problematic. There is an absence of measuring passion standalone in literature. It has been described as an integral part of Grit, but a separate non-commingled metric is undeveloped. Jachimowicz et al. (2018) assert that the measurement offered by the 12-point Grit Scale is for only perseverance. It appears that passion is assumed when someone perseveres at one activity over time. Additionally, passion seems to facilitate perseverance. So, passion for something should be encouraged in students, and the resulting perseverance will result in mastery of the subject matter.

2.2 Perseverance of Effort

Recent research with college students suggests that only one aspect of Grit, perseverance of effort, is significantly related to increased academic achievement (Wolters and Hussain, 2018). Jachimowicz et al. (2018) assert that Grit is likely a measure of perseverance alone. However, its measurement does not align with its definition. They point to a recent metanalysis study and others that found a weak, non-significant relationship and several achievement indicators. Furthermore, MacCann and Roberts (2010) found that the relationship between Grit and achievement was mediated by conscientiousness in high school students. This relationship was entirely mediated by self-regulated learning skills, suggesting that for gritty individuals to experience improved academic performance, they also require well-developed self-regulated learning skills.

Educational persistence models are centred around self-regulated learning behaviour. The mediators are the student's social and academic integration. This also helps retention, but more importantly, it determines the level of goal and institutional commitment (Robbins et al., 2004). So, in other words, some level of acceptance socially and academically may facilitate student commitment to learning at a particular institution.

2.3 Consistency of Interest

The level of Grit determines emotional engagement to task and may facilitate deeper learning. Grit is a strong predictor of later literacy achievement via the meditator of achievement. A recent study found that literacy positively affects socioeconomic factors affect literacy and vice-versa. This is known as a reciprocal effect. It specifically focused on low income, ethnic-minority, and dual-language learners (O'Neil et al., 2017). A significant mediating effect of learner engagement between learner's Grit and perceived academic achievement was found. This was consistent with other studies. The more persistent learners are, they are more actively engaged (Yoon et al., 2018).

Knowing an individual student's life journey is an additional part of raising a student's motivation to learn and apply concepts and principles. Teachers who know their student's interests help them create a strong post-graduation vision. Passion assists memory which is an integral part of any profession's job skills. Organising knowledge for quick retrieval assists effectiveness. (Maranville 2001). Passion and context are two keys to learning. Context can be considered the "why" of the content taught. Delivering compelling reasons for learning course material can unleash passion.

2.4 Grit and Academic Achievement

If Grit is a predictor of long-term achievement, should not it follow to predict academic achievement? Recently, Grit has become one of the leading educational goals and markers of success upheld by many schools, parents, and education policies (Stitzlein 2018). Grit positively predicts academic performance, but only the conscientiousness component is statistically significant (Mason, 2018). Others assert the perseverance of effort (PE) (Steinmayr, Weldinger, and Wigfield 2018; Crede, Tynam and Harms 2016). Park et al. (2018) state that Grit is a psychological resource for students to utilise and has positively predicted an array of accomplishments in school settings, including academic achievements. From a holistic perspective, academic performance is multi-dimensional, and an integrated model of this phenomenon is not well understood (Moreira et al., 2013).

Golding et al., 2018, state that if one has Grit, a person possesses perseverance, resilience, and passion for accomplishing long term goals; these characteristics are essential for first-generation university students to graduate. As Grit becomes a standard part of education intent, it has rightly drawn our attention that good education is more than just nurturing one's mind or demonstrating knowledge capture. Instead, it extends into character development, outlook, and ways of being (Stitzlein, 2018).

The Grit personality characteristic makes students less distracted and prone to stress. Therefore, Grit is negatively associated with stress. However, if stress is not managed well in the long term, it could negatively impact Grit and its components (Lee, 2017).

2.5 Developing Grit

Attaining a higher level of Grit is a journey. It is a series of associations and transformations. This trait is the result of the evolution of study in learning achievement (Kirchgasier, 2018). According to Duckworth's 2016 book, Grit is due in a small part to one's nature (genetics) but mostly is from nurture (experiences). There is a positive correlation between Grit and age in students. In a recent study, students in their last year of undergraduate study scored higher than first-year students. Additionally, those aged 31 and above received higher grit marks than those who were 21 and younger. This might be explained by more setbacks and challenges one experiences with each year of life and a more holistic view of existence. This translates into an appreciation of the difference between a quality life and one that is not (Kannangara et al., 2018).

One does not instantly develop Grit, nor can one solve all personality issues and become exemplary (McCabe, 2016). Since it is almost entirely a product of one's existence, Duckworth (2016) concludes that Grit grows during one's life. She asserts that adverse events and a person's determined reaction to them are shared among the grittiest. Golding et al. (2018) assert that Grit can be self-developed. People are not born gritty. The majority is developed from negative life events if the person has a striving mindset and not a victim mentality. With this understanding, is there a way to increase Grit while a person attends a construction management program?

The stability of Grit is unchanged in the short term, in one case study, six months (Jiang et al., 2019). This aligns with Duckworth's (2016) findings that life's events typically infrequently occur and, when they do, have an outsized effect on a person's grittiness.

Research suggests that Grit is a characteristic that can be strengthened. It has been found that the mutual reinforcing pattern between Grit and academic achievement flow enhances a student's self-concept (Jiang et al., 2019). There seem to be two significant contributors to the emergence of Grit in students. A learning environment that consistently explicitly and implicitly indicates that it values effort. Demonstrations showing successful goal perseverance should lead students to adopt these attitudes (Park et al., 2018). Over four years, a university construction management program may influence its student's grittiness by encouraging and perseverance while emoting a passion for the construction industry.

3. Research Methodology

The researchers surveyed the Western Sydney University construction management student cohort and used the 12-Item Grit Scale (see Figure 1). The survey was distributed to students via a common course learning website through an announcement utility. The student population consists of over 1,400 students enrolled in Construction Management, Construction Technology and Building Design Management programs.

12-Item Grit Scale

Respond to the following 12 items. Be honest – there are no right or wrong answers.

1. I have overcome setbacks to conquer an important challenge.
   - ☐ Very much like me
   - ☐ Mostly like me
   - ☐ Somewhat like me
   - ☐ Not much like me
   - ☐ Not like me at all
2. New ideas and projects sometimes distract me from previous ones.*
   - ☐ Very much like me
   - ☐ Mostly like me
   - ☐ Somewhat like me
   - ☐ Not much like me
   - ☐ Not like me at all
3. My interests change from year to year.*
   - ☐ Very much like me
   - ☐ Mostly like me
   - ☐ Somewhat like me
   - ☐ Not much like me
   - ☐ Not like me at all
4. Setbacks do not discourage me.
   - ☐ Very much like me
   - ☐ Mostly like me
   - ☐ Somewhat like me
   - ☐ Not much like me
   - ☐ Not like me at all
5. I have been obsessed with a certain idea or project for a short time but later lost interest.*
   - ☐ Very much like me
   - ☐ Mostly like me
   - ☐ Somewhat like me
   - ☐ Not much like me
   - ☐ Not like me at all
6. I am a hard worker.
   - ☐ Very much like me
   - ☐ Mostly like me
   - ☐ Somewhat like me
   - ☐ Not much like me
   - ☐ Not like me at all
7. I often set a goal but later choose to pursue a different one.*
   - ☐ Very much like me
   - ☐ Mostly like me
   - ☐ Somewhat like me
   - ☐ Not much like me
   - ☐ Not like me at all
8. I have difficulty maintaining my focus on projects that take more than a few months to complete.*
   - ☐ Very much like me
   - ☐ Mostly like me
   - ☐ Somewhat like me
   - ☐ Not much like me
   - ☐ Not like me at all
9. I finish what I begin.
   - ☐ Very much like me
   - ☐ Mostly like me
   - ☐ Somewhat like me
   - ☐ Not much like me
   - ☐ Not like me at all
10. I have achieved a goal that took years of work.
    - ☐ Very much like me
    - ☐ Mostly like me
    - ☐ Somewhat like me
    - ☐ Not much like me
    - ☐ Not like me at all
11. I become interested in new pursuits every few months.*
    - ☐ Very much like me
    - ☐ Mostly like me
    - ☐ Somewhat like me
    - ☐ Not much like me
    - ☐ Not like me at all
12. I am diligent.
    - ☐ Very much like me
    - ☐ Mostly like me
    - ☐ Somewhat like me
    - ☐ Not much like me
    - ☐ Not like me at all

Figure 1. 12-item Grit Scale. Source: Duckworth et al., 2007

Our survey approach used Qualtrics software. We asked individual questions concerning a) number of hours working in total while attending university full-time, b) the average number of hours worked per week, c) the average number of hours of study per week, d) discipline of study. Survey responses were anonymous. We reviewed results for disqualifying information such as identical IP addresses and incomplete surveys.

The 12-item Grit Scale scores participants' answers from 1 to 5, which total to a possible of 60. Duckworth alternates the questions from ones that are Grit positive where "Very much like me" is given 5 points (1, 4, 6, 9, 10, 12). In Grit negative questions (2, 3, 5, 7, 8, 11) the exact phrase is given a score of 1. This ensures that each survey is read carefully.

Our research is beginning, and we plan to measure student Grit until 2025 on a quarterly basis. We are interested in longitudinal trends as we further explore and understand the personality's dynamics. However, this paper has captured and analysed results from two months of survey responses.

The researchers received and analysed 61 completed surveys with SPSS 27 (Table 1). We split our survey scores into four groups of students representing each of the four years of study.

Average grit scores were generally centred around 41 and 42 for all groups. The significance did not reach .005; therefore, the null hypothesis is not rejected. Furthermore, each group's score is unaffected by the varaible's tested. See Table 1.

Table 1. ANOVA Statistical Test Between and Within Groups' Result

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Average Weekly Study Hours	Between Groups	9.621	23	.418	1.023	.465
	Within Groups	15.133	37	.409		
	Total	24.754	60			
Total Number of Work Hours	Between Groups	107.605	23	4.678	1.088	.400
	Within Groups	159.083	37	4.300		
	Total	266.689	60			
Average Weekly Work Hours	Between Groups	67.580	23	2.938	.845	.660
	Within Groups	128.617	37	3.476		
	Total	196.197	60			
Year of Study	Between Groups	30.633	23	1.332	1.018	.470
	Within Groups	48.417	37	1.309		
	Total	79.049	60			
Course Pursuing	Between Groups	4.806	23	.209	1.131	.361
	Within Groups	6.833	37	.185		
	Total	11.639	60			

The researchers tested the 12 item Grit Scale for reliability (internal consistency) as a quality check. Duckworth's 12 Item Grit Scale Items measured .572. The study's 18 item questionnaire, which included demographic questions and the 12 Item Scale, measured .497 An acceptable minimal level of reliability is .7 (out of a possible 1.0). The sample size may be the problem - n=61. The researchers calculated that the survey needs approximately 302 completed surveys. Our assumptions for this calculation were: a) population size 1400 b) confidence level .95 c) proportion 50%.

4. Findings and Discussion

The lack of significant difference in Grit scores from year one to year four is not surprising. The literature review suggests that this personality is set over a person's life and most student experiences occurred before they entered the University. The addition of a construction management program's and employment demands does not statistically affect their Grit score.

The sampled construction management program's student cohort appears not to be homogenous in major categories such as life's experience and immutable personal characteristics. Each student is dissimilar in their perspective, skills and work pace, including their level of Grit. Therefore, the personal and professional support system around each student is critical. It is an attempt to give every student a less variable starting point, and participating University in this research has focused on making this a reality in the last decade.

4.1 Passion

W. B Yeats once stated, 'Education is not the filling of a pail, but the lighting of a fire'. Can a construction management educator inspire passion? Research on learning asserts that positive emotions help learning in several ways. The building of an unambiguous learning culture that nutures passion can add to student Grit.

Any construction management program can strengthen its present learning culture but, more importantly, direct it to worthy ends for students, employers, and the industry. The instructor and well as others have an opportunity to inspire students toward specific goals such as constructing projects with safety and quality.

A program's culture can start in an individual classroom. It has its own "ecosystem" of values and expectations with a grading system that assesses it. An instructor can build a culture in their course. University Culture is reflective of an institution's beliefs, values, and attitudes. It is guided by its mission and intentions (Sporn, 1996). A construction program's organisational culture sets norms, values, beliefs, and traditions that direct a sense-making process somewhat differently from other groups (Roxå, Mårtensson and Alveteg, 2011). A learning culture that inspires passion and perseverance crosses ethnic, racial, gender or national characteristics. The researchers observe that many construction management program's student cohorts do not appear to be homogenous in significant categories.

Given the complexity and ambiguity of the construction process, we assert that the non-cognitive characteristic of Grit is a consistent ingredient in successful hires and long-term employees. They must have CI and PE to keep working in an industry that can be dirty, thankless, and draining. Graduating students whom employers value attract more attention of other construction organisations. In the researchers' industry experience, a person's Grit is a valued characteristic in the construction industry. Employers' sometimes seen it as "stick-to-it-ivness" i.e. the determination to pursue long term goals with passion and perseverance helps organisations and individuals achieve excellence.

Since construction educators are at the front of improving the industry's human capital pool, efforts to strengthen Grit in graduates appear to be worth making. Suppose construction management programs view Grit as a continuing evolution of a student's character stewarded by the University and its instructors. In that case, a natural starting point may be the first day of the student's attendance. If so, then the 12-point Grit Scale would be valuable. It can serve as a beginning assessment and as an ongoing self-check for each student. Certainly, this instrument can be part of presentations and discussions during matriculation.

So, for example, tests can be re-apportioned to be a series of smaller tests given more often. This would engage the student in iterative work, much like the industry. A consistent effort each week (a quiz) to reach a goal (an above-average grade). This type of format signals from the teacher to the student the real iterative work effort that construction professionals are engaged in daily.

From an industry perspective, organisational leaders agree that those construction professionals who have been continuously employed in the construction industry for over a decade or more certainly have a high amount of Grit. Therefore, it appears to align well with a construction organisations long-term employment strategy to test those who are just beginning their career to test for Grit. Said differently, if there is a characteristic manifesting itself in most 10-year employees, then hiring those who have it makes for improved employment success.

The student experience of learning in a construction management curriculum is a series of interactions with instructors and support staff, program leadership, fellow students, and professionals in internship opportunities. These influence the student's perception of learning and can challenge what the student's perceived limits are.

4.2 Perseverance

A steady teaching and assessment regimen facilitates students to be more disciplined and consistent in their efforts. In addition, this predictable regimen should lower stress.

The significant challenging variable is the student's changing personal and work demands during the years toward graduation. This irregular schedule can become an indirect teaching tool if coupled of many small assessments over a semester. (See Table 2) This forces students to focus on the short-term importance of mastering material for a weekly quiz. This challenge of steadily working while conflicts arise is a helpful lesson for an above-average construction career.

Table 2: Two Assessment Scenarios and Their Possible Grit Enhancement

Factors	**2 Assessments per Course**	**10 Assessments per Course**
Student depth of understanding	To the standard set by University	To the standard set by University
Student Effort	Two large waves of effort – 1 for mid-term and 1 for final	Smaller but steadier focus with the same overall effort
Instructor grading time required	Intense during post assessment grading	Steadier and more consistent
Student self-discipline	Can be focused on intense studying twice during course	Must be focused and disciplined ten times during the semester.
Possible Grit enhancement	Negligible since there is a short, intense period of content understanding. For the student, this routine is easier to manage with external demands	More since consistent learning is critical. In addition, external demands during the weekly learning cycle make students more

		disciplined and conscious of long-term planning.

If too great a challenge is presented, then the student is overwhelmed with adverse effects on their confidence. Too little a challenge and they don't progress significantly. A construction management program's ability to positively affect cognitive factors is limited whereas, influencing non-cognitive is greater. Universities have focused on "at-risk" students with training and support for improving study skills, academic discipline, self-regulation, and time management. This is important work; however, if construction management programs focus on all the students, this would help also. Thus, focusing on the more significant opportunity is a better investment of time, effort, and money. However, individual sessions concerning these factors can be cost-prohibitive to a program. Fostering a culture of grittiness is less expensive.

5. Conclusion

Each student's Grit personality is well-established before they enrol in a tertiary education institution. However, we believe that a directed learning culture can enhance this valuable trait and make it more stable. Additionally, construction organisations desire this characteristic as part of undergraduate's preparation for the industry.

The paper proposes developing a learning culture to include an atmosphere that promotes excitement in a construction career and a professional commitment to excellent work. The research is just beginning. Additionally, we suggest a steady teaching and assessment approach for increasing students' grittiness in a construction management program. This will lead to a distinct culture that supports and nurtures this personality.

It is a consistent conclusion in the research literature that a teacher significantly influences students' perceptions. As a result, many have cited great teachers as the reason for a range of positive classroom experiences, life lessons and career choices.

This paper adds to the body of knowledge by exploring the Grit personality's value and quantifying its measure's employment and academic demands.

Further research will be pursued to explore potential program changes that might help increase the Grit personality in CM Students, such as specific sections teaching its utility, the value of steady work habits and COVID Pandemic effects. Additionally, we plan to assess Grit in our program's graduates for comparison. These possible additions should raise student awareness and prompt important discussions at a minimum.

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Understanding the Blockages to Sustainability in Building Projects

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Abstract
This paper presents an investigation into the blockages to sustainability in building projects. Recent emphasis on Sustainability Assessment in buildings entails a cluster of life cycle considerations including energy management, life cycle costing, circular economy, innovation, well-being, and pollution. Different organisations in Australia utilise standard rating tools such as GreenStar to appraise the sustainability initiatives. However, this often fails in appraising newer building innovations and materials, where there is no data regarding the sustainability considerations.
This research is based on a focus group workshop and questionnaire survey involving 10 different building organisations comprising of architects, engineers, and sustainability professionals. Three key findings emerged from the investigation namely: (1) lack of transparency in current sustainability rating tools; (2) lack of clear guidelines regarding innovative products; and (3) lack of strong institutions driving sustainability
Future work in this research project is expected to inspire the development of a framework that can facilitate an improved measurement of the life cycle sustainability potential for different scenarios and options in building projects. In particular, more work is required to deepen understanding on the blockages to sustainability within different contexts. In the future, it could be necessary to develop a Life Cycle Sustainability tool that could be used in benchmarking and evaluating the project design, during the conceptual stages.
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Keywords - building lifecycle, innovation, rating tools, sustainability assessment

1 Introduction

The building and construction industry accounts for approximately 60% of resource usage, 35% of energy consumption and 35% of GHG emission (ASBEC 2021, Tokede et al., 2021). Sustainability is believed to be connected to all areas of human life, even though its definition has not been unified yet (Wilson, 2007). Sustainability may, however, be realistically described as activities that demonstrate the inclusion of social, environmental, and economic concerns in business operations and interactions with stakeholders (Van Marrewijk, 2003). It is, therefore, acknowledged that sustainability can be achieved in many different ways and considering innumerable factors (Mura et al., 2018). Based on empirical data, Laine (2010) proved that over the years, sustainability has transformed from a "revolutionary concept" into" preserving the status quo", thereby, endorsing poor practices (i.e where good becomes the enemy of better); also greenwashing is becoming commonplace in many sustainability verification and assessment process.

In building projects, sustainability measurement has become a growing multi-billion dollar industry, with developers and investors spending vast sums of money in order to receive accreditation from rating organisations and providing demonstration projects acclaimed to be 'best-practice' in different parts of the globe, but most especially in Western nations. Furthermore, sustainability is gradually being incorporated into the building code in many countries. For instance, in Australia, sustainability benchmarks have been established through mandatory regulation in the National Construction Code (ABCB, 2013) and voluntary certification, for example through the National Australian Built Environment Rating System (NABERS) (Bannister, 2012) and GreenStat rating tools (Mitchell, 2010). Minimum standards and specific requirements for certain buildings classes, location or specific contexts are regulated by Australian state and federal governments (ABCB, 2013). Furthermore, the Building Regulatory bodies govern in each state and territory and are underpinned by many legislative acts and regulations aligned to the built Environment. One of the key areas in construction is the Building Act (1993) and Domestic Building Contract Act (1995). The Building Act (1993) further determines that the a 'Building Practitioner' (S.3.1) is a professional engaged in construction namely a Building Surveyors, Building Inspector, Building Designer, Quantity Surveyors and Builder. Each of these have required building qualifications and/or demonstration of building knowledge.

Despite a strong regulatory system not all professionals have sustainability knowledge embedded in their respective qualifications. This is particularly found missing in the national training packages adopted by all States and Territory in building construction. Neither the Cert IV or Diploma of Building Construction training qualification deems sustainability a core knowledge subject. Both national qualifications see sustainability as an elective that is an optional subject. The reality on ground however reflects the growing demand for more sustainable approaches and industry expectations are that new building developments in future will meet or exceed minimum legislated sustainability standards and also provide voluntary or higher ranked sustainability certification. This paper conducts an investigation on the blockages to sustainability in building projects. A review of sustainable assessment tools is conducted followed by an analysis of the scope of existing sustainability tools. Our research method comprises of a focus group workshop and questionnaire survey involving 10 different building organisations comprising of architects, engineers, and sustainability professionals.

The next section undertakes an overview of sustainability assessment in building. Following on this, an analysis of the key sustainability considerations in building projects is provided. Upon completion of the literature review section, the research methodology is explained and the findings and discussions are extracted. The conclusion provides insights on the blockages to sustainability and highlights the future for rating tools in buildings.

2 Sustainability Assessment in Buildings

Recent estimates have suggested that there are over 200 green building assessment schemes globally (Afroz, Burak Gunay, & O'Brien, 2020). Common Building rating tools include Building Research Establishment Assessment Method (BREEAM), Leadership in Energy and Environmental Design (LEED), Comprehensive Assessment System for Building Environmental Efficiency (CASBEE),Green Star and WELLS. These rating systems are revised and updated periodically to adapt to the changing requirements. The relevance of these indicators tend to vary in different context. BREEAM – the dominant UK rating tool tends to change over time, and is questionable (Al-Waer et al., 2008). LEED, used in the US has similar categories to BREEAM, but fails to address social or economic considerations adequately.
In Australia, NABERS embraces a performance-based approach but is static, and does not measure the building design resilience or proficiency (Hampton and Clay, 2006) LEED is adopted by the United States and Canada for rating the buildings, whereas CASBEE is used by

Japan. Buildings certified under LEED system uses 25-30% less energy and BREEAM certified buildings use 6-30% less energy (Turner, Frankel, & Council, 2008). Green star rated buildings are considered to create 62% fewer greenhouse gases emission, uses 66% slighter electricity, consume 51% less potable water when compared to other conventional buildings of a similar type, also 96% of respective execution and demolition waste can be recycled (Weerasinghe et al., 2017).

It is therefore understood that considerable variations exist in the level of performance and criteria stipulated for sustainability assessment schemes (Afroz et al., 2020; Lee, 2013). These large variations amongst assessment schemes lead to increase in cost of acquiring certifications, including cost of submission, preparation, and hiring experts to conduct compliance checks (Castellano et al., 2016; Kang, 2015). Areas of consensual scope coverage across certification systems are: pre-design, design, construction, renewable energy, materials, potable water, impacts on site, greenhouse gas emission, commissioning of building system, and indoor environmental quality. Conversely, Aspects of limited scope coverage across certification systems are – operations, performance data, total life cycle primary non-renewable energy use, flexibility and adaptability (Lee, 2012).

Nevertheless, sustainability assessment provides effective approaches to substantially reduce environmental impacts in buildings (Kang, 2015; Lee, 2013). They offer flexibility in improving image, raising public awareness, promote achievement of set standards and maintain dialogue with the private sector (Afroz et al., 2020; Frischknecht et al., 2019). However, sustainability assessment tools are not exactly an easy communication tool as their technical language is limited to technicians and specialists (Castellano et al., 2016; Ferreira et al., 2014). It is also claimed that Sustainability assessment tend to place emphasis on energy as it brings the most tangible benefits to the environment as well as developers (Lee, 2012).

In concise terms, the primary purpose of sustainability assessment schemes are to establish benchmarks for mitigating against negative impacts of buildings (Alwisy et al., 2018) and in creating shared understanding on the requirements for achieving sustainable buildings (Greer et al., 2019). More generally, building assessment schemes are tools used in benchmarking the performance of buildings with the national set standard or other buildings. Benchmarking, in this sense, involves the process of accounting for, and comparing a building's performance with a baseline (Duverge, Rajagopalan, Fuller, & Woo, 2018). Benchmarking tends to follow two clear protocols: prescriptive path, used to assess diverse areas listed, and evaluates criteria necessary to achieve required performance; or a performance path – which evaluates the overall performance based on mathematical modelling (Kang, 2015). Alternative classification of benchmarks include the top-down and bottom-up categories. Top-down benchmarks are based on a global budget, while bottom-up benchmarks are based on individual building elements, and national building component catalogue (Frischknecht et al., 2019).

In systematically benchmarking buildings, many factors need to be considered including the contextual similarity of buildings; the age of the benchmark, the categories of the benchmark (i.e. best-case or average), and the reference year (Olivia & Christopher, 2015). Furthermore, systematic benchmarking can explicate the characteristics of assessment schemes leading to improved credibility of results (Lee, 2013). There are four categories of systematic benchmarks in buildings. This include (i) Distance-to-target value - which assesses the highest values theoretically availabl e; (ii) Best-in-practice – best value attainable in an experimental way; (iii) Regular value – commonly expected to represent average value; or (iv) Limit value – lowest exactable value (VTT, 2012). Most certification systems are however based on a limit or target value metric, and do not represent best-in-practice values (Schlegl et al., 2019). Target values could be achieved by applying national reduction targets (Frischknecht, Wyss, Knöpfel, & Stolz, 2015) or based on the ecological carrying capacity of the earth (Russell-Smith et al., 2015); while limit values are achievable based on scoring systems (e.g. DGNB, GreenStar).

Olivia and Christopher (2015) doubts the effectiveness of benchmarking sustainability performance, as standardised methods are not always meaningful and tend to be difficult in practice. Furthermore, most certification systems are yet to incentivise performance through benchmarks and targets due to uncertainty of data accuracy, scope boundaries for inclusion and standardisation of methodologies (Adams et al., 2020; Alwisy et al., 2018). In addition, emphasis of sustainability assessment tend to be solely on the negative impacts of products, services and systems (Alvarenga et al., 2020), and they do not address the holistic function of the buildings (Bribián, Capilla, & Usón, 2011; Kang, 2015). Moreover, problem-shifting could occur, when there is only focus on few environmental indicators (Frischknecht et al., 2019), as environmental data tends to be limited and imprecise (Russell-Smith et al., 2015; Schneider-Marin & Lang, 2020). There is therefore, increasing acknowledgement and agreement among the building industry that sustainability rating schemes or tools are not a remedy for improving the buildings and construction sector (Castellano et al., 2016; Phillips, Troup, Fannon, & Eckelman, 2017). In fact, current benchmarking schemes are considered too weak to support the building sector in contributing significantly to the required CO2 emission turn-off and accompanying sustainability targets (Frischknecht et al., 2019; Greer et al., 2019).
Nevertheless, benchmarks offer a good opportunity to receive information on environmental issues at an early stage (Ferreira et al., 2014). Empirical evidence from Russell-Smith et al. (2015) based on an experimental and control groups, suggests that building design teams given quantitative sustainability targets are equipped to achieve more environmentally sustainable designs than teams with no targets. Katzenbach and Smith (1993) corroborate that specific numeric goals facilitate communication and constructive conflict within teams and lead to improved performance. In addition, design teams with targets, experience increased collaboration, evaluate more design options for dynamic and complex projects, and deliver optimal designs within budget (Russell-Smith et al., 2015). Afroz et al. (2020) also concurs that certification schemes should be quantitative as qualitative strategies are not measurable. This opinion however undermines immeasurable sustainability attributes and constrains mathematics as the only legitimate yardstick to evaluate sustainability outcomes (Tokede and Traverso, 2020).
To rectify the limitations in sustainability assessment schemes, an incorporation of life cycle perspective has been suggested to enhance integrated design practice, improve resource utilisation (Llatas et al., 2020), and facilitate the achievement of sustainable development goals in holistic and resilient manner (Goh, Chong, Jack, & Mohd Faris, 2020; Phillips et al., 2017; Rehman & Ryan, 2018). The theoretically-resulting advantage of a life cycle perspective is transparency as it allows us to identify trade-offs between the different dimensions of sustainability (Heijungs et al., 2010).The challenge with life cycle approaches however lies in its comprehensiveness with regards to coverage, potential impacts and interdependency among the dimensions of sustainability (i.e. social, economic, and environment)(Sala, Farioli, & Zamagni, 2013b). Till date, there has been limited application of life cycle approaches to sustainability assessment. The research therefore, aims to appraise the insights that life cycle sustainability assessment can bring to material selection in buildings, over the conventional sustainability assessment schemes.

3 Key Sustainability Considerations in Building Projects

In order to understand the blockages to sustainability, it will be crucial to identify the metrics commonly used in appraising sustainability in building projects. Bothwell (2015) proferred that sustainable buildings are characterised by their minimal consumption of energy, materials, water, and other resources, and by their use of materials that lower negative impacts on the natural environment. Meadows (1998) however believes that Sustainability indicators must be more than environmental metrics, they need to consider the time and/or thresholds associated. Moreover, stimulating innovative solution is difficult to achieve in environmental assessment (Bothwell, 2015). Studies in the UK by Cyril Swett and BRE Trust 2005 reveal that additional cost of constructing the most exemplary sustainable building ranges between 1 – 7%. These studies agree with Heujing and Reijinders (2004) that economic measures and standard sustainability are not properly reconciled to dealing with the ecological challenge in buildings.

There have been different scopes on the requirements for sustainability in buildings. Petit-Boix et al (2017) believes that energy and resource consumption are the most important considerations in achieving sustainability in buildings. Other authors believe that the main impacts of the built environment are water consumption, metal pollution and global woarming (Min ho et al., 2015; Li et al., 2016). The ISO21929-1 (2011) *Sustainability in building construction — Sustainability indicators — Part 1: Framework for the development of indicators and a core set of indicators for buildings* identifies 14 expansive areas of protection namely Emission to air, Use of non-renewable resources, Fresh water consumption, Waste generation, Change of land use, Access to services, Accessibility, Indoor conditions and air quality, Adaptability, Costs, Maintainability, Safety, Serviceability, and Aesthetic quality. These indicators however run across the entire life cycle from planning, design, construction, use and disposal/re-use. Operationalising these metrics for future buildings is therefore complicated. Another more practical approach is to assess the focus of the different sustainability rating tools in order to identify the main considerations across board.

The Australian Sustainable Built Environment Council (ASBEC, 2021) recently published a rating snapshot of the built environment sustainability frameworks commonly used in Australia. Table 1 provides an analysis of some of the key foci of some mainstream tools in Australia. It is clear from the Table 1 that Green Star and NABERS are perhaps the most versatile tools. However, there is no single tool that completely fulfils all the array of considerations necessary to achieve sustainable buildings. This situation, therefore, cast some doubt on the future of rating tools in Australia, as the verification processes are expensive and onerous. Moreover, there is little evidence that combining multiple rating tools in sustainable building projects can achieve better outcomes.

Table 1 – Analysis of Building Rating Tools used in Australia (adapted from ASBEC, 2021)

		GreenStar	NABERS	Basix	Liveability Real Estate	EnviroDevelopment
	Energy	✓	✓	✓	✓	✓
	Pollution in Indoor environment	●	●	●	✓	✓
	Climate resilience	✓	●	●	●	●
	Economic performance - LCC	✓	●	●	✓	●
	Circular Economy (Materials and Waste)	✓	✓	●	●	✓
	Social Sustainability	✓	●	●	✓	✓

	Innovation (i.e. Decarbonisedsed energy sources)	✓	✓	●	✓	●
	Well-being (Health and Wellbeing)	✓	✓	●	●	✓

✓ - Full or some considerations in the scope; ● – No consideration given in the scope

It is noteworthy that the building regulator in various States in Australia apply rules that are not consistent in the application for licensing and renewing of Builders. In New South Wales (NSW), the building regulator Department of Planning, Industry and Environment requires Continuing Professional Development (CPD) as part of licensing renewal while in Victoria, the Victorian Building Authority does not have same requirement as noted in NSW.

4 Research Methodology

An experimental methodology was adopted in this work and builds on previous work conducted by Tokede et al., (2021). This approach enables us to provide the empirical insights needed to address the research aim and objectives. Our research method comprises of a focus group workshop and questionnaire survey involving 10 different building organisations comprising of architects, engineers, and sustainability professionals
Questionnaires Surveys have a two-fold purpose: (i) To collect objective data, and (ii) To transform semi-quantitative information characteristic about the project into quantitative data needed for result analysis Within the questionnaire session, participants could respond to the populated questions that displayed on the screen using a code. The respondents used their mobile devices to provide answers in a synchronous manner. The question consisted fo two parts. The first part was on sustainability considerations and participants were expected to highlight key drivers of sustainability in a building project. Following on from this was a discussion in focus-froup settings.

Focus groups are a type of group interview where great importance is given to the interaction between participants who are selected ad-hoc according to the topic under discussion. Focus group is flexible, economically efficient and can be implemented quickly (Freitas et al. 1998; Silverman 2016). The focus group was conducted at an Architecture and Built Environment School. 25 different professionals were invited to respond to questions based on a real-time app –'Slido'- an easy-to-use Q & A and polling platform for live or remote meetings, events, classes and webinars. Participants were grouped into four main groups bringing together a cross-section of stakeholders that have a role in Design, Construction, Operation, and End-of-Life stages. Each of this group were made to respond to discuss the different questions about eliminate the blockages to sustainability during design, construction, operation and end-of-life stages. After the discussion, in which notes were taken, each participant individually vote using Slido to indicate the degree of relevance for the different variables in a hypothetical building project.

This research therefore conducted an investigation based on a focus group workshop and questionnaire survey involving 10 different building organisations comprising of architects, engineers, and sustainability professionals.

5 Findings and Discussion

Overall, we received 18 responses out of the 25 participants (72%) targeted in the workshop and all representatives of 10 organisations. It emerged from this studies that predominant focus is placed on "energy management" and "innovation" while "pollution" and "circular economy ranking as the least. It also emerged that current sustainability approaches do not explicitly consider opportunities for decisions made in the future that could enhance the sustainability potentials in buildings. Initial findings reveal that there is a three key challenges faced by all sustainability professionals across the building life cycle:

a. Lack of transparency in current sustainability rating tools (M = 1.9; SD = 0.25)
b. Lack of clear guidelines regarding innovative products (M = 2.575; SD = 0.18)
c. Lack of strong institutions driving sustainability (M = 2.4; SD = 0.43)

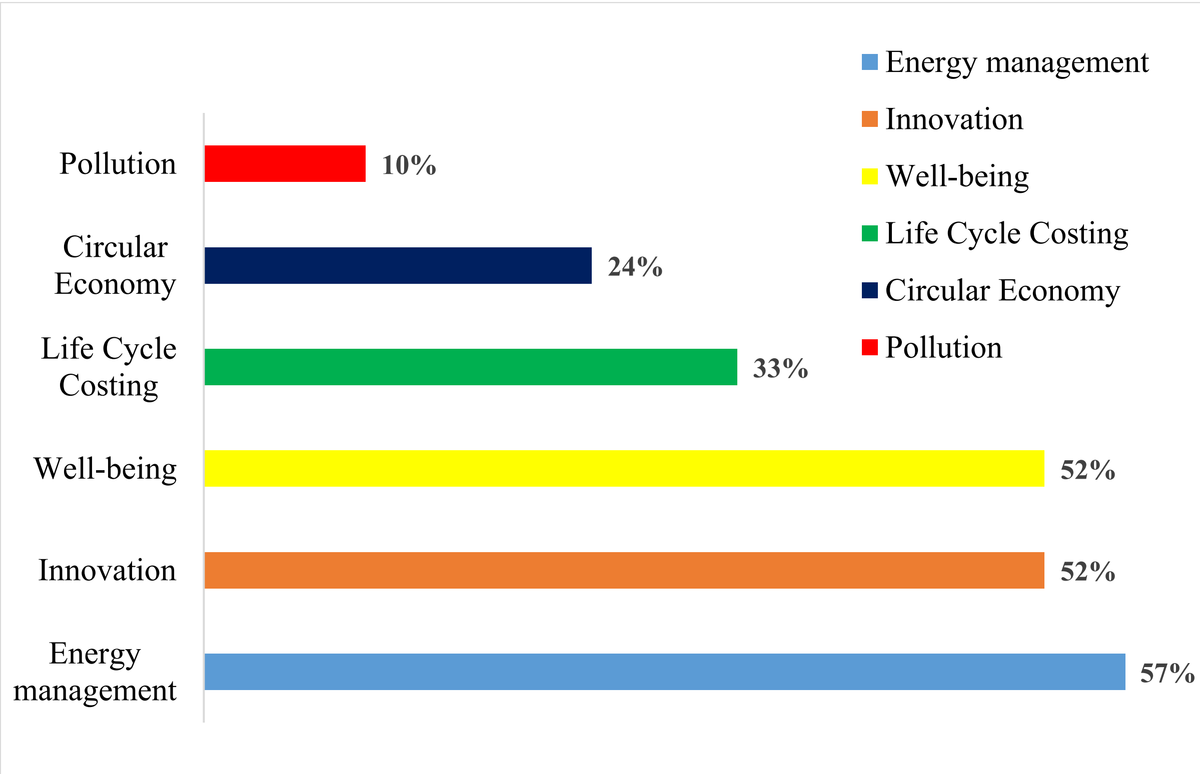

Figure 1 Survey results on sustainability initiatives in Australian organisation

There were other sustainability challenges more specific to individual phases (i.e. design, construction, operations, and end-of-life). However, sustainability initiatives pertaining to the end-of-life stages seem to be most lacking. In view of these, the perceptions of professionals imply that more work is required to deepen understanding on the blockages to sustainability within different contexts.

Recent research has recognised the deficiency in sustainability measurement systems. Mura et al (2018) suggests that the general approach to sustainability measurement involve simple application of existing models and approaches to new concepts or inclusion of new variables. In a recent study, by Slee (2020), it was recognised that technical solutions are insufficient to fulfil sustainability in buildings, rather social-based solutions (i.e. sustainable people) need to be integrated in the sustainability pursuit of the building sector

Given the increasing emphasis on circular economy to ensure improved material efficiency, there is a need for construction organisations to better integrate the principles of circular economy in their sustainability framework especially to proactively manage the end-of-life decisions of the materials used in buildings. Furthermore, there is need for better tracking of the pollution at different stages of the life cycle. Life Cycle Sustaianbility Assessment and Evaluation, provides a useful approach to ensure that the negative impacts are mitigated and positive impacts are leveraged in delivering buildings (Goh, Chong, Jack, & Mohd Faris, 2020, Tokede et al., 2021).

A promising solution to address the blockages in building project is therefore to adopt a life cycle sustainability approach to enhance holistic considerations in buildings. The Life Cycle Sustainability Approach is beneficial in that (1) It covers the entire life cycle of a building project; (2) It has a feedback loop; (3) It also allows for life cycle optioneering for different sustainability initiatives (i.e. Retrospective rating tool and a mechanism for recognising the prioritising buildings that need attention); and (4) Stakeholder involvement. It is expected that the life cycle sustainability approach will birth outcomes that lead to significant savings in energy and other utilities consumed in buildings.

6 Conclusion

This paper conducts an investigation on the blockages to sustainability in building projects based on a focus group and survey. 25 participants from 10 organisations provided data at a workshop event organised to discuss the challenges to sustainability. Findings from the survey reveal that the most considered sustainability initiatives in the Australian Organisations considered are Energy management, Innovation and Well-being. Equally, the least considered initiatives are life cycle costing, circular economy and pollution. Results from the focus group discussion also established that three key blockages faced by all sustainability professionals across the building life cycle are : (1) Lack of transparency in current sustainability rating tools; (2) Lack of clear guidelines regarding innovative products, and (3) Lack of strong institutions driving sustainability.

Given the results from this research, it is believed that adopting a life cycle sustainability approach by Australian organisations will facilitate a holistic and improved sustainability benchmarking in buildings. Future work in this research project is therefore expected to inspire the development of a framework that can facilitate an improved measurement of the life cycle sustainability potential for different scenarios and options in building projects

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The Application of Emotional Intelligence in Construction Project Management: A Systematic Literature Review

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Abstract
Emotional intelligence (EI) is a critical attribute of successful project management professionals. This paper aims to identify the recent trends in EI research in the context of construction projects to inform future research opportunities. To do so, a systematic literature review (SLR) was conducted to examine the ambit of relevant research in the construction sector between January 2010 and August 2021. A total of 20 peer-reviewed empirical articles published between January 2010 - August 2021 were identified and synthesised. The findings revealed that EI in the context of the construction industry has been narrowly researched in the last decade. The reviewed studies appeared to be highly country-specific and adopted predominantly quantitative research approaches. They addressed various aspects connected to EI including project performance, project professionals' performance, conflict management, leadership and mediating factors. The paper concludes by identifying a number of research areas moving forward. This study, despite its obvious limitations, contributes to the existing knowledge by providing a single point of reference not only for interested researchers but also practitioners who have a growing interest as to how EI is practised, applied and harnessed in construction projects.

Keywords
Construction industry, construction projects, emotional intelligence, systematic literature review.

1 Introduction

Construction projects are generally large, complex and involving so many stakeholders (Zhang and Fan 2013, Wu *et al.* 2017). As such, teamwork is prevalent in all construction projects (Wu *et al.* 2017). The success of construction projects is a challenging endeavour as it requires a high degree of collaboration and teamwork among various stakeholders (Zhang and Fan 2013, Maqbool *et al.* 2017, Potter *et al.* 2018). Considering the large degree of complexity and collaboration among different stakeholders, construction project professionals must demonstrate the ability to work in a team and cope up with the challenges and uncertainty involved in the process (Zhang *et al.* 2018).

According to Rezvani *et al.* (2018), the challenges encountered in large-scale projects are more associated with the human skills of construction project professionals rather than their technical skills. Individuals such as designers, clients, suppliers, contractors and project managers (Lawani and Moore 2021) from a variety of backgrounds and cultures work together as a team to accomplish a common goal (Potter *et al.* 2018). As a result, conflicts may arise due to several reasons such as distinction in behaviour, conflict of interest (Lawani and Moore 2021), miscommunication and collusion among project team members (Wu *et al.* 2017).

Recently, emotional intelligence (EI hereafter) has been considered for the successful completion of construction projects (Wu *et al.* 2017). While EI has gained increased attention as a critical success factor in various industries such as business, nursing, law, medicine and engineering (Zhang and Fan 2013), the application and use of EI in the construction industry seem to be obscure (Lawani and Moore 2021). For instance, Winardi *et al.* (2020) systematically reviewed the association between EI and conflict resolution in the context of business organisations. In the setting of construction projects, Lawani and Moore (2021) conducted a literature review to investigate an account of existing EI literature, discuss potential lines of enquiry and explore methodological concerns by a chronological and interpretative approach. However, the authors in that study called for a comprehensive overview of how existing studies were carried out and what was found to identify potential areas for future work. Therefore, this SLR attempts to fill this gap. In particular, the SLR is guided by the following research question:

(1) What is the status quo of empirical research on the trend of EI research in the construction industry to inform future research opportunities?

2 Research Method

A SLR was conducted to identify peer-reviewed empirical research articles on EI published between January 2010 and August 2021 that are specific to the construction industry. The process of conducting the SLR was in alignment with the process discussed in the study of Ayat *et al.* (2020). Two phases were conducted to complete the SLR process. The first phase consists of five stages including establishing research objectives, defining conceptual boundaries, setting inclusion criteria, applying exclusion criteria and validating the search results (Ayat *et al.* 2020). In the second phase, data regarding research method(s) used, sample size, the geographical distribution of sampling plan, publication time and journal names were extracted by following a systematic quantitative literature review (SQLR) as adopted by Roy *et al.* (2012). The findings of the retained articles were organised in 'high-level' themes using interpretive synthesis consistent with the methodology adopted by Riebe *et al.* (2016).

2.1 Stages of SLR

The five stages adopted for the SLR are discussed below in detail.

2.1.1 Establishing Research Objectives

The aims and objectives of this SLR are to identify (1) the peer-reviewed empirical scholarly articles about EI in the construction industry, (2) the trend in the identified articles in terms of publication years, distribution across journals, geographical distribution of sampling plan, research methods, sample size and results (3) the potential gaps for future research.

2.1.2 Defining Conceptual Boundary

The conceptual boundary of this SLR is to explore peer-reviewed empirical research on EI specific to the construction industry published between January 2010 – August 2021.

2.1.3 Inclusion Criteria

The searches were conducted in the following electronic databases: Science Direct, Scopus, SAGE journals online, Taylor and Francis, Emerald, Wiley online, ProQuest, and Web of Science. Before starting an initial literature search, a number of search strings were formed such as "Emotional intelligence" AND Projects, "Project manager's emotional intelligence", "Emotional intelligence" AND "Project success", "Emotional intelligence" AND "Project outcomes", "Emotional intelligence" AND "Project success factors", "Emotional intelligence" AND "Project success criteria", "Emotional intelligence" AND Construction. The search terms were applied in the selected databases. The searches were limited to the titles and abstracts of studies to ensure that the potential articles have an adequate level of coverage regarding EI in the construction industry.

2.1.4 Exclusion Criteria

By following the above-mentioned processes, a total of 2459 studies were obtained. The exclusion criteria were applied in four stages. Firstly, the search was limited to peer-reviewed journal articles, published in English and within January 2010 and August 2021. By following this phase, 1084 articles were obtained. Then, the duplicates were removed across the databases and within the database. After removing the duplicates, 963 articles were taken to the next step for title analysis. Secondly, the titles of those 963 articles were checked to investigate whether EI was discussed in the context of construction projects. If the title did not explicitly indicate the context in which EI was discussed, the article was taken to the next stage to read the abstract. This stage brought the number of articles down to 155. Thirdly, the abstracts of those 155 articles were read. There remained 34 articles for the full-text analysis. In the fourth stage, the full text of the identified 34 articles was read thoroughly to ensure that the retained 34 articles are aligned with the inclusion and exclusion criteria of the SLR. Through this stage, another 14 articles were excluded which were deemed irrelevant to the inclusion and exclusion criteria of the SLR. Any article which was not predominately focused on construction projects such as defence projects, general projects and engineering projects and did not discuss EI in the context of construction projects was excluded. Any peer-reviewed empirical article which discussed EI either qualitatively or quantitatively in the context of construction projects was included in the analysis. Finally, only 20 peer-reviewed empirical articles were included in the data analysis. The flowchart of the screening process for the SLR is presented in Figure 1.

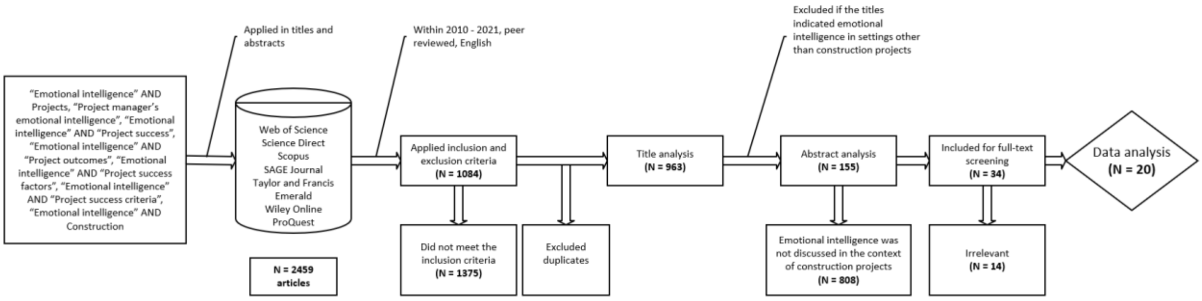

Figure 1. The flowchart of the screening process for the SLR

2.1.5 Validating the Search Results

The search results were validated by each author independently by reading the abstracts of the retained studies to ensure that included studies have met the inclusion criteria and mitigated some of the limitations of the SLR. A Cross comparison of the two researchers was then carried out. Furthermore, Ulrichsweb was used to verify whether all included empirical articles were peer-reviewed. For example, a non-peer-reviewed article was identified and taken out from the analysis during cross-comparison of the included articles.

2.2 Methods of Data Extraction

All the 20 peer-reviewed empirical articles were carefully read and key information such as article name, author details, samples size, research method, publishing year, country of sampling plan and results was listed in a spreadsheet sheet.

3 Results

3.1 Summary Table of Articles

A summary table is provided below (Table 1) with the list of articles used in the SLR with the journal's name, research method, country of sampling plan and sample size.

Table 1. Summary of key information of the empirical research articles included in this SLR

Authors	**Journal name**	**Research method**	**Country of sampling plan**	**Sample size**
Khosravi *et al.* (2020)	International Journal of Project Management	Quantitative (survey)	Australia	365
Konanahalli and Oyedele (2016)	Construction Management and Economics	Mixed methods (interviews and survey questionnaire)	29 different countries from Sub-Saharan Africa, China, Middle East and Indian Sub-Continent	209 (18 unstructured interviews and questionnaire survey of 191)
Ladika *et al.* (2020)	International Review of Management and Marketing	Quantitative (survey questionnaire)	Indonesia	102
Lindebaum and Jordan (2012)	Construction Management and Economics	Quantitative (survey questionnaire)	UK	55
Livesey (2017)	Construction Economics and Building	Quantitative (e-Delphi through survey questionnaire)	Australia	22
Maqbool *et al.* (2017)	Project Management Journal	Quantitative (survey questionnaire)	Pakistan	107
Moshood *et al.* (2020)	Social Sciences & Humanities Open	Quantitative (survey questionnaire)	Malaysia	146
Potter *et al.* (2018)	Journal of Financial Management of Property and Construction	Quantitative (questionnaire)	New Zealand and the UK	73 (New Zealand; 39 and UK; 34)
Pryke *et al.* (2015)	Construction Management and Economics	Mixed (surveys and live observations)	Republic of Serbia	68
Rezvani *et al.* (2018)	International Journal of Project Management	Quantitative (survey)	Australia	408
Rezvani *et al.* (2019)	Team Performance Management	Quantitative (survey)	Australia	389
Sarwar *et al.* (2017)	Journal of Global Entrepreneurship Research	Quantitative (survey questionnaire)	Pakistan	213
Sunindijo (2015)	International Journal of Business Performance Management	Quantitative (survey questionnaire)	Australia	107
Sunindijo and Hadikusumo (2014)	Journal of Management in Engineering	Quantitative (survey questionnaire)	Thailand	34

Sunindijo and Maghrebi (2020).	Journal of Architectural Engineering	Quantitative (survey questionnaire)	Australia	273
Sunindijo and Zou (2013)	Construction Economics and Building	Quantitative (survey questionnaire)	Australia	273
Tang *et al.* (2020)	SAGE Open	Quantitative (survey questionnaire)	China	169
Zhang *et al.* (2015)	International Journal of Conflict Management	Quantitative (survey questionnaire)	China	159
Zhang *et al.* (2018)	International Journal of Project Management	Quantitative (survey questionnaire)	China	365
Zhang and Fan (2013)	Engineering, Construction and Architectural Management	Quantitative (survey questionnaire)	China	112

3.2 Publication Years of Articles

A total of 20 peer-reviewed empirical scholarly articles was retained about EI in the construction sector between January 2010 – August 2021 (including 2010 and 2021). Of the 20 articles, 16 articles (80 percent) were published between 2015 – 2021. No articles were published in the year 2010, 2011 and 2021. On the other hand, five of the 20 articles (25 percent) were published in 2020 alone. Table 1 outlines the year of publication for each article included in this SLR. The recent surge in EI publication in the context of construction projects can be attributed to the positive relationship between construction project professionals' EI and their improved performance in projects (Sunindijo *et al*. 2007).

3.3 Distribution of Articles across Journals

The reviewed 20 articles were published across 15 journals. International Journal of Project Management and Construction Management and Economics journals hosted three articles each amounting to 30 percent of total published articles. Construction Economics and Building journal published two articles (10 percent) of the reviewed 20 articles. The rest 60 percent of the articles were published in 12 different journals. All the 12 journals hosted only one article each. Table 1 lists the journal's name against each article. The publications were not concentrated in any specific journal which reflects the recent demand in understanding the significance and application of EI of project professionals in various aspects of construction projects.

3.4 Geographical Distribution of Sampling Plan

The samples of the reviewed 20 articles were collected from eight different countries and four regions including Sub-Saharan Africa, China, Middle East and Indian Sub-Continent. Table 1 exhibits the country of the sampling plan for each article. Of the 20 articles, seven articles (35 percent) and five articles (25 percent) were published in Australia and China respectively. As shown in Table 1, the rest of the articles' samples was drawn from a number of countries including Pakistan, Indonesia, Malaysia and the UK. This indicates the interest in EI in the context of construction projects was highly country specific.

3.5 Research Methods Used in Articles

Of the 20 articles, 18 articles (90 percent) used the survey/questionnaire research method. The popular measurement scales used in the surveys were predominately Likert scale questions. One of the remaining two articles used a mixed method of analytical surveys and live observations of site-based project meetings whilst the other one used a mixed method of unstructured interviews and questionnaire survey as shown in Table 1.

3.6 Sample Size Used in Articles

Of the 20 articles, 15 articles (75 percent) used 100 or more individuals in the sample. Only 25 percent of the reviewed articles used a sample size of fewer than 100. Table 1 shows the sample size of each article included in this SLR on EI in the construction sector. The sampling plan employed in the reviewed articles included a wide range of construction professionals such as construction project managers/leaders, team members (engineers, designers, project managers, architects), technical managers, health and safety managers and senior procurement managers.

3.7 EI and Project Professionals' Performance (number of articles = 04)

Of the 20 reviewed articles, four articles (20 percent) explored the association between EI and individual and team performance in construction projects (Zhang *et al.* 2015, Rezvani *et al.* 2018, Rezvani *et al.* 2019, Tang *et al.* 2020). Rezvani *et al.* (2018) and Rezvani *et al.* (2019) highlighted the relationship between EI and project team performance. Whilst Rezvani *et al.* (2019) aimed to examine EI's influence on a team level project performance, Rezvani *et al.* (2018) investigated EI on multiple levels (e.g., the influence of individual EI on individual performance and team EI on individual performance). The findings in Rezvani *et al.* (2018) and Rezvani *et al.* (2019) advocated a strong and promising association between individual EI and performance on the individual, a positive association between team EI and project team performance and a cross-level effect of team EI on the individual level of performance respectively. Similarly, Zhang *et al.* (2015) and Tang *et al.* (2020) studied the correlation between EI and project team members' innovation and job performance respectively. Construction project managers with a high level of EI can contribute to the employees' job performance (Tang *et al.* 2020) and innovation (Zhang *et al.* 2015, Tang *et al.* 2020). Emotionally intelligent construction managers are able to control employees' negative emotions and encourage subordinates to participate actively and promote innovation (Tang *et al.* 2020).

3.8 EI and Project Performance (number of articles = 04)

This SLR indicates that four (20 percent) of the 20 reviewed articles focused on EI in the light of project performance and success (Zhang and Fan 2013, Sunindijo 2015, Maqbool *et al.* 2017, Khosravi *et al.* 2020). The correlation between EI and project performance was investigated by Zhang and Fan (2013) and Khosravi *et al*. (2020). Zhang and Fan (2013) identified a positive correlation between EI and project performance. Similarly, emotionally intelligent team members develop strong team cohesion, thus improving the project performance (Khosravi *et al.* 2020). Furthermore, Maqbool *et al.* (2017) investigated the impact of construction project managers' EI on project success and found that construction project managers with a high level of EI are better at relationship management and self-awareness which help them develop better team building, leadership traits and collaboration, thus contributing to project success. Sunindijo (2015) was more specific by identifying the positive impacts of EI on project cost performance and quality performance.

3.9 EI and Conflict (number of articles = 03)

Of the 20 articles reviewed, three articles (15 percent) discussed the relationship between EI and conflict in the context of construction projects (Sunindijo and Hadikusumo 2014, Rezvani *et al.* 2019, Khosravi *et al.* 2020). The association between EI and relationship, task and process conflict was examined by Khosravi *et al.* (2020). On the other hand, Rezvani *et al.* (2019) delved into team EI in relation to their relationship conflict. Rezvani *et al.* (2019) and Khosravi *et al.* (2019) found that project team members with a high level of EI can control their own emotions and those of others in conflict. Only one study explored EI and conflict management styles of construction project managers in the Thai construction industry (Sunindijo and Hadikusumo 2014). Emotionally intelligent construction project managers are willing to adapt to collaborating leadership styles. However, due to the cultural context in Thailand, construction project managers can use avoiding and accommodating styles to manage their stakeholders (Sunindijo and Hadikusumo 2014).

3.10 EI and Leadership (number of articles = 02)

Only two (10 percent) of the 20 reviewed articles studied construction project managers' leadership in the view of EI (Potter *et al.* 2018, Zhang *et al.* 2018). To improve interpersonal skills and project performance, the relationship between construction project managers' adopted leadership styles and EI was investigated by Potter *et al.* (2018). Project managers demonstrating transformational leadership seemed to identify others' emotions (OEA) and their own emotions (SEA), regulate their own emotions (ROE) and use emotions effectively (UOE) (Potter *et al.* 2018). In a similar vein, Zhang *et al.* (2018) explored the relationship between EI and transformational leadership (TFL), active transactional leadership (ATL), passive transactional leadership (PTL) and laissez-faire leadership (LFL) styles in an integrated project delivery setting. However, Zhang *et al.* (2017) found that along with TFL, EI is also positively associated with ATL.

3.11 Mediating Factors (number of articles = 06)

Two (10 percent) of the 20 reviewed articles discussed conflict as a mediator between EI and performance (Khorsvari *et al.* 2019, Rezvani *et al.* 2019). All types of conflicts including relationship, task and process seemed to have a negative impact on the association between EI and project performance (Khorsvari *et al.* 2019). In a similar vein, Rezvani *et al.* (2019) discovered a positive effect between team EI and team relationship conflicts on team performance.

One study discussed conflict management styles as a mediator between EI and innovation performance (Zhang *et al.* 2015). Emotionally intelligent project managers also consider others' interests important when resolving conflicts (Zhang *et al.* 2015). Trust as a mediator between EI and performance on an individual and team level was elucidated by Rezvani *et al.* (2018) and Rezvani *et al.* (2019) respectively. Trust in teams appeared to be positively related to EI and performance on the team level (Rezvani *et al.* 2019) and individual level (Rezvani *et al.* 2018).

On other hand, Zhang *et al.* (2018) examined leadership styles as a mediator between EI and four collaboration satisfaction outcomes such as performance contribution satisfaction (PCS), efficiency satisfaction (ES), relationship satisfaction (RS) and interest satisfaction (IS). Transformational and active-transactional leadership fully mediated the relationships of EI with PCS, ES and IS and partially mediated the relationship between EI and RS. However, owing to the non-significant effects of laissez-faire leadership on dimensions of collaboration satisfaction, this leadership style did not play a mediating role in the relationships of EI with four dimensions of collaboration satisfaction (Zhang *et al.* 2018). On the other hand, EI acted as a mediator between project success and psychological capital such as self-efficacy, resilience and optimism (Sarwar *et al.* 2017).

3.12 EI and Task Types (number of articles = 03)

A careful investigation of the 20 reviewed articles revealed that three articles (15 percent) discussed EI in the light of construction tasks. One of those articles discussed the use of EI along with other human skills to explain contractors' risk attitude in construction projects (Moshood *et al.* 2020). In a similar line, the relationship between EI and safety management tasks was explored by Sunindijo and Zou (2013). Lindebaum and Jordan (2012) added another layer to this discussion by focusing on the types of construction works and the use of EI.

3.13 Other Connected Soft Skills (number of articles = 06)

This SLR identified six articles that discussed the impact of EI on construction managers' dealing with various issues identified in construction projects (Livesey 2017) and several skills development including interpersonal skills (Pryke *et al.* 2015), negotiation skills in construction disputes (Ladika *et al.* 2020), political skills (Sunindijo and Maghrebi 2020), collaboration skills (Zhang *et al.* 2018) and their work, interaction and general adjustment (Konanahalli and Oyedele 2016).

4 Discussion

This section discusses the main findings, provides a summary of future recommendations and limitations of this SLR.

4.1 Discussion of the Main Findings

This SLR revealed that EI was researched in relation to project performance, project individuals and team performance, leadership, conflicts, mediation factors, project managers' skills development and task types. However, none of the areas was extensively discussed as evident by the number of articles found in each category. The findings of the SLR showed that scant attention was paid to EI research in the construction industry which was consistent with the findings of Lawani and Moore (2021).

The retained articles were published across 15 journals showing a growing interest in EI across different journals. With regard to the geographical distribution of the sampling plan of the reviewed articles, Australia (35 percent) and China (25 percent) published 60 percent of the articles followed by Pakistan and the UK. This demonstrates the growing interest of EI in the construction industry in those countries. In fact, in the last four years (2018 – 2021), the research on EI in construction projects was primarily conducted in Australia and China. Very little research has been conducted in Europe, Africa and Asia. It was surprising to see that the SLR did not identify any peer-reviewed empirical article which was published in the USA in the last decade. Hence, it is difficult to argue that EI in the construction industry has attracted attention across the globe.

The number of published empirical articles on EI in the last decade was not substantial. Very few or no empirical articles were published on EI in the context of the construction industry in 2010 and 2011. The average number of articles per year was only 1.6 articles. However, it seems that there is an increased attention on EI in the construction industry in 2020 as 25 percent of the reviewed articles were published. Very little empirical insight has been provided to EI in the construction industry in 2021 until the time of writing. Therefore, the annual research trend shows a progressing but slow interest in EI research in the construction industry.

This SLR divulged that quantitative research methods were widely used to explain EI in the context of the construction industry. Eighteen of the 20 articles (90 percent) adopted a single survey/questionnaire method. The remaining two articles adopted a mixed research approach. It was perhaps easier and convenient to collect data by using a survey technique. However, qualitative research and mixed-method approaches are richer in text and less ambiguous. So, EI should be researched both qualitatively and quantitatively to get an in-depth understanding of the studied phenomena. In this regard, the SLR finding appears to be consistent with prior work by Lawani and Moore (2021) who criticised the wide use of quantitative research approaches to explore EI in the construction industry.

Four studies were conducted on EI to investigate individual, team performance and innovative performance in the construction industry (Zhange *et al.* 2015, Rezvani *et al.* 2018, Rezvani *et al.* 2019, Tang *et al.* 2020). The results of those studies indicated that EI has a significant contribution to the individual, team and innovative performance of construction project team members. Rezvani *et al.* (2018) and Rezvani *et al.* (2019) conducted their studies in the Australian construction industry. On other hand, Zhang *et al.* (2015) and Tang *et al.* (2020) conducted their studies in the Chinese construction context. However, the generalisation of the results was questioned in the reviewed studies as they were highly country specific.

The association between EI and project performance and success was explored in three studies (Zhang and Fan 2013, Magbool *et al.* 2017, Khosravi *et al.* 2020). The findings of the studies suggested that the EI of construction project managers contributes substantially to project performance and success. Despite being carried out in three different countries (e.g. Australia, Pakistan and China), all the studies echoed the findings with each other. However, Zhang and Fan (2013) and Magbool *et al.* (2017) drew the conclusion based on construction project managers' opinions only which seemed to limit the opinions of other key personnel in a typical construction team. Khosravi *et al.* (2020) appeared to address this limitation by surveying designers, site managers, engineers, architects alongside construction project managers.

Further analysis of the SLR revealed that trust acted as a mediator between EI and project team performance on a team level in construction projects (Rezvani *et al.* 2018, Rezvani *et al.* 2019). It was evident from Zhang *et al.*'s (2018) study that EI and collaboration satisfaction relationship was mediated by transformational and active-transactional leadership. Furthermore, integrating, compromising and dominating styles performed as a mediator between EI and innovation performance of construction employees. Additionally, this SLR indicated that construction managers with EI have the ability to deal appropriately with the task, relationship and process conflicts (Rezvani *et al.* 2018, Rezvani *et al.* 2019, Khosravi *et al.* 2020). Furthermore, emotionally intelligent project managers have the propensity to adopt transformational leadership styles (Potter *et al.* 2018, Zhang *et al.* 2018). These two studies' samples were collected from New Zealand and the UK (Potter *et al.* 2018) and China (Zhang *et al.* 2018). Although the findings appear to be promising for construction project managers who possess EI in their skill sets, more research is required to generalise the findings as the studies are confined to specific countries.

4.2 Summary of Future Recommendations

The majority of the studies (Zhang *et al.* 2015, Rezvani *et al.* 2018, Zhang *et al.* 2018, Rezvani *et al.* 2019, Tang *et al.* 2020) were conducted in Australia and China which significantly limited the generalisation of the findings. Future studies may replicate the studies identified above in other socio-economic and cultural contexts. A vast majority of the reviewed articles were based on quantitative research approaches (mostly survey/questionnaire) which might lack rigour. Therefore, qualitative research approaches including interviews, focus groups, observations and case studies can be employed. In addition, mixed methods can also be implemented which might offer triangulation of the findings to enhance the robustness of future research. The reviewed literature did not compare the findings across projects with varied nature and sizes (e.g. complex and large construction projects). Hence, comparing the findings across different project sizes might open up new avenues for future researchers to understand whether EI requires different attention depending on the size or nature of the projects.

Some studies used self-report measurement of questionnaire (Konanahalli and Oyedele 2016), self-assessed data (Sunindijo and Zou 2013) and self-assessment of construction project personnels' own EI and leadership styles (Potter *et al.* 2018). This might have influenced the outcomes of the research as the studies considered individuals' interpretation of behaviour and might have introduced method bias (Khosravi *et al.* 2020). Future research might consider applying the procedures mentioned by Podsakoff *et al.* (2012) such as increasing validity and decreasing the effects of the method to reduce the impact.

The reviewed articles explored how trust, conflicts, leadership styles and conflict management strategies can act as mediators between EI and construction project outcomes and project professionals' performance. It would be worth investigating factors such as other forms of relationships, task interdependence, impacts of the separate construct of EI dimensions on the relationship between EI and team performance as suggested by Rezvani *et al.* (2018) and Rezvani *et al.* (2019). In addition, the impact of communication, trust, team building, task dependencies and other human skills as mediators needs to be assessed further (Zhang *et al.* 2015, Zhang *et al.* 2018).

4.3 Limitations

A range of search terms and combinations of them such as "Emotional intelligence" AND projects, "Project manager's emotional intelligence", "Emotional intelligence" AND "Project success", "Emotional intelligence" and "Project outcomes", "Emotional intelligence" AND "Project success factors", "Emotional intelligence" AND "Project success criteria", "Emotional intelligence" AND Construction were applied in an array of databases. However, it might be possible that some of the relevant studies did not use any of the search terms as keywords. In addition, some fundamental relevant studies could be indexed in other databases and therefore were not included in this study. While the authors read the data analysis, results, discussion and conclusion sections of the retained articles a number of times to alleviate any potential errors during the screening process, the process might have some cognitive bias. The search process was limited to peer-reviewed empirical scholarly articles published in the English language. Hence, peer-reviewed empirical scholarly articles written in languages other than English were excluded which might complement or contradict the findings of this SLR.

5 Conclusion

This SLR identified 20 peer-reviewed empirical articles which advocated the use of EI in the construction industry between January 2010 and August 2021. This SLR revealed that limited attention has been paid to EI in the construction sector. In addition, EI research in the construction sector was predominantly limited to Australia and China. Although the findings appear to be promising for construction project managers who possess EI in their skill sets, more research is required to generalise the findings. The findings of the SLR also indicated that the survey/questionnaire research method was primarily adopted to investigate EI in the construction industry.

With regards to the application of EI in the construction industry, an influx of empirical articles was not found as expected. The association between EI and project performance, success, individual and team performance was explored in the literature. Furthermore, some research was conducted in relation to the mediators between EI and project performance, team and individual performance, collaboration satisfaction and innovation. Nonetheless, as indicated in the previous section, there is an enormous scope of future research in EI in the context of construction projects.

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An investigation of digital technology implementation in off-site construction: current practice, challenges and expectations

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Abstract
Off-site construction has generally been regarded as a more productive construction method, and digital technologies are considered to provide higher productivity and safety. However, there is a lack of research on how digital technologies can be best utilized to achieve the potential advantages of off-site construction. Some literature has made exploration in this area, while first-hand investigations from the construction industry are still rare. This study aims to identify the issues which can be potentially resolved by adopting digital technologies in off-site construction projects, and investigate the current practice and possible approaches to improve the technology utilization to achieve the goal. Practitioners including designers, manufacturers and site engineers working in Chinese off-site construction projects were interviewed based on a semi-structured question, and qualitative analysis was carried out using thematic analysis to provide a taxonomy of technology utilisation in NVivo. 16 critical challenges and 16 main expectations are identified. BIM, photogrammetry, laser scanning, AR/VR are categorised as promising technologies with more strengths for future implementation. This study provides the directions of future studies on digital technology implementation from practitioners' perspective, which is of great practical and theoretical value for off-site construction industry.

Keywords
BIM, digital construction, off-site construction, technology implementation, technology utilization

1 Introduction

Off-site construction (OSC) has generally been regarded as a more productive and sustainable construction method, and many publications have summarized OSC's potential benefits in quality, productivity and sustainability (Chowdhury *et al.*, 2019, Wang *et al.*, 2019, Wang *et al.*, 2020, Kabirifar *et al.*, 2021). However, in the current practice, the performance of this construction method still encountered many challenges regarding time, labour and cost aspects due to more complex processes and stakeholders involved (Li *et al.*, 2016, Zhai *et al.*, 2019). Some research reported that the total time from design to onsite assembly could be longer than conventional construction (Liu *et al.*, 2018). In addition, the cost of prefabricated buildings was estimated 26.3% to 72.1% higher than that of conventional buildings (Arashpour *et al.*, 2018, Hong *et al.*, 2018). These facts indicated that many problems need to be solved to fully realize the potential benefits of OSC, and digital technologies are regarded as the key solutions to improve productivity in the construction industry (Maskuriy *et al.*, 2019, Alaloul *et al.*, 2020).

Some digital technologies have been reported that could improve the quality, reduce cost, save time and labour for OSC projects, such as building information modelling (BIM) (Sepasgozar *et al.*, 2016b, Yin *et al.*, 2019), radio frequency identification devices (RFID) (Luo *et al.*, 2020), laser scanning (Sepasgozar *et al.*, 2016a, Sepasgozaar *et al.*, 2017, Guo *et al.*, 2020), etc. Previous studies also made investigations of digital technology implementation for OSC. A systematic review of digital technology adoption in OSC have been conducted, and identified virtual reality (VR), augmented reality (AR), photogrammetry, laser scanning, and artificial intelligence (AI) are relatively less explored in OSC, but they are regarded as promising technologies to be very effective in improving OSC performance (Wang *et al.*, 2020). However, there is a lack of first-hand investigations from the construction industry towards digital technology implementation in OSC. Interviews are recognized as the most effective approach to gain deep knowledge of the construction industry (Jiang *et al.*, 2018). The interview manuscripts could be analysed based on NVivo which is a qualitative data analysis software (Adetoro Adewunmi and Damilola Ajayi, 2016, Samad and Steven, 2018).

Therefore, this study conducted an in-depth interview in OSC to explore the current practices of these available digital technologies, and how they can be utilized in contributing to fully achieve the advantages of OSC. Based on interview data analysis, this research aims to identify the issues which can be potentially solved by adopting digital technologies, and investigate the current practice and possible approaches to achieve the goal. To be specific, this research has the following three objectives: (1) to explore the current digital technology implementation in the OSC industry and identify capabilities and limitations of available digital technologies utilization in OSC, (2) to identify the challenges related to digital technology implementation in OSC, (3) to present expectations of digital technology implementation from the perspective of practitioners.

2 Literature Review

Firstly, many digital technologies have been reported that could improve the quality and efficiency of the construction industry. For example, RFID could improve productivity in supply chain management and construction site monitoring (Dallasega *et al.*, 2018, Voordijk, 2019). Laser scanning could obtain thousands of points from the target buildings and create geometries with high efficiency (Lu *et al.*, 2020, Wu *et al.*, 2021). Web-based technologies can improve onsite project communication(Wang and Xue, 2008, Shirowzhan *et al.*, 2017). In addition, BIM, Internet of Things (IoT), photogrammetry, AI are all seen as promising digital technologies (Dallasega *et al.*, 2018, Voordijk, 2019). While other technologies such as augmented reality, artificial intelligence are still being enhanced and somehow influence sustainability (Zou *et al.*, 2017, Alaloul *et al.*, 2020). These technologies are presented to be able to contribute to the construction industry. However, due to the difference in construction processes, more investigations should be carried out to demonstrate if these digital technologies are applicable in OSC projects.

Secondly, for digital technology implementation in OSC, some studies are made by case studies or simulations to validate the effectiveness of specific digital technology. For example, some research tried to use technologies to automate the construction process and track the rea-time construction. To track the materials, many advanced technologies have been adopted in the off-site construction to collect the data on-site, such as bar code (Cheng and Chen, 2002), RFID, GPS (Ergen *et al.*, 2007) so on. Based on the data collection, information management systems are used to monitor the work, make decisions or give feedback, such as BIM, VR, IoT and so on (Li *et al.*, 2018, Luo *et al.*, 2020). These digital technologies could be used for geometry quality checks (Arashpour *et al.*, 2020, Guo *et al.*, 2020), supply chain management (Luo *et* *al.*, 2020), onsite assembly optimization (Chen *et al.*, 2018, Zhai *et al.*, 2019), waste management (Kabirifar *et al.*, 2020, Kabirifar *et al.*, 2021), etc. Although some digital technologies have been validated to be beneficial, there is a lack of comprehensive evaluation of digital technology implementation for OSC. How to use the available digital technologies to improve work performance remains unsolved.

Thirdly, in OSC, the design needs to consider the convenience of manufacture and assembly (Yuan *et al.*, 2018). And construction management requires more coordination between manufacture, logistics, and on-site assembly since the manufacturing and installation works are happening concurrently (Luo *et al.*, 2020). The success of onsite assembly relies on the appropriate design, accurate manufacture, and timely delivery of the prefabricated elements (Moghadam *et al.*, 2012). Despite some researches are trying to develop a framework that could integrate all the stages in one management system, it remains on the conceptual level and fail to contain all design, manufacture, transportation and installation stages (Ramaji *et al.*, 2017). In this case, the opinions from different practitioners are critical for integration and coordination on digital technology implementation. However, there is a lack of investigations that integrate opinions from all practitioners in OSC.

In summary, the research gaps can be grouped into two categories. One is technology limitation, that is if these technologies are mature enough to solve the current problems in OSC. Another is the inefficient use of technologies, which is due to the inappropriate use of the technologies or conservative attitude from the practitioners. This study will conduct an in-depth investigation in OSC, to explore the current practice, challenges and expectations of digital technology implementation from the perspective of different practitioners.

3 Research Methodology

3.1 Data collection

Semi-structured interviews were preferred to structured interviews to prevent the bias of the interviewer when asked to clarify a question (Alazzaz and Whyte, 2015, Sepasgozar *et al.*, 2018). The interview questions were designed to develop a comprehensive framework that can provide a better understanding of digital technology implementation in Chinese OSC projects. The questions were compiled based on a literature review on recent and related publications, including digital technologies (Chowdhury *et al.*, 2019, Akbarieh *et al.*, 2020), off-site construction (Jin *et al.*, 2018, Yuan *et al.*, 2020), technology adoption theory (Webster and Gardner, 2019), technology adoption in off-site construction (Wang *et al.*, 2020). Interview with open questions makes it possible that participants can explain their attitudes about the technology implementation. The criteria for selection of the qualified interviewees are mainly from two aspects: (1) Professionals working in different construction stages, including design, manufacture and on site construction in OSC, (2) With various age, professions, and experience to avoid biased interview outcomes.

The interview was carried out by face-to-face interview and took about 1 hour to 1.5 hours for each interview. It was noted that face-to-face interviews may result in more socially desirable responses and lower accuracy than computer administered questionnaires or paper-and-pencil questionnaires (Richman *et al.*, 1999). Interviews were beginning according to the provided guidance at first with open and public questions and then continued with in-depth questions. As the interview continued, more open and deep questions were asked to clarify the details of their answers. Adequate sample size is usually reached at saturation point when themes start to repeat themselves (Mason, 2010). Therefore, the completion of the interview is based on that there is no more new information after several runs of interviews. Finally, a total of 22 practitioners from different stages involved in OSC were interviewed in China. Among them, 8 are from the design stage, 8 from the manufacturing stage, 6 from the onsite construction stage.

3.2 Data analysis

The interview transcripts were made by note-taking during the interview, and further tidy-up according to the recordings. After writing the recorded interviews, the texts were reviewed by interpreters. The following step is to make a qualitative analysis of these interview data to identify the attitudes and experiences of the interviewees. Data collected from semi-structured interviews are analyzed based on thematic analysis, through the development and allocation of codes and themes. A thematic analysis was the most suitable qualitative method for analyzing interview data, as it focuses on themes and patterns to understand people's experiences, views, opinions, knowledge of things (Lamptey et al., 2020). The NVivo software is used to provide a taxonomy of technology utilisation, which could reduce manual tasks and assist in identifying tendencies, recognizing themes and deriving conclusions (Akbarieh *et al.*, 2020). The categories of thematic coding are from three aspects: current practice, challenges and expectations of digital technology implementation in OSC. There are four steps to analyze the interview data (Adetoro Adewunmi and Damilola Ajayi, 2016, Samad and Steven, 2018):

Step 1: This step is to obtain an overall picture of all transcripts. The first is to quickly browse through all interview transcripts as a whole, then make notes about the first impressions. After that, a re-read process on the transcripts is conducted one by one carefully.

Step 2: This process is called coding or indexing. The first is to label relevant phrases or sentences in the transcripts. The labels are about concepts, opinions, processes, and other relevant information about digital technologies implementation in OSC. Things that can be coded include repeated texts in multiple places, something surprising, interviewees' explicit statements on something important, something similar to a previously published literature review, and other reasons that can be regarded as relevant. This coding process aims for a conceptualization of underlying patterns.

Step 3: This step is to conceptualize the data. After conducting step 2 for all transcripts data, this step will decide which codes are the most important and create categories by bringing several codes together. The first is to go through all the codes created in the previous step, and new codes can be created by combining two or more codes. At this stage, some of the initial codes can be dropped, while the codes that are regarded as important will be kept. The second is to group the codes into different categories. The categories do not have to be of the same type, they can be about objects, processes, differences, or whatever.

Step 4: This step is to label categories and identify how they are connected. In this study, the current practice, challenges and expectations of digital technology implementation are considered for the labelling process. Then the importance of categories is analysed. It is assumed that the number of codes represents the importance of the category. The word frequency query in NVivo is selected to provide the most frequently occurring words during the matrix coding process, which could maintain analytic integrity in data analysis (Feng and Behar-Horenstein, 2019, Wilk *et al.*, 2019). These categories and their importance are the main results and will be presented in Section 4.

4 Findings and Discussion

After thematic analysis in NVivo software, all interview data are assigned to suitable categories. The proportions were used to indicate how frequently the concepts were mentioned by participants. A total of 894 quotes were collected where 175 (19.57%) were coded as current capability of digital technologies, 112 (12.53%) as technology limitations, 287 (32.10%) as challenges, 320 (35.79%) as expectations of future implementation. Detailed discussions of the results are presented below in three aspects: the capabilities and limitations of digital technologies utilization in OSC, the challenges, and the expectations for technology implementation from the perspective of practitioners.

4.1 Capabilities and limitations

12 digital technologies have been identified from the interview as well as their capability in solving construction problems, including BIM, laser scanning, photogrammetry, VR/AR, big data, RFID, robot, IoT, GPS, 3D printing, and AI. BIM is the most mentioned technology with 68 quotes (38.20%), especially in the design stage. The second and third mentioned technologies are photogrammetry with 28 quotes (15.73%) and laser scanning with 27 quotes (15.17%) both in the manufacture and onsite construction stages, where VR/AR with 12 quotes (6.74%) and big data with 11 quotes (6.18%) are also mentioned. From the perspective of professions, most of the designers mentioned BIM, while for the manufacturer and contractors, they are more focused on the 3D data collection technologies, such as photogrammetry and laser scanning, which might be helpful in real-time monitoring in their practices.

However, from the perspective of designers, BIM is still not perfect to be used in the design of OSC projects. For example, many respondents have pointed out that there is a lack of hardware or software to support a complete BIM model, in this way, it could be impossible for BIM implementation throughout the construction process currently. From the perspective of designers, compared with CAD (computer-aided design) design, it is time-consuming to design BIM models and there is a lack of automated design of DfMA (design for manufacture and assembly) method integrated with BIM software. The manufacturers claimed that some BIM models are unqualified for guiding production, which still requires many manual adjustments of the drawings. And in terms of the onsite assembly stage, there is a lack of skilled BIM engineers available in OSC projects to analyse BIM models.

Another main problem is that most technologies are still developing, and may not have mature and commercialized products in the market, which means the available technology products are still in their early stage, and cannot be directly adopted in current practice. For example, there is a lack of fair-priced and accurate VR/AR devices available in the market. The device with suitable accuracy is not available and needs to be customized with high costs. In addition, there is a need for sensors that could contribute to concrete health detection, while there is no type of sensor that could detect the inner condition of concrete structures in the market.

3D data collection methods are most mentioned by professions from the manufacture and assembly stage since they could do real-time monitoring, such as photogrammetry, laser scanning and RFID. Currently, the sensors and RFID are ready to be used for location identification of elements. They also have some limitations and need to be further improved. It is challenging to recognize materials during the manufacturing process using photogrammetry, such as rebars. The use of photogrammetry technology relies on the environment. There is the same problem for using laser scanning, such as irregular object recognition from a point cloud. Although it is easy to extract information from RFID tags, there are still many extra efforts on type selection, identification of installation position, dismantle and reuse works of RFID tags, which is inefficient to easy in real practice.

Some technologies, including big data, IoT, robots, 3D printing and AI, are less mentioned. This is because they are less introduced in the OSC industry or some of them lack the capability in solving practical problems. For example, a robot is not able to connect rebars, so that it is not utilized in a factory. And most of the interviewees have limited knowledge in 3D printing, big data, AI. These technologies need to be more investigated in OSC.

4.2 Challenges

By matrix coding and word code analysis in NVivo, the results of the nodes of professions' worries of digital technology implementation are organised in Table 1. 16 items have been identified as challenges. From the analysis of the first level of nodes, it is obvious that the two major items of threat are people's negative attitudes and the company's high expectation of technology adoption. Followed by the standardization problems in OSC. The lack of suitable organizational structure, inappropriate management strategies, economical burden on purchase of digital technologies, daily use and development of technology are also negative factors that prevent technology to be adopted in OSC successfully. In addition, some technologies might be labour-intensive and time-consuming to use compared with manual operations, especially at the early stage. Some there is a lack of skilled technology users in the construction industry. In addition, the standardization problems are also a critical issue in the current practice of OSC projects. In conclusion, there are many barriers to digital technologies adoption in OSC and the technologies need to be improved and adopted properly to meet the requirement and benefits.

Table 1. Matrix coding of challenges in NVivo

	Design			**Manufacture**			**Onsite**		**Total codes**
	SD	AT	BE	MG	TE	ME	PM	SE	
1 Company expectations of technology adoption	78	17	55	25	153	46	232	147	753
2 Complicated construction site environment	35	0	41	37	44	57	200	20	434
3 Data extraction issues	0	0	0	97	0	0	0	0	97
4 Difficulty in technology diffusion in construction industry	0	0	27	0	0	0	0	31	58
5 Digital data security issues of using technology	0	0	0	37	0	0	0	11	48
6 Economical burden on purchase, use and development of technology	87	0	67	169	83	16	69	51	542
7 Extra works required of technology adoption	0	0	25	11	36	0	0	0	72
8 Inappropriate utilization of technologies	58	0	32	0	53	0	11	0	154
9 Lack of professional technology operators in OSC industry	115	0	0	91	21	0	97	18	342
10 Lack of suitable organizational structure and management of technology adoption	57	14	80	173	89	66	29	73	581
11 Lack of supporting measures of technology adoption from government	55	0	0	0	26	0	41	0	122
12 Little value creation during whole construction life cycle	0	0	0	36	0	0	44	68	148
13 Not all collisions are detected by current BIM practice in OSC projects	26	0	13	0	0	0	33	27	99
14 People' negative attitude on technologies adoption	216	76	179	60	156	32	261	64	1044
15 Standardization problems in OSC prevent technology adoption	128	19	33	324	55	82	8	33	682
16 Time and labour consuming of adopting technology	51	0	0	47	0	0	70	0	168

Note: Structure designer=SD, Architecture=AT, BIM engineer=BE, Manager=MG, Technique engineer=TE, Machinery management engineer=ME, Project manager=PM, Site engineer=SE

4.3 Expectations

Although there are many challenges of digital technologies implementation, the practitioners in OSC expect their wide adoption can potentially improve the OSC process. The matrix coding of expectations from professions is given in Table 2. 16 items have been identified to demonstrate the needs or potential requirements of digital technologies in OSC. There is an urgent need for information delivery and exchange by using digital technologies, especially in the design stage. Many practitioners in the construction industry are willing to use technologies, which is also a great advantage of technology adoption. In addition, as different from the traditional construction industry, there is a higher expectation of achieving digitalization and informatization of OSC, especially in the manufacturing stage in the factory. These are the top three most important factors. Moreover, the stakeholders from different stages also emphasized the importance of efficiency improvement by using digital technologies.

Table 2. Matrix coding of professions and expectations factors in NVivo

	Design			**Manufacture**			**Onsite**		**Total codes**
	SD	AT	BE	MG	TE	ME	PM	SE	
1 Higher accuracy requirement than manual works	0	0	0	0	60	0	0	0	60
2 Government support on technology promotion	19	0	0	0	0	0	0	0	19
3 Shortage of labour in OSC	32	0	0	52	10	0	0	0	94
4 Need of digital data in partial processes with less data processing pressure	32	0	0	102	0	0	16	31	181
5 Need of automated design	68	49	25	23	14	0	0	0	179
6 Some technologies are available in OSC	0	0	20	32	84	0	40	16	192
7 Need of automated and efficient quality control methods	0	0	0	175	92	0	0	102	369
8 Lack of fully achieving advantages of digital technologies	135	0	37	21	0	0	9	23	225
9 Requirement of whole construction process services in OSC	327	47	26	0	10	0	0	42	452
10 Need of real-time monitoring of construction site	38	0	46	122	26	25	55	112	424
11 Need of automated production of PC	30	20	13	57	59	52	5	32	268
12 Need of guidance of construction tasks from technologies	121	37	0	190	51	0	61	29	489
13 Need of technology to improve working efficiency	54	12	17	82	174	0	152	134	625
14 Willing of realizing automation, digitalization and informalization in factory	164	0	18	92	126	0	77	296	773
15 Need of real-time information exchange and delivery	774	316	26	368	104	0	103	227	1918
16 Some people are willing to use technologies	429	41	96	167	97	28	122	44	1024

Note: Structure designer=SD, Architecture=AT, BIM engineer=BE, Manager=MG, Technique engineer=TE, Machinery management engineer=ME, Project manager=PM, Site engineer=SE

5 Conclusions

Digital technology implementation is critical for the development of OSC. Based on the in-depth interview of participants from OSC projects, opinions from different professions on digital technology implementation are analysed qualitatively. The results are summarized as follows.

It can be concluded that there are high demands for digital technologies in the OSC industry. The real-time information exchange and delivery of the whole process, automated design, construction monitoring, higher accuracy checking techniques are the major expectation from professions. In addition, specific professions presented different needs of digital technologies. For designers, they are more concerned about BIM technology, which could be integrated with automated design and DfMA. For manufacturers, they expect to realize automation, digitalization and informatization in the factory, which is mainly focused on BIM, RFID, robot, VR/AR, photogrammetry, laser scanning. While for onsite workers and project managers, their needs are more about real-time monitoring using photogrammetry, laser scanning, VR/AR, to ensure quality and efficiency of the assembly process. In conclusion, BIM, VR/AR, photogrammetry, laser scanning can be regarded as the most promising digital technologies in the OSC industry.

In another aspect, the challenges at the current stage for digital technology implementation in OSC are caused by people's negative attitude toward adopting new technologies, lack of standardization in OSC, inefficient organizational structure and management of technology implementation. Some people may not be supportive of utilizing digital technologies due to their limited knowledge. Standardization of prefabricated elements also plays a significant role in digital technology implementation. This is because if there are too many types of prefabricated elements, a higher level of digital technologies needs to be developed to accommodate them, and more associate preparations need to be carried out, therefore it leads to lower efficiency and higher cost. The higher the standardization level of OSC projects, the easier and more efficient digital technology implementation. Moreover, government and organisational strategies for using digital technologies in OSC should be established according to the identified challenges.

The current capability and limitations of digital technologies are more from a technological perspective. The way to improve the technologies capability should take their limitations into consideration. There are four types of limitations. First, technologies like RFID and sensors are quite mature and can be used directly in OSC, however reluctance from human aspects, and other management issues have prevented their wide usage. Second, some technologies are mature enough to provide adequate support to issues in OSC, however, they have not been developed to suitable commercial software packages ready to be used directly in OSC, such as BIM and VR/AR. Third, some technologies require further improvement for practical implementation. For example, automatic recognition of rebar, built-in fittings, etc. from the point clouds provided by laser scanning and photogrammetry. Forth, some technologies, such as IoT, AI, digital twin, etc. are still developing, and they are further away from practical implementation.

This study attempts to provide an overall vision on technology implementation in the current OSC industry, future research should pay more attention to how to address technologies' limitations, to meet the industry's expectations of digital technologies implementation. This study can also provide some practical guidance to government and construction organisations on how to facilitate digital technologies' development and effective utilization in OSC.

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Augmented Reality Adoption in the Australian Construction Industry: A Qualitative Framework

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Abstract
The adoption of innovative technologies in the construction industry has provided significant benefits to the industry. In Australia, the use of innovative construction technologies has grown increasingly over the past decade and received a significant increase in the level of adoption in construction site activities due to the recent pandemic. One technology that is receiving additional attention to be beneficial to the industry is Augmented Reality (AR). However, its current level of adoption is still very limited due to several reasons the theoretically advantages are not yet well received by the practitioners. To address this gap, this study aimed at investigating the low-level adoption and widespread use of AR technology in the Australian construction industry. To this end, semi-structured interviews were conducted to explore perceptions of the use of AR technology and its limitations from end-users perspectives and managers of construction companies in particular. As a result, a model is presented to map the influential factors and barriers to the adoption of AR. Findings revealed several concepts including lack of knowledge about AR, conservative management attitudes, absence of feasibility analysis, operability and work culture as factors influencing AR adoption in the industry. Moreover, the model provides a basis to direct future research on the topic.

Keywords
Augmented Reality, Technologies, Innovation, Construction Management, Implementation

1 Introduction

The construction industry is moving towards digitalisation and virtual buildings, making engineering innovation and new technologies an effective driver for improving project execution within the industry (Badamasi *et al.*, 2021). Augmented Reality (AR) is such emerging smart technology that superimposes virtual 3D models onto physical reality (Fenais *et al.*, 2020) and can bring new changes and developments to the industry. The use of AR technology in the construction industry has been slow to develop and the current industry use is focused on the following areas: virtual site visits, collaboration opportunity enhancement, project planning and training, monitoring construction progress and managing construction activities (Rankohi and Waugh, 2013), construction simulation (Behzadan *et al.*, 2015), assembly guidance (Shin and Dunston, 2008) and operational training of heavy equipment (Wang and Dunston, 2007). Lee *et al.* (2018) also proposed an augmented reality-based work management system that generates AR data and shares construction information in real-time, effectively improving pipe installation and construction management, reducing waste and errors. The implementation of AR has been proven in practice to bring considerable benefits to the construction industry. The visualisation features of augmented reality technology can enhance communication between workers and construction/site managers on the job site and also improve understanding of the information labours need to perform construction-related tasks leading to increased efficiency and fewer errors (Chu *et al.*, 2018). In addition to being on-site, AR improves communication and collaboration between field and office, reducing communication barriers between clients, construction professionals and designers, thus greatly facilitating cooperation, communication and teamwork between all parties, enabling all stakeholders to identify, perceive and resolve potential design defects throughout the lifecycle of the project, reducing problems and saving costs (Tariq *et al.*, 2019). Although AR is considered to be an effective mechanism with great potential to improve efficiency and effectiveness in the construction industry, its adoption has been observed to be extremely limited (Chu *et al.*, 2018). According to Khan *et al.* (2021), the complexity and dynamic nature of the industry and the lack of robust reliability of the technology limit the adoption and use of AR technology in the construction industry. A survey was done in 2018, just before the COVID-19 pandemic, revealed that digital skills were ranked the lowest for contractors when hiring project construction managers (Vaz-Serra and Mitcheltree, 2020). However, crises like COVID-19 can boost the transformation accelerating the shift toward digital transformation in engineering and construction (Meisels, 2021).

This study aims to investigate the influential factors and barriers to AR adoption in the Australian construction industry from an end-user perspective. Moreover, the study attempts to map all the identified factors, barriers and their relationships to develop an integrated framework that supports the project managers in the industry by simplifying the now available knowledge for practical adoption of AR in the Australian construction industry.

1.1 Theoretical model

Recent studies on technology adoption in the construction context have confirmed that AR adoption is closely aligned with innovation adoption (Bello *et al.*, 2020). Moreover, the process of adopting technologies including BIM and AR through the innovation adoption lenses is highlighted as the most effective approach for the adoption of technologies in construction organisations and projects (Murphy, 2014, Hosseini *et al.*, 2016). Thus, the Innovation Diffusion Theory (IDT) is considered a suitable theory to frame research questions concerning the processes of adopting technologies in construction organisations (Gledson, 2016). As a result, IDT is selected as the theoretical framework in the present study and to direct this research.

In light of having IDT as the theoretical framework in this study, the study by Poirier et al. (2015) identified four key factors influencing the innovation adoption within construction firms including *industry*, *institutional*, *organisational*, and *project*. These contexts are mainly interconnected in which industry and institutional factors influence organisational factors which can manipulate project-level factors. Later, the study by Hosseini *et al.* (2016) merged industry and institutional factors into a single context, namely *'supply chain'*. However, given that this study focuses more on the Australian construction companies (end users), some modifications are made to the arrangement of these factors. Since most of the technology companies providing AR applications are not part of the construction industry, the supply chain context is further split into the industry (demander), supplier and institutional contexts to distinguish between different stakeholder perspectives. As a result, the study's theoretical model (Figure 1) comprises three main constructs, (1) '*supply chain*' that refers to relevant stakeholders within the Australian construction industry, (2) '*organisational*' that relates to policies and culture within the construction companies, and (3) '*project'* construct which is the environment that the actual AR technologies are used.

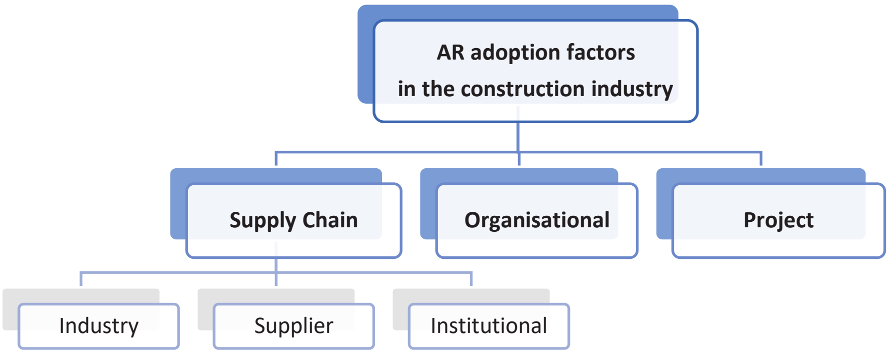

Figure 1. Theoretical model of the study

1.2 Challenges and barriers to the AR adoption and use

As discussed, the current acceptance rate of AR technology in the construction industry is relatively low and this technology has not been fully adapted due to several barriers hindering the development of practical use. A summary of these barriers is demonstrated in Table 1.

Table 1. Barriers to AR adoption in the construction sector

Code	Barriers	References
1	Conservative industry culture: resistibility to changes and adopting innovative technologies	(Gomez-jauregui et al., 2019, Elshafey et al., 2020)
2	Immature Technologies- Lack accuracy: GPS positioning, tracking and image capture techniques	(Dong *et al.*, 2013, Rankohi and Waugh, 2013, Meža *et al.*, 2015, Fenais *et al.*, 2020)
3	Immature Technologies- Visual occlusion	(Behzadan *et al.*, 2015, Meža *et al.*, 2015)
4	The immaturity of the AR and VR market: insufficient commercialisation of products	(Heinzel et al., 2017, Davila Delgado et al., 2020)
5	Less long-term investment: lack of budget Heterogeneity of construction projects	(Edirisinghe, 2019, Noghabaei et al., 2020, Pan et al., 2020)
6	Initial cost: high cost and time consumption	(Fu and Liu, 2018)
7	lack of understanding of new technology by managers	(Noghabaei et al., 2020)
8	Lack of cost-benefit analysis	(Heinzel et al., 2017, Noghabaei et al., 2020)
9	Inconvenient hardware: e.g. tablets require both hands make it less convenient for construction activities	(Gomez-jauregui et al., 2019, Fenais et al., 2020)
10	Lack of training: more training and guidance is required	(Elshafey et al., 2020, Yang et al., 2021)
11	Lack of knowledge and awareness	(Davila Delgado et al., 2020)

A review of the literature indicates the perception barrier is a major factor that makes the construction industry reluctant to embrace AR technology. The survey conducted by (Noghabaei *et al.*, 2020) showed that factors such as "lack of understanding of new technology by managers", and "lack of cost/benefit analysis" limited the adoption of AR technology. The conservative and traditional industry culture (Elshafey *et al.*, 2020) and lack of long-term investment were cited as the main reasons why it was difficult to apply new technologies to upgrade the skills of the workforce in the industry (Pan *et al.*, 2020). Another critical barrier to the use of AR is the immaturity of the technology (Meža *et al.*, 2015). Since tracking and image capture techniques still need to be improved (Rankohi & Waugh, 2013), AR technology lacks accuracy when it overlays a virtual model on a real image, causing some technical issues (Wang and Dunston, 2007). Also, the lack of security-certified hardware hinders large-scale deployment (Davila Delgado *et al.*, 2020). And the fact that portable or wearable devices may affect the user's hands and field of vision makes AR devices less convenient for construction training or practical use on the site (Gomez-jauregui *et al.*, 2019). Indeed, the inherent nature of the construction industry such as heterogeneity of construction projects and sites (Edirisinghe, 2019), low profits (less than 1% of revenue) and less investment in R&D (Davila Delgado, 2019) are other important influential factors to technology adoption. The high requirements on the management system like data collection, storage and management for the use of AR technology are also one of the main challenges. The use of AR requires high accuracy of the input data location, and the process generates a large amount of data which increases the cost and difficulty of storage and management (Golparvar-Fard *et al.*, 2013). Also, the lack of integration with other management systems and the lack of interoperability limits the use of AR (Davila Delgado *et al.*, 2020).

1.3 Influential factors to the AR adoption and use

In the next stage, based on the analysis of previous literature, the factors influencing the adoption of and using AR technologies in the construction industry were identified and classified according to the theoretical framework of the study (Table 2).

Table 2. Influential factors to the AR adoption in the construction industry

Category		**Influential factors**	**Barriers' Codes (See Table 1)**
Supply Chain	Industry	Industry nature	5
	Supplier	Technical maturity	2, 3, 9
	Institutional	Market maturity	4
		Industry culture	1
Organisational	Organisational	Management attitude	7
		Feasibility analysis	6, 8
Project	Project	Safety risk	9
		Compatibility	12
		Relevant knowledge and awareness	10, 11

2 Research Methodology

The 'exploratory' type of research was used to investigate the Australian construction industry's perceptions of the use of AR and to identify the corresponding influential factors as it provided the opportunity to gain an initial understanding of the topic through interaction with stakeholders (Jain, 2021). The research methodology was 'qualitative' which facilitated the gaining of insight into individual participants, including their opinions, views, understandings and attitudes (Nassaji, 2015). Semi-structured interviews were chosen as the mean of qualitative data collection (conducted between March and May 2021) to add depth to the study with a limited response rate. The structured part of the interviews was divided into three main sections: (1) general information about the interviewees' backgrounds, experiences and roles, (2) exploring their perceptions of AR technology and ideas for its use in the construction industry, and (3) to investigate respondents' perceptions of the factors and barriers that affect the use of AR in the Australian construction industry. The questions were designed based on a review of the relevant literature on the use of AR in the construction industry.

2.1 Sampling and participants

Interview invitations were distributed via the LinkedIn platform and a two-level non-random sampling strategy was used: 'purposive sampling' and 'snowball sampling' to ensure that knowledgeable and experienced construction industry professionals who met the requirements were included in the interviews. The potential participants in this study were considered to be construction managers, site managers, and project managers with a minimum of ten years of experience in the Australian construction industry who have some knowledge and interest in AR. Invitations were sent to 200 potential participants, of which 41 invitees have raised their interests to participate in interviews. Eventually, due to some constraints such as work commitments, only 7 respondents participated in the interviews which resulted in a response rate of 17.1%. Participants in this study were mainly from Tier 1 and Tier 2 construction firms in Australia and had relevant knowledge of AR. As shown in Table 3, all the participants had construction or engineering background, with practical experience in residential, commercial and infrastructure construction projects. Their working experience ranged from 15 to 37 years and had various roles including site manager, construction manager and project director.

Table 3. Participants' profiles

ID	Experience	Role	Background	Company	Project experience
A	30 years	Site Manager	Construction	Tier 1	Commercial
B	34 years	Site Manager	Construction	Tier 1	Commercial & Infrastructure
C	20 years	Head of Construction	Construction	Tier 2	Residential & Commercial
D	20 years	Project Director	Engineering	Tier 1	Commercial & Infrastructure
E	15 years	Construction Manager	Engineering	Tier 1	Infrastructure
F	27 years	General Manager	Construction	Tier 2	Residential & Commercial
G	37 years	Construction Director	Construction	Tier 2	Residential & Commercial

2.2 Analysis

In this study, a qualitative data analysis approach using NVivo software was considered. In the first stage, audio-recorded interviews were transcribed into text documents to generate enough and clear information from recordings while minimising misunderstanding and errors (Creswell and Creswell, 2018). In the second stage, category coding and thematic analysis were applied. Indeed, after reviewing the transcripts of the interviews to have a general sense of all the information, NVivo software was used as a tool for coding collected data against the theoretical framework of the study. To this end, the researcher started coding the interview transcripts against the factors shown in Table 2, as the initial codes. During the coding process, new codes have emerged which required the coding process an iterative coding process to ensure earlier texts have been coded against the new codes. The final step is the development of the framework. Based on the above qualitative analysis, the influential factors and barriers to the adoption and use of AR in the Australian construction industry are identified and mapped in a way to form the integrated framework, as the outcome of this study.

NVivo has the ability to code and categorise a variety of data and analyse open-ended responses. To analyse the qualitative data, a mixed coding approach, namely deductive and inductive, was utilised in this study. In the deductive approach, codes were developed based on the existing literature (theory-driven coding), whereas in the inductive approach codes were developed inductively based on the respondents' subjective opinions (data-driven coding) (Oraee *et al.*, 2021). To this end and for the first step, the theoretical structure, as demonstrated in Table 1, was used as the basis for creating a set of original themes and codes to start the analysis. During the coding process, the qualitative data collected was categorised against the codes the theoretical structure. The next step was to interpret the relevant information in response to the disagreements. In this stage, original codes were either modified, removed, or new codes were created.

3 Findings

As the codes are dynamically updated, the coding process had to be repeated for all the transcripts until all the collected data are exposed to the identified codes. Figure 2 illustrates the process of modifying the theoretical model through qualitative analysis. Altogether, 203 passages from the seven interview transcripts were assigned to different codes, resulted in identifying a total of 17 themes (sub-factors) as influencing factors to the use of AR in the Australian construction industry and were grouped into four main factors including *Policy*, *Supply Chain*, *Organisational*, and *Project*. Of these, the *organisational* and *project* factors are in line with the factors in the original model and the *policy* is a newly created factor based on the collected data. In addition, the *industry culture* sub-factor was modified to industry (as a sub-factor to Supply Chain).

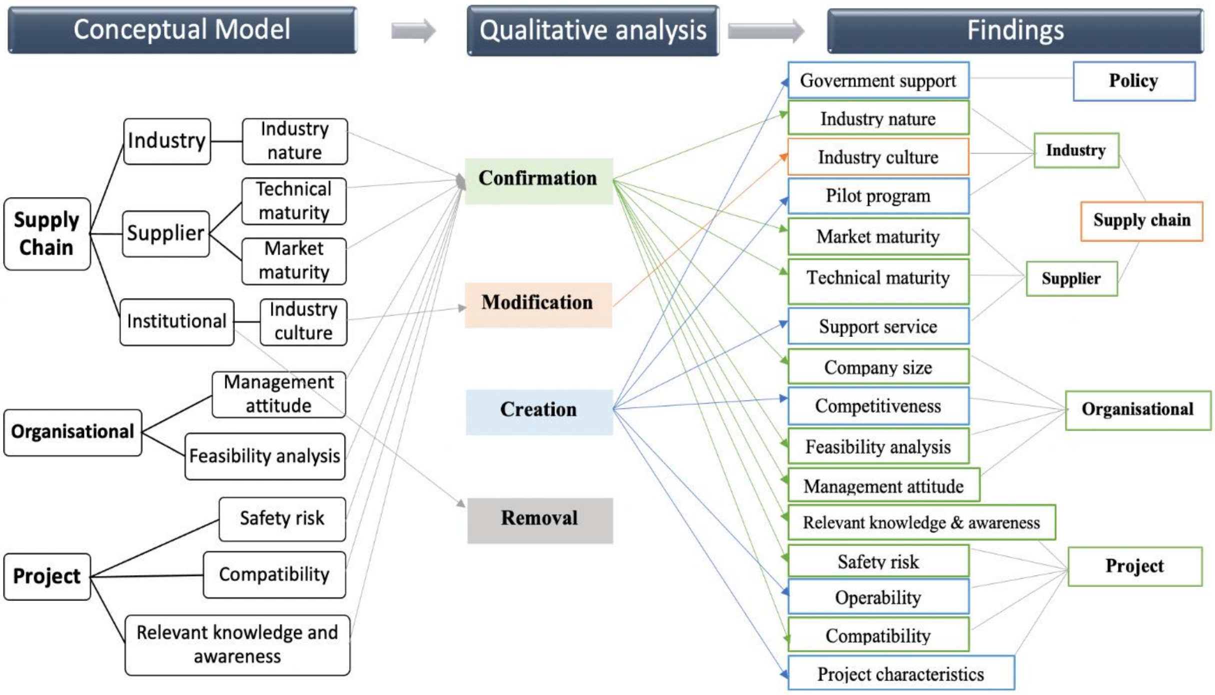

Figure 2. Model development through data analysis

As shown in Figure 2, the qualitative analysis of the data resulted in either confirming, modifying or removal of the original factors or creating new factors. A description of each factor is discussed next.

3.1 Policy

'Policy' was found to be a new influential factor to the AR adoption and interviewees discussed its influence on the use of AR in the construction industry. For example, they valued government promotion because the government is "an important stakeholder" (Interviewee G) and can facilitate that "everyone who's bidding for the project is on the same playing field" (Interviewee B). They believed that government and policy are important for AR adoption because supportive policies reduce the risk of companies investing in new technologies and the government have greater capacity and capability to support the significant upfront costs which can play a pioneering role.

3.2 Supply chain

The supply chain was seen as relatively important and was divided into two main sub-factors, the construction industry (demand side) and suppliers (AR technology companies).

3.2.1 Industry

The volatility of the construction industry makes companies hesitant to invest large amounts of money in new technologies (Interviewee B, C and F) and felt that the industry changes rapidly and "is not as reliable as manufacturing" (Interviewee B), thus negatively impacting long-term investment decisions. And "coronavirus made the industry the most volatile" (Interviewee F). In addition, "this industry is mostly cashflow negative" (Interviewee F) which makes it more difficult for construction firms to take on huge investments in new technologies. Respondents largely agreed that industry culture has a strong influence on the adoption of AR but in very different directions. Nearly half of them felt that the construction industry is very "traditional" (Interviewee D, E and F) and decision-makers usually lack understanding of new technologies (Interviewee E). "The industry does not embrace change easily, especially the older construction personnel" who "felt threatened by new technologies" (Interviewee D) and are reluctant to challenge themselves to learn new things. Sometimes the industry "is not really that innovative and wait until something been tried and tested" (Interviewee F). Other respondents had the opposite attitude, seeing it as "a fairly innovative industry" (Interviewee C) and "being definitely optimistic about new technology" (Interviewee G). The way things have changed dramatically over the past years and the industry "is keeping up, just doesn't change as quickly" (Interviewee C). Moreover, pilot programs were highly recommended since it "allows people to see real measures" (Interviewee B), "the changes (benefits)"(Interviewee C), "get a better understanding of AR and be able to comprehend how it can improve the industry" (Interviewee D).

3.2.2 Suppliers

Respondents provided little feedback on this factor. The relevant market is not yet mature (Interviewee D). Lack of awareness of the use of AR due to "less strong marketing" (Interviewee C). The industry prefers to "waiting for a more perfect product" rather than reluctantly "accepting an imperfect one" (Interviewee F). Training employees to use AR is an important factor for the adoption of AR technology to ensure that "all teething problems are resolved" (Interviewee D). Information (Interviewee C and D) and ongoing training especially bespoke training (Interviewee A and B) are expected from their suppliers.

3.3 Organisational

Respondents identified this factor as an influential factor, with four sub-factors, of which competitiveness was newly generated based on data analysis. The majority of respondents believed that company size has an impact on the adoption and use of AR. They generally considered that small companies may not use AR quickly due to a lack of Research and Development budgets (Interviewee D), while "leading companies are more willing to embrace new technologies (Interviewee A). The larger the company, the greater its ability to "absorb costs" and "resist risk" (Interviewee G). Moreover, respondents valued the competitiveness of their business and were willing to adopt AR if it can improve competitiveness and vice versa. For example, they worried that they may become uncompetitive because of the "increased costs" assigned to projects (Interviewee B) and "losing time" for AR training (Interviewee G). And the industry usually focuses on weighing up the pros and cons (Interviewee B and C). All interviewees were interested in feasibility studies and cost-benefit analyses to see the real benefits and how it will improve their business and competitiveness, as the significant costs may be a risk (Interviewee D, E and G). Moreover, the majority of respondents believed that management has a positive attitude towards the adoption of AR if it can be proven to be beneficial. "There will be people who resist and embrace it" while leaders can "push the improvements and changes" (Interviewee D). Interviewee C felt that management was reluctant to be the first to try AR due to "insecurities about the unknown".

3.4 Project

From the participant's perspective, the project was identified as another important factor, which consisting of five sub-factors, and two of them (operability and project characteristics) were newly generated based on the data collected. According to the interviewees, people in the industry must be aware of and familiar with AR technology. "Lack of understanding or appreciation of the potential benefits" makes it difficult to adopt at the outset (Interviewee D). Also, Introducing AR to "people who are unskilled or less knowledgeable about AR" can be an initial challenge and barrier (Interviewee A, C and E). Safety was found to be an important sub-factor to those in the construction industry, and the use of AR devices on construction sites may present potential hazards such as "obstructed vision" (Interviewee D & F), which may influence people to adopt AR technology. The vast majority of construction companies have their management systems and many interviewees were very concerned about the compatibility of AR technology with existing technologies. If there is a lack of compatibility, construction companies will be more reluctant to use AR as they "do not want to waste extra money and time" (Interviewee C). Participants also felt that the ease of use of AR technology greatly influenced the adoption and use of AR in the construction industry. Interviewee F expected more automated work rather than a lot of upfront data entry. Respondent A expressed concerns about the charter and resource allocation for using AR. Also, "a user-friendly interface" was considered important (Interviewee D). Moreover, it is less possible to "change the system and technology during the project" and is "more of a wait for the new work" (Interviewee C). Also, the wide variation between projects, whether it would cause a lot of extra work (Interviewee D) and the slow payback (Interviewee F) were also concerns for people considering using AR.

4 Discussion

Analysis of the collected data resulted in the development of a model of influential factors, showing the main factors, sub-factors and corresponding barriers in different contexts that influencing the industry adoption of AR, and the links between them (Figure 3). Promotion policies were found to have a strong impact on driving AR adoption in which the government needs to play an active role such as providing incentives to motivate stakeholders to adopt new construction technologies (Darko *et al.*, 2018). Industry culture is also identified to be influential in AR adoption. This is because most activities in the industry are still based on traditional approaches and those decision-makers are either unaware or unwilling to adopt new technologies (Oraee *et al.*, 2019). However, those who considered the industry to be innovative and positive to the adoption of new technologies agreed that characteristics such as fragility, volatility and poor cash flow make the adoption of new technologies challenging. This is in line with the statement by Edirisinghe (2019) that the nature of the construction industry poses unique challenges to the adoption and full implementation of technology.

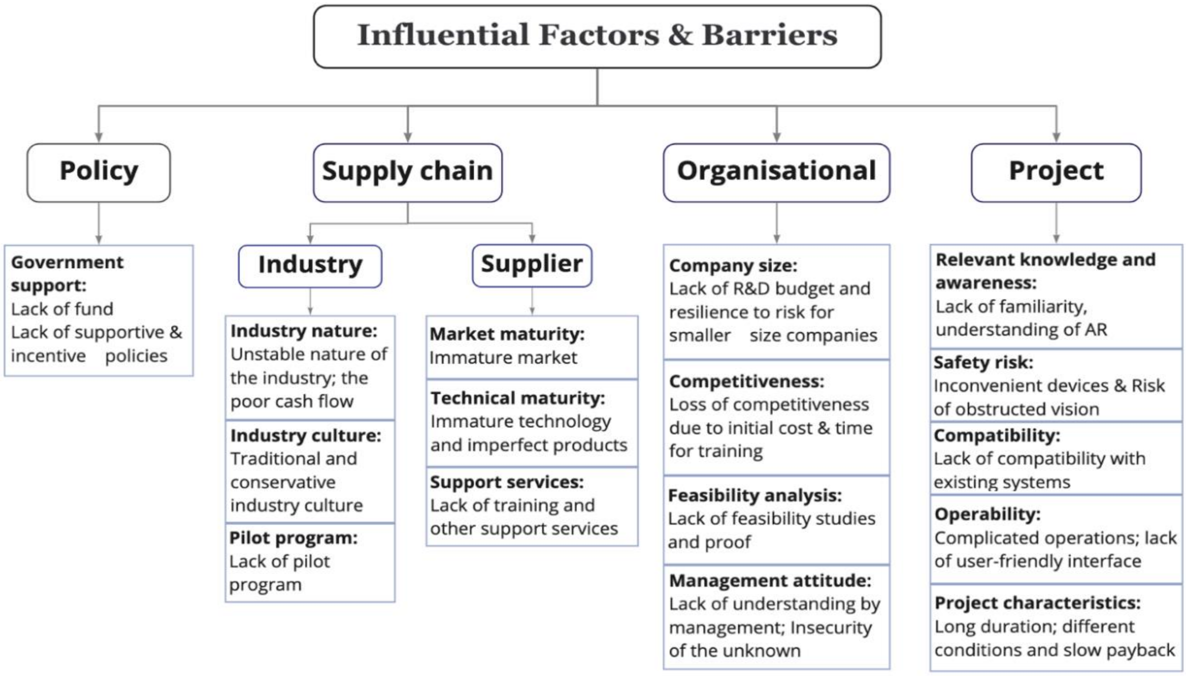

Figure 3. The qualitative model for AR adoption

From end-user perspectives, different firm sizes have different capital reserves and resilience to risk, so it is important to plan different strategies for different sizes of organisations as different firm sizes have different focuses. Indeed, SMEs emphasise less on the challenges of new technology adoption, but more on the risks of the implementation process Hong *et al.* (2019). For senior managers, they prefer to see more evidence that the implementation costs are worthwhile and will improve their competitiveness in the long term. This result coincides with the work of Noghabaei *et al.* (2020) that firms are reluctant to invest their money without knowing the true costs and benefits of AR. This necessitates empirical studies to assess the true cost of implementing these technologies and also cost savings during the project delivery phases. This leads to another important sub-factor, namely pilot programs. For the Australian construction industry, there is a lack of pilot projects to illustrate how AR can be used and to reveal the implementation costs as well as potential benefits. Davila Delgado *et al.* (2020) argue that the lack of experimentation to demonstrate the significant potential benefits that "engineering-grade" AR technologies can bring to the AEC sector limits the adoption.

In addition to organisation factors, project factors were also considered to have a significant impact on AR adoption. Studies findings show that operability, compatibility, safety, and skills factors are important to project-level people and have created a demand for improvements of AR hardware, software as well as related training (Vaz-Serra and Mitcheltree, 2020). It should be noted that vendor-related factors were less discussed by the respondents, mainly because the respondents were from construction companies and did not have enough knowledge about AR vendors. They did, however, expressed the expectations of the Australian construction industry regarding the technical and market development of AR suppliers and vendors. Furthermore, although the interviewees mentioned that they were aware of AR and related virtual reality (VR) technologies, the findings revealed that these concepts were not well understood. For example, in most cases, differences between AR and VR technologies can not be clearly distinguished in the industry. In light of this, an important finding of this study is that end-users in the construction industry do not have enough knowledge of the available technologies, thus limited knowledge of their benefits, which highlighted investment in upskilling professionals in the industry through providing relevant education and training.

5 Conclusion

This study reveals the perceptions of AR adoption from end-users in the Australian construction industry. As a result, a qualitative model including original views and new insights was developed by interviewing professionals in the industry. The proposed model revealed new knowledge in comparison to the previous studies in this context. Firstly, the role of policymakers in defining relevant policies and guidelines was found to be influential for the adoption of AR in the industry. Also, 'management attitudes', 'feasibility analysis' and 'industry culture' are identified as other influential factors to the adoption of AR in the industry. Moreover, piloting and operability factors were found to be important to be considered in the adoption process. As a result, the main implication of the proposed model for the Australian construction industry is that it will assist the industry professionals and organisations in taking a suitable approach for promoting the use of AR in the industry. Moreover, given the similarities of the construction industries in many countries, this model can also be used by construction professionals and firms in other countries and regions.

Despite the contributions, several limitations must be highlighted. First, due to the limited number of AR professionals in the Australian construction industry, the study's findings are based on the data collected through seven interviews only. Thus, further research through interviewing more relevant AR professionals needs to be considered. Moreover, this study focused on the adoption and use of AR in the Australian construction industry through collecting data from the perspective of the end-user (construction companies) and lacked some analysis of other key stakeholders such as suppliers (AR companies). Therefore, future research can focus on collecting data in other regions, including different stakeholders. Also, the proposed model can be further validated through different methodologies including case studies or questionnaire surveys.

6 References

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Improving Safety Compliance of Construction Workers: A Conceptual Framework

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Abstract
Construction is one of the most hazardous occupations worldwide. Among all the factors, construction workers' safety compliance plays a decisive role in improving safety performance on site. The study applied the concept of differentiating safety compliance into deep compliance and surface compliance based on workers' safety compliance behavior and aims at identifying the influential factors and their effects on construction workers' deep and surface compliance, respectively. Four existing theoretical models relating to safety compliance are reviewed and analyzed, including technology acceptance theory, theory of job performance, trait activation theory, social exchange theory, and social identity theory. The key factors from these theoretical models are identified, which include perceived usefulness, perceived ease of use, safety motivation, management commitment to safety, situational awareness, emotional intelligence, safety communication, and safety knowledge. Then, a conceptual framework is developed to describe the relationships among those factors and the effects of them on deep and surface compliance, respectively. This conceptual model sets a basis for the empirical study focusing on safety compliance of Australian construction workers. This study also provides practical implications as understanding this framework can help construction workers achieve improved safety performance by enhancing deep compliance or avoiding surface compliance.

Keywords
Australia, Construction Safety, Deep and Surface Compliance, Safety Compliance.

1 Introduction

The construction industry is notorious for work-related fatalities and serious accidents (Zou et al., 2014). According to the International Labor Organization (ILO, 2020), the construction industry employs 6-10% of the total workforce but accounts for 20-40% of the occupational fatal accidents in developed countries. In Australia, Safe Work Australia (SWA) reported that there were 27 construction workers killed at work and that 14,280 construction workers were seriously injured in 2019-20 (SWA, 2020a). The statistics of fatality and injury speak to the need for a determined effort to develop and implement measures to resolve the safety issue in the construction industry. For high-risk industries, such as the construction industry, the factor that has the greatest impact on safety is workers' safety compliance (Dekker et al., 2011, Hopkins, 2011). This highlights the importance of improving safety compliance to maintain safety at work in the construction industry.

Although it is widely established that safety compliance is crucial for improving safety compliance, there are few, if any, papers critically reviewing the studies on the antecedents of safety compliance in the construction industry. To fill this gap, the purpose of this paper is to review the literatures of safety compliance in various industries to identify the factors relating to safety compliance and analyze the validity and applicability of those factors in the construction industry, followed by the discussion of the relationships between those factors and deep/surface safety compliance. By doing so, it sheds light on developing a framework to improve construction workers' safety compliance in Australia.

2 Definitions of Deep and Surface Safety Compliance

Neal et al. (2000) recognized safety compliance and safety participation as the two dimensions of safety behavior. Safety participation refers to voluntary safety activities that may not directly contribute to workplace safety but do help to create a safety environment. For example, attending voluntary safety workshops and participating in safety meetings. In contrast, safety compliance is used to describe the primary activities for maintaining workplace safety, such as following safety procedures and wearing compulsory protective clothes (Griffin and Neal, 2000). Since then, although the definition of safety compliance remains similar across various industries, the practices in the different industries are slightly different. For example, in the healthcare industry, safety compliance can be considered as meeting or exceeding the legal, ethical, and professional standards continuously (Eckler et al., 2010); in the mining industry, safety compliance includes following the Work Health and Safety (Mines and Petroleum Sites) Acts 2013, Health and Safety (Mines and Petroleum Sites) Regulation 2014 and Chapter 5 of the Occupational Health and Safety Regulations 2007 (SWA, 2020b); and in the agricultural industry, safety compliance includes having emergency plans and first aid, wearing personal protective equipment (PPE), and recognizing and controlling fatigue (SafeWork NSW, 2020). In the construction industry, safety compliance includes complying with the Work Health and Safety (WHS) Act, following safety plans and procedures, and wearing PPE as required (Zin and Ismail, 2012, Okoye et al., 2016).

The conceptualization of deep and surface safety compliance stems from the emotional labor theory, which suggests that workers can enact display rules via two different approaches: deep acting and surface acting (Ashforth and Humphrey, 1993, Grandey, 2003). Following this theory, the positivity of safety compliance as observable behavior is challenged since the safety procedures are sometimes superficially performed. A newly developed framework highlights that the safety compliance may perform as either deep compliance, which is a form of safety compliance involving the intention and strategy to complete the required task, or surface compliance, which is a form of safety compliance reflecting the intention and strategy to merely demonstrate compliance (Hu et al., 2020). Deep compliance and surface compliance can be used to differentiate the ways that worker comply with safety rules. On the one hand, deep compliance is defined as a type of safety compliance with the intention and strategy to complete the required task safely (Hu et al., 2020). When workers have deep compliance with safety rules, they intend to provide high quality safety performance, instead of simply following the rules. For example, a construction worker's reporting a safety hazard to the site manager can be considered as deep compliance. On the other hand, if workers present surface compliance with safety rules, they would follow the rules to keep the job or avoid negative consequences of non-compliance, rather than to improve the safety performance (Grandey, 2003, Totterdell and Holman, 2003). For example, the workers will perform the minimum effect to complete the safety procedure without actively thinking about the effectiveness of the procedure.

3 Research Methodology

A systematic search of the literature was conducted, using a computerized search on Scopus and Web of Science databases. Studies were identified that contained the following combination of keywords: at least one of safety performance, safety behavio(u)r, safety compliance, and construction. The databases were searched for records between January 2000 to May 2021. The studies included are published in English and address at least one of the following: (i) safety compliance survey development and/or testing in a construction population; (ii) examination of the relationship between safety compliance and safety performance; and (iii) factors or indicators contributing to safety compliance in the construction industry. Figure 1 shows the process of conducting the systematic literature review.

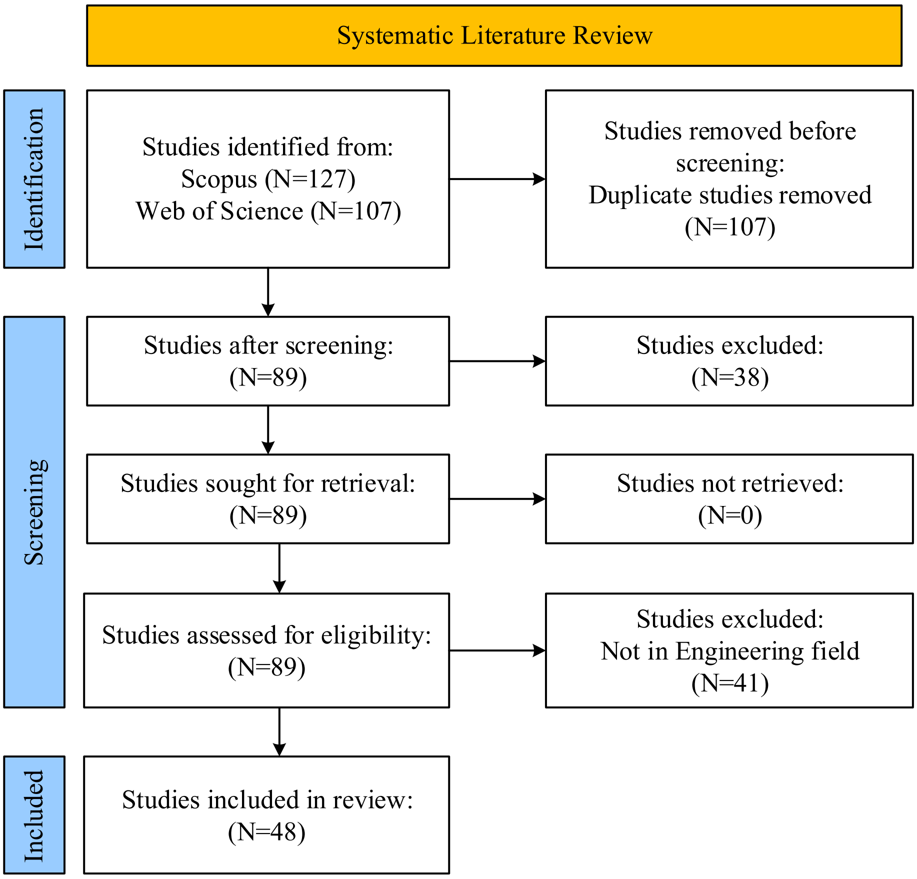

Figure 1. Literature Review Process

4 Discussion

4.1 Perceived usefulness

The term "perceived usefulness" first appears in the technology acceptance model (TAM). Davis (1985) developed this model to assume that individuals' attitude towards using the computer-based information system could be determined by two major variables: perceived usefulness and perceived ease of use. The first definition of perceived usefulness is the degree to which an individual believes that using a particular system would enhance his or her job performance. TAM suggests that users' perceived usefulness has positive impact on their intention to use the system, and of their performance when using the system.

Although TAM was first introduced for computer science studies, other researchers have used TAM in studying workplace safety. In safety critical areas, the perceived usefulness is defined as perceived improvement of safety performance by enacting safety compliance (Hu et al., 2016). Previous studies have indicated the relationship between perceived usefulness and safety compliance. For example, Borys (2009) found that if employees perceived a rule or procedure to be unhelpful or unimportant for their safety, they were more likely to not comply the rules. Hu et al. (2016) developed a model using TAM and concluded that workers' perceived usefulness had a positive impact on safety compliance in the mining industry. Zhang et al. (2020b) concluded that perceived usefulness contributed to less occurrence of unsafe behavior at nuclear power plants in China.

Workers who perceive that following safety rules is useful and beneficial are more likely to comply with safety rules and procedures in the mining industry (Hu et al., 2016), so similar case should appear in the construction industry. In the construction safety context, perceived usefulness refers to the extent to which construction workers believe that following the safety rules and procedures on site is useful and effective for them to gain a better safety performance. Accordingly, construction workers who perceive that following safety rules is useful and beneficial are more likely to spend effort on adhering to safety rules and procedures, which allows them to gain deep safety compliance. However, if they found safety rules and procedures are not helpful, they are likely to avoid following safety rules and procedures, and gain surface compliance, which compromise safety performance. Thus, perceived usefulness is likely to have a positive impact on construction workers' deep compliance, while have a negative impact on their surface compliance. The following hypotheses were developed:

Hypothesis 1a: Perceived usefulness is positively related to deep compliance.

Hypothesis 1b: Perceived usefulness is negatively related to surface compliance.

4.2 Perceived ease of use

The term "perceived ease of use" first appeared in the technology acceptance model (TAM). Davis (1985) defined perceived ease of use as the degree to which an individual believes that using a particular system would require little physical and mental effort. TAM suggests that users' perceived ease of use will positively impact their willingness to use the system, and their actual performance when using the system.

By applying TAM to workplace safety context, previous studies have defined perceived ease of use as perceived level of effort when using the system (Hu et al., 2016). Laurence (2005) suggested that high levels of effort when following safety rules and procedures was one of the reasons why workers violate safety procedures in the mining industry. Hale and Borys (2013) also highlighted that workers are often found to take shortcuts or use their own methods if they believed that the use of procedures was effortful and time-consuming. Zhang et al. (2020b) concluded that workers' perceived ease of use had a positive impact on workers safety compliance by reducing their unsafety behavior.

In the construction safety context, perceived ease of use refers to the extent to which construction workers believe that complying with safety rules and procedures on site can be achieved with a certain level of effort. Hu et al. (2016) stated that workers in the mining industry were likely to stick to the safety rules and procedures if they found the safety rules and procedures were easy to follow. By doing so, their deep compliance is enhanced. Accordingly, construction workers may also find following safety rules and procedures to be an effortful process due to the complexity of construction work, which may contribute to workers' choice of non-compliance or surface compliance. Thus, the following hypotheses are developed:

Hypothesis 2a: Perceived ease of use is positively related to Deep Compliance.

Hypothesis 2b: Perceived ease of use is positively related to Surface Compliance.

4.3 Safety Knowledge and Safety Training

In the theory of job performance, Campbell (1993) defined workers' performance as being determined by three factors, including declarative knowledge, procedural knowledge and skills, and motivation. Declarative knowledge refers to the "suggestive or real knowledge", that are fully understood and can be expressed clearly, while procedural knowledge and skills refers to the knowledge that explains how to perform an action within the framework of clear procedures (Yilmaz and Yalcin, 2012). The researchers in the field of safety often merged those two terms into "safety knowledge" (Neal et al., 2000, Guo et al., 2016, Vinodkumar and Bhasi, 2010).

Previous studies have proven the correlation among safety knowledge, safety training and safety compliance. For example, Tsoukas and Mylonopoulos (2004) highlighted that a safe workplace involved the constant engineering of workers' knowledge and skills, equipment, and social interaction. Christian et al. (2009) found that safety knowledge was strongly related to safety performance. Dahl (2013) suggested that enhancing worker's safety knowledge, such as providing safety training, accessing to the safety management system, understanding the work characteristics and gaining social interaction could promote safety compliance in the petroleum industry. Through a survey with 170 construction workers, Xu et al. (2019) concluded that workers' learning ability and their vulnerability to emotional stress could influence the effectiveness of safety training and thus influence safety knowledge and safety performance.

In the construction safety context, safety knowledge refers to the theoretical and practical understanding of occupational safety (Akinwale and Olusanya, 2016). Construction workers' safety knowledge is commonly gained from safety training courses or other settings (Idoro, 2008). By gaining safety knowledge, construction workers can receive deeper understanding of safety rules and procedures and the importance of adhering to those rules (Guo et al., 2016). They are therefore more likely to achieve deep compliance. In addition, gaining safety knowledge can increase construction workers' awareness of how construction work can be carried safely and help them to understand the consequences if they fail to adhere to safety rules procedures (Okoye et al., 2016, Sarita et al., 2019, Wang et al., 2021), and thus encourage them to perform surface compliance.

Hypothesis 3a: Safety knowledge is positively related to deep compliance.

Hypothesis 3b: Safety knowledge is negatively related to surface compliance.

4.4 Safety Motivation

In the theory of job performance, Campbell (1993) defined workers' motivation as one of the dimensions of their job performance. Motivation is described as a purpose to act or as a psychological process causing the arousal, direction, and persistence of behavior (Campbell, 1993) and has been seen as a significant factor influencing safety behavior (Griffin and Neal, 2000).

As safety performance is considered as one of dimensions of job performance (Ng and Feldman, 2008), many researchers applied the theory of job performance to safety criteria area and described safety motivation as an individual's willingness to exert effort to perform safety behaviors and the valence associated with safety behavior (Andersson and Paqarizi, 2016). Christian et al. (2009) introduced a conceptual framework to identify the antecedents of safety performance and found that safety motivation was most strongly related to safety behaviors and improved safety performance. Hu et al. (2016) found that safety motivation was associated with safety compliance through a cross-sectional survey with 374 mining workers. Guo et al. (2016) concluded that safety motivation was significantly and positively related to safety participation but did not significantly predict safety compliance in the New Zealand construction industry. The findings of Guo et al. (2016) differed from Neal et al. (2000) who indicated that safety motivation predicted both safety compliance and participation in a large Australian hospital.

In the construction safety context, safety motivation refers to the extent to which construction workers want to comply with safety rules and procedures. If construction workers are motivated to achieve better safety performance, they ought to place a high emphasis on safety when complying with safety rules and procedures (Guo et al., 2016), and thus achieve deep compliance. On the contrary, once construction workers are motivated to attain better safety performance, they are less likely to be involved in surface compliance because surface compliance does not emphasize the importance of safety performance.

Hypothesis 4a: Safety motivation is positively related to deep compliance.

Hypothesis 4b: Safety motivation is negatively related to surface compliance.

4.5 Management commitment to safety

The organizational climate literature highlighted that workers' climate perceptions can influence work behaviors by signaling the organization's priorities and behavior-outcome expectations (Dieterly and Schneider, 1974, Schneider, 1975). The term "management commitment to safety" is defined as the extent to which management staff value the importance of safety in the workplace (Hansez and Chmiel, 2010).When workers perceive that certain behavior is prioritized and valued by the organization, they are more likely to do so (Zohar, 1980, Zohar and Polachek, 2014). This theory has been applied to workplace safety studies by many researchers. Zhang et al. (2015) found that workers' safety performance can be identified by measuring management commitment in the construction industry. Through a questionnaire survey with 20 rail construction workgroups in Australia, Lingard et al. (2019) emphasized that safety compliance could be predicted when supervisor provide contingent reward. Jacobs and Pienaar (2017) also concluded that management commitment to safety could impact safety compliance in the mining industry.

In the construction safety context, management commitment to safety refers to the extent to which site managers or supervisors value the importance of complying with safety rules and procedures on site. Through a survey covering various industries, including the construction industry, Hu et al. (2020) found that when the management staff prompted workers to attain improved safety performance, they would provide signals that adhering to safety rules and procedures is necessary, and workers were likely to follow the requirements made by the management staff and thus achieved deep compliance. On the other side, if workers are not encouraged to prioritize safety in the workplace by the management staff, they may choose to achieve surface compliance.

Thus, the following hypotheses are developed:

Hypothesis 5a: Management commitment to safety is positively related to deep compliance.

Hypothesis 5b: Management commitment to safety is negatively related to surface compliance.

Hypothesis 6: Management commitment to safety is positively related to safety motivation.

4.6 Situational awareness

Tett and Burnett (2003) introduced Trait Activation Theory (TAT) to study the relationship between individuals' internal traits and external situation. TAT suggests that situational awareness can activate an individual's way of expressing their traits, therefore influencing job performance (Tett and Burnett, 2003). The term "situational awareness" is defined as the perception of elements of the environment, the comprehension of their meaning, and the projection of their future status (Endsley, 1988). As safety performance has been considered as one of dimensions of job performance (Ng and Feldman, 2008), some researchers applied TAT to workplace safety concept and investigated the relationship between situational awareness and safety performance. Zhou et al. (2011) suggested that employees' awareness reduced workers' unsafe behavior in the Chinese construction industry. Haas et al. (2020) also found that gaining awareness to the potential causes of injury could prompt safety management initiatives. Wang et al. (2021) found that workers' Emotional intelligence (EI) contributed to their situational awareness that led to safety performance, while safety training played a moderating role in such relationship.

In the construction safety context, previous studies have found that workers' situational awareness can reflect to their psychological states and thus improve safety performance (Irwin et al., 2019). Workers who have high situational awareness are more likely to identify the hazard around them, be aware of the importance of following safety rules and procedures, and understand the consequences of not adhering to safety rules and procedures (Albert and Hallowell, 2014, Bakhshi et al., 2021). Thus, they are likely to achieve deep compliance to avoid being harmed by the hazards on site. Thus, situational awareness is likely to have a positive impact on construction workers' deep compliance, while have a negative impact on their surface compliance. The following hypotheses are formulated:

Hypothesis 7a: Situational awareness is positively related to deep compliance.

Hypothesis 7b: Situational awareness is negatively related to surface compliance.

4.7 Emotional Intelligence

As discussed in the previous section, TAT suggests that situation can activate individuals' trait, and thus influence their performance (Tett and Burnett, 2003). In the workplace, it is important to maintain a comfortable and stable mood without the interference of negative emotions (Muchinsky, 2000). Previous studies have proven the importance of workers' EI for improving job performance. For example, Sunindijo and Zou (2013) found that EI was a key factor for implementing safety management tasks. Also, Khosravi et al. (2020) found that EI was positively linked to performance. Rezvani et al. (2018) concluded that workers' EI was positively related to performance at both individual and team level.

In the safety context, EI is often considered as a trait-like attribute that can influence individuals' performance by provoking cognitions or psychological states (Blickle et al., 2018, Ifelebuegu et al., 2019). Workers' EI are positively related to their situational awareness and safety compliance (Wang et al., 2021), and thus construction workers with high EI can manage their emotions while performing safety compliance. They are more likely to deeply comply with safety rules and procedures as their emotion would not play a disturbing role. Thus, the following hypotheses were formulated:

Hypothesis 8a: EI is positively related to deep compliance.

Hypothesis 8b: EI is negatively related to surface compliance.

Hypothesis 9: EI is positively related to situational awareness.

4.8 Safety Communication

The Social Exchange Theory (Blau, 1964) suggests that people's interaction is an exchange process that may result both in economic and social gains. Previous studies applied the Social Exchange Theory to safety context and identified safety communication as an important factor for improving safety performance outcomes in organizations (Jin et al., 2015). Parker et al. (2001) concluded that communication quality enabled staff to be more aware of the importance of following safety rules and procedures and clearly understand the consequences of not adhering to safety rules and procedures. Huang et al. (2018) also suggested that safety communication was one of the factors that were strongly related to workers' safety performance. Abuashour and Hassan (2019) addressed that safety communication was one of the antecedents of workers safety performance. Through a survey with 20 workgroups across 11 different worksites in Australia, Zhang et al. (2020a) concluded that good communication between supervisor and workers could improve safety compliance.

In the construction safety context, safety communication refers to the formally or informally interaction of supervisors, co-workers, and groups with a view to improving safety performance (Abuashour and Hassan, 2019). With effective safety communication, workers are more likely to understand safety rules and procedure, and be motivated to comply (Lingard et al., 2019). They are prompted to report safety hazards and recommendations to the management staff (i.e., site managers or safety supervisors), as well as communicate safety issue with their co-workers (Zhang et al., 2020a), thus achieving deep safety compliance. In contrast, they are likely to gain surface compliance due to miscommunication or misunderstanding of safety goals or feeling unnecessary to adhere safety rules and procedure. The following hypotheses are formulated:

Hypothesis 10a: Safety communication is positively related to deep compliance.

Hypothesis 10b: Safety communication is negatively related to surface compliance.

Hypothesis 11: Safety communication is positively related to safety motivation.

Figure 2 summarizes the proposed relationships among key factors (i.e., perceived usefulness, perceived ease of use, safety knowledge, safety motivation, management commitment to safety, situational awareness, emotional intelligence, and safety communication) and two dimensions of safety compliance (i.e., deep compliance and surface compliance) with consideration into control variables (i.e., gender, age, work experience, educational level, ethnic groups, hazard type, work location, and working hours).

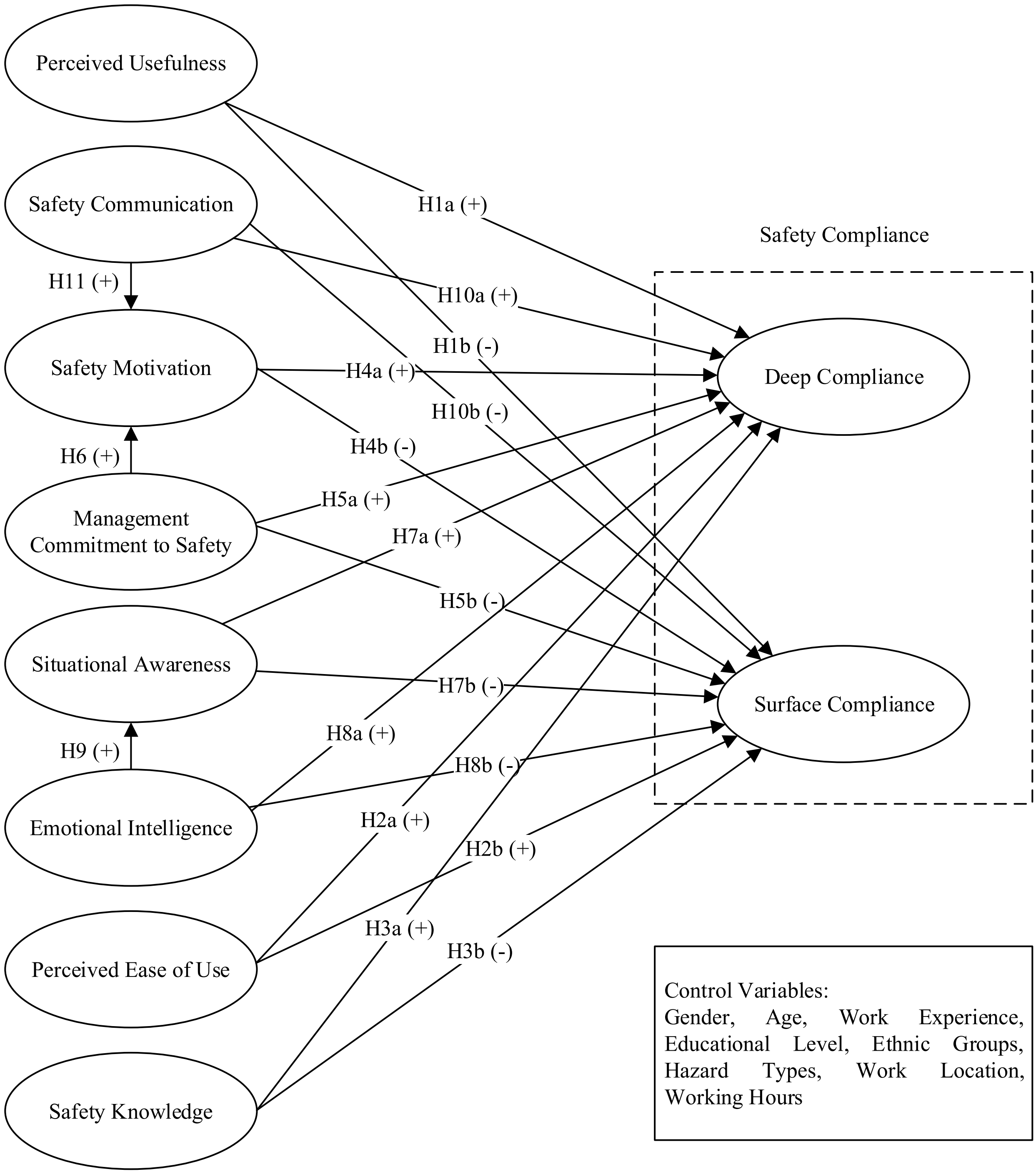

Figure 2. A Priori Model

5 Conclusion

This paper has conducted a literature review on the antecedents of safety performance and safety compliance in various industries. There are three major contributions from this paper. First, this review contributes to the literature by identifying the factors of safety performance and safety compliance, including perceived usefulness, perceived ease of use, safety motivation, management commitment to safety, situational awareness, emotional intelligence, safety communication, and safe knowledge.

Second, this paper brings progress by summarizing major theories that have been used in the construction industry for studying safety performance, including Technology Acceptance Model, Theory of Job Performance, Trait Activation Theory, and Social Exchange Theory.

Third, this paper discusses each factor relating to safety performance and safety compliance in the construction safety context and develops hypotheses about the relationship between those factors and deep/surface safety compliance.

This paper does have limitations as it only covers limited number of factors and theories. However, this paper sheds light on investigating the antecedents of deep and surface safety compliance in the construction industry. Based on the discussions of this paper, further study is required to test the hypotheses and validate the findings.

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Development of A Framework for Successful Last Planner System Implementation: A Systematic Review

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Abstract

Last Planner System (LPS), as one of the most effective lean construction tools to improve planning reliability, has been adopted by increasing numbers of construction companies worldwide. However, previous studies found that the full benefits of LPS are still hindering due to considerable problems, which prevents a wider spread of the technique. To address this gap, this study aims at developing a framework of LPS adoption for construction companies to realize the full effectiveness of LPS. A systematic literature review is undertaken to synthesize existing critical success factors (CSFs) and barriers reported in the literature, followed by a mixed-method analysis to develop an integrated framework to support successful LPS implementation. The proposed framework can be used as a checklist for construction companies to investigate the missing parts in their current operating procedure and develop a corresponding implementation strategy. With a detailed evaluation of identified CSFs and barriers, this study also reveals that project participants, the organization as well as external enablers are required to make relevant efforts in order to secure the full benefits of LPS.

Keywords

Barriers, Critical Success Factors (CSF), Implementation, Last Planner System (LPS), Systematic Literature Review

1 Introduction

Last Planner System (hereafter LPS) is one of the most effective lean construction tools to improve planning reliability through the collaboration of the entire project team and greater involvement of the 'last planner' (Kalsaas, 2012, Perez & Ghosh, 2018). LPS implementation has been investigated over the last two decades, and numbers of best practices are proposed to support and facilitate LPS adoption (e.g., Daniel et al., 2019; Perez & Ghosh, 2018). However, the full benefits of LPS still cannot be realized (Abusalem, 2020). One of the reasons is the impact of existing barriers, which are not fatal to the success of LPS adoption but lower the productivity value of LPS, hence decrease the level of LPS adoption (Fernandez-Solis et al., 2013, Vignesh, 2017). The need to guide companies with a better demonstration of 'what is actually required for a successful LPS implementation' is revealed. This research aims to develop an integrated framework for successful LPS implementation, including critical success factors (CSFs) and barriers through a review of existing literature, which can assist construction companies in understanding the underpinning of best practices and making the required change effort. The research objectives are to (1) identify CSFs supporting LPS adoption, (2) define subfactors in relation to each CSF, (3) identify barriers to LPS adoption, and (4) integrate subfactors and barriers to construct the framework.

2 Literature Review

A complete LPS implementation contains four levels (master schedule, phase schedule, lookahead plan, weekly work plan) and relevant methods (e.g., pull planning, reliable promising, etc.) to enable full performance of LPS. Further, Ballard et al. (2009) introduced five fundamental principles of LPS to guide the LPS implementation, which include (1) plan in greater detail when the activity is closer to execution; (2) plan collaboratively; (3) identify and remove activity constraints together in a team; (4) enable reliable promising; (5) enable continuous learning. In terms of performance measures, Percentage Plan Complete (PPC) is the key performance indicator to measure workflow reliability (Ballard, 2009). These efforts benefited LPS adaptors, which is evident in the number of reports that emerged in the research community. Daniel et al. (2015) found 57 IGLC reports related to LPS implementation between 1993 and 2014 across 16 countries. Elkherbawy (2019) found that 72 out of 189 lean case studies focus on LPS implementation. The conclusion can be made that the implementation of LPS is on the rise but still at an early developing stage globally (Tezel et al., 2018).

The adoption of LPS is proven to bring benefits to not only a single project but also the organization itself. Construction companies that adopt LPS as a long-term business strategy can develop a new culture of collaborative planning and experience continuous improvement in organization performance (Mejía-Plata et al., 2016). The managerial decision-making process can be improved mainly by avoiding centralized leadership and reducing the number of urgent procurement requests (Alarcón et al., 2008, Castillo et al., 2018). At the project level, the benefits of LPS include reduced project cost and duration and improved project productivity (Fernandez-Solis et al., 2013). Existing literature also showcased that LPS has the potential to improve quality, site safety, and job satisfaction (Andersen et al., 2012, Enshassi et al., 2019, Khanh & Kim, 2015).

According to Abusalem (2020), the full benefit of LPS is still hindered due to considerable problems. Porwal et al. (2010) and Fernandez-Solis et al. (2013) have summarized a number of common challenges encountered by the construction team, covering both implementation and usage perspectives. Several newly emerged barriers have also been reported in recent case studies, including the inappropriate selection of procurement methods and the complexity of work (Daniel et al., 2018, El-Sabek & McCabe, 2017, Fuemana et al., 2013). To solve the problems, LPS best practices have been proposed by researchers. Perez and Ghosh (2018) and Mejía-Plata et al. (2016) presented best practices of LPS focusing on the implementation process. Daniel et al. (2018) again suggested an LPS Path Clearing Approach focusing on achieving successful implementation at both organization and project level. El-Sabek and McCabe (2018) have developed a process framework for international megaprojects (IMPs) with the integration of desired organizational behaviours. Existing literature also identified numbers of CSFs supporting LPS implementation in relation to the context of the case studied. Common CSFs include top management support, collaboration between teams, sufficient LPS knowledge, and the engagement of facilitators (Perez & Ghosh, 2018; Tayeh et al., 2018).

Even though LPS has been proved beneficial at the organizational level and operational level, considerable problems still exist in current implementations, which prevent achieving the full benefits of LPS. Most barriers and CSFs are reported on a project-by-project basis without proper consolidation. LPS best practices have been proposed merely focus on the process of implementation. A framework modelling CSFs and barriers is lacking for construction companies to aid their implementation process and provide guidance and alerts for the construction company when attempting change effort. In light of the research problems, the main research question is *What will be the framework for successful adoption of LPS in construction projects?* The sub-questions are *(1) What are the main CSFs supporting the LPS adoption in construction projects?; (2) What are the sub-factors influencing the adoption of LPS?; (3) What are the barriers to LPS adoption identified under each factor?*

3 Research Methodology

In this study, a systematic literature review approach is used, which arguably is the most effective method to build on the existing knowledge and combine the existing CSFs and barriers to LPS adoption, which have been thoroughly studied (Gopalakrishnan & Ganeshkumar, 2013). The sole use of Scopus has been proven reliable in the previous construction-related systematic review by Tetteh and Chan (2019). Next, inclusion and exclusion criteria are developed to provide a rationale for selecting eligible studies, which follow a similar approach as demonstrated by Hussein and Zayed (2021) to avoid publication and selection bias. The inclusion criteria include (1) Studies that mentioned barriers to LPS adoption; (2) Studies that mentioned CSFs supporting LPS implementation; (3) Studies in any countries, projects type, and publication year. The exclusion criteria are: (1) Studies published not in English; (2) Studies do not include empirical evidence; (3) Studies not related to AEC industry; (4) Type of document other than article and conference paper; (5) Studies integrated with other advanced construction technology; (6) Studies focusing on more than one lean techniques. To identify eligible studies for analysis, the systematic flow determined by PRISMA is adopted (Shown in Figure 1). Relevant keywords to the topic, such as "last planner system" and "implementation' were considered, and the search was conducted in the Scopus platform. The type of document was set to journal articles and conference papers in English only. The initial search resulted in identifying **223** studies. Further analysis of the findings resulted in removing five duplicated studies and 121 irrelevant studies to the topic. In the next stage, analysis of the remaining studies resulted in removing another 54 studies. Indeed, the full text of five studies cannot be accessed online, and 49 studies were integrated with other technology and lean techniques. As a result, a total of **43** studies were identified as the study's dataset.

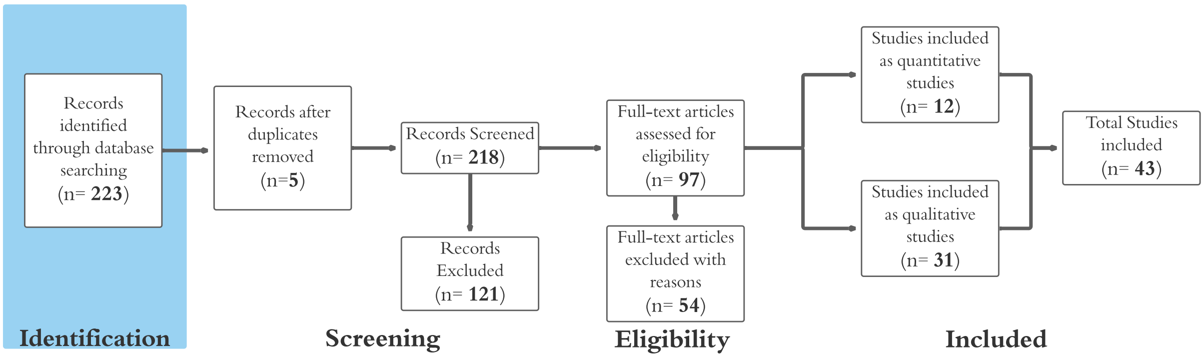

Figure 1. Searching Strategy Adopted from PRISMA (Moher et al., 2009)

4 Findings and Discussion

4.1 Most Common CSFs

As discussed, the final dataset includes 43 studies published between 2005 and 2020 (19 journal articles and 24 conference papers) is reviewed to identify CSFs and barriers. 10 out of 43 literature acknowledged the importance of 'Provision of LPS Training', hence the most common CSF. Ahiakwo et al. (2013) stated that training is the key to successful LPS implementation for any construction project. A proper training program involving all project participants can provide guidance and support to ensure the entire team has the same level of understanding of LPS benefits and procedures utilized in the specific project (Cerveró-Romero et al., 2013; Daniel et al., 2019; Perez & Ghosh, 2018). Through the training of LPS, the participants are sure to be aware of their role and responsibility in the new system and provide correct responses and attitudes to carry out the work (Daniel et al., 2016). The second most common CSF being nominated is 'Organization and Top Management Support and Commitment.' The commitments from the management team are important to manage the change of procedure and resistance from project participants (Vignesh, 2017). The adoption of LPS is time-consuming and therefore requires a strong commitment from the management team, including the head of the organization, division managers, and middle-level managers, to support the entire process (Ahiakwo, 2015; Hamzeh, 2011). Hicham et al. (2016) recognised the relationship between the commitment of the organization and successful LPS implementation as positive involvement of management level through high-level commitment could facilitate constraint removal during the planning process. Another common CSF identified is 'Involvement of All Required Stakeholders in LPS Planning Process.' To provide a more in-depth understanding of required stakeholders, Cerveró-Romero et al. (2013) revealed the necessity to involve the project management team, while Tayeh et al. (2018) found involvement of other management-level staff is also expected in the LPS implementation process. The involvement of subcontractors, architects, engineers, and clients or client representatives in the production planning session is also highlighted by a few researchers (Anand et al., 2019; Hamzeh et al., 2016; Kalsaas et al., 2009). In addition, Daniel et al. (2019) found the necessity to involve the commercial arm of the business into the LPS process to reduce time on decision-making and thus support the implementation.

From the analysis of the most frequently mentioned CSFs, the critical role of the construction company is emphasized as the top 3 most common CSFs are all related to the **organization**. This finding aligns with the findings from a survey with LPS participants where 'Trained staff' and 'Top management support' are the most important factors identified by Murguia (2019) and Abusalem (2020). The strong effort required from the organization is possibly because that LPS is not a one-off planning technique but an organization management tool that focuses on the internal planning, analysis, monitoring, and improvement of construction activities (González et al., 2019). Through the adoption of LPS, the organization itself will need to experience the change of the organizational culture from the traditional fragmented and adverse culture to a culture of collaborative planning and continuous improvement (Mejía-Plata et al., 2016). Therefore, the top management level and the entire organization should have a strong commitment and make a great effort to support the organization-level of change (El-Sabek & McCabe, 2018).

4.2 Most Common Barriers

The top 3 most common barriers being reported in the literature are 'Lack of Effective LPS Training Programs', 'Organization Inertia/ Resistance to Change', and 'Lack of Personnel Knowledge/ Understanding to LPS'. All three barriers were nominated by 11 literature (19% of total). LPS training is time-consuming and requires significant effort from the organization (Hicham et al., 2016). Although most of the organizations have a current training program, the training process remains problematic. Existing studies have found LPS training sometimes insufficient (Mahmoud et al., 2019) or not intensive enough (El-Sabek & McCabe, 2018) for the participants to understand the actual procedure and the underpinning of methods (Mahmoud et al., 2019), thus failed to facilitate process change. Others pointed out training is not adequately provided to *all staff* participated in the LPS process (Cerveró-Romero et al., 2013; Hamzeh, 2011). Salvatierra et al. (2016) and El-Sabek and McCabe (2017) have found that training lacks continuity. The available training program is not designed correctly for all participants as Khanh and Kim (2013) have pointed out that there is a lack of training program primarily for managers in terms of leadership training. Salvatierra et al. (2016) further highlighted that the existing training plan does not consider the level of pre-established skills and the critical skill required for a particular position.

'Organization Inertia/ Resistance to Change' is being emphasized in the literature in relation to the challenge of managing resistance to change from project participants. General resistance to change among contractors and subcontractors is highlighted in the literature (Hamzeh, 2011; Mahmoud et al., 2019; Mejía-Plata et al., 2016; Hatmoko et al., 2018). Cerveró-Romero et al. (2013) pointed out that experienced staff is the one who prevents the change forward as Koskenvesa and Koskela (2012) explained that people tend to stay in their comfort zone and are reluctant to learn new things. For current LPS participants, there are also consequential challenges in relation to resistance to change, such as lack of commitment to change and innovation as identified by Ahiakwo (2015) and Vignesh (2017) and in turn result in difficulty to modify the original widely accepted operational procedures by the construction team (Nieto-Morote & Ruz-Vila, 2012).

A wide range of studies has also found that LPS participants are lack of personnel knowledge and understanding of the new system (Hunt & Gonzalez, 2018; Tayeh et al., 2018). Insufficient understanding of LPS leads to misunderstanding of plan development and misuse of workflow measurement and root causes (Kim & Jang, 2005; Koskenvesa & Koskela, 2012; Tillmann et al., 2014). Hamzeh et al. (2016) also highlighted among all participants, there is a varying level of understanding of Lean Construction and LPS tools. Viana et al. (2010) explained that the difference in the level of understanding is caused by the variation in personnel qualification, which is one of the main problems the contractor faces to manage the implementation of LPS.

4.3 Increasing Number of Barriers Reported

Compared to the review of barriers conducted by Porwal et al. (2010) and Fernandez-Solis et al. (2013), where a similar result of 12 barriers is obtained, an increasing number of barriers is identified through increasing studies in LPS implementation over the last decades. Previous studies indicated that the barriers are mainly found in relation to the implementation process and user challenges, focusing on the problems at the organization and project level (Porwal et al., 2010). However, in this study, it is evident that new problems of LPS implementation have emerged from external parties, covering a broader perspective. Challenges arise when academia and client do not offer sufficient support to the organization (Gao & Low, 2014; Hunt & Gonzalez, 2018). In addition, problems related to the standardization of process and financial costs are uncovered by a few researchers, which have not been covered in the previous review (Cerveró-Romero et al., 2013; Hicham et al., 2016; Nieto-Morote & Ruz-Vila, 2012). Therefore, despite some barriers are mentioned less frequently, the importance of those cannot be overlooked, which should be further investigated in other similar projects to build generalization. It is also worth to be noticed that the top 3 most common barriers are mentioned as ongoing issues as numbers of literature have all revealed the same issues, which implies a lack of effective strategy to address the barriers (Perez & Ghosh, 2018). All three most common barriers are related to the effort devoted by the organization and support from the management level to build on the new culture. As previously mentioned, the organization plays a key role in LPS implementation. Thus, the top management should be responsible for addressing those barriers and provide a corresponding strategy together with the engagement of academia (Hunt & Gonzalez, 2018).

5 Development of Framework

5.1 Overview

To develop the conceptual framework, the first step is to identify the main factors contributing to successful LPS implementation (Whetten, 1989). The main factors are developed through the synthesis of all the identified CSFs. A number of 8 main themes are emerged, including (1) participant awareness, (2) technique integration, (3) system standardisation, (4) participant engagement, (5) external drivers, (6) organisation commitment, (7) system control, and (8) strategy development. Subsequently, sub-factors are also identified through the analysis and grouping of CSFs. Similarly, all identified barriers are grouped against these 8 main factors.

Among all 8 factors, it is found that the most important factors are 'Organization Commitment' and 'System Control', which have been most frequently mentioned by literature. The organization plays a key role in LPS adoption and implementation to facilitate the change in organization culture (Mejía-Plata et al., 2016). 'System control' is also commonly mentioned among existing literature as most cases studied indicate the necessity to offer sufficient monitoring, leadership, and communication. LPS itself does not provide a standardized communication system and requires the guidance of the relevant management team to control and monitor the whole process. Communication plays an essential part among all subfactors to ensure the information is well-distributed and updated through a proper communication channel. Similarly, LPS requires effective communication between the parties to establish collaboration and trust among the team, which contribute to improvement in workflow reliability and overall performance (Gao & Low, 2014; Tillmann et al., 2014). The identified barriers mainly fall into three factors: 'Strategy Development', 'System Standardization' and 'Participant Awareness'. The results demonstrate a greater focus is on the implementation process and individual level when analysing barriers to LPS implementation in contrast to the identification of CSFs, where the role of organization and external drivers is much more emphasized. This is possibly because LPS is still a relatively new planning technique, and its users are still unfamiliar with the implementation process and theoretical underpinning. Despite increasing LPS implementation has been found across different locations, Koskenvesa and Koskela (2012) found that only one of the four companies in Finland successfully passed the trial LPS implementation and started to implement LPS systematically. Ryan et al. (2019) also found that the implementation process of LPS is not standardized across projects, which brings difficulties for the LPS participants to understand the actual procedure of LPS.

5.2 Integration of Framework

The developed conceptual framework is shown in Figure 2, which constitutes of main factors, subfactors, and barriers under each subfactor. It is worth mentioning that the identification of main factors has been influenced by the Unified Theory of Acceptance and Use of Technology (UTAUT) model. During the consolidation of existing empirical evidence, more themes have been uncovered and, therefore modified to fit in the specific context of LPS implementation. All 8 main factors are rearranged hierarchically in terms of the nature of support to successful LPS implementation. 4 main factors refer to the technical support at a lower project level, and the remainder 4 factors indicate the contribution from project stakeholders at project, organization, and external level. To be more specific, the top-level constitutes two factors, which are ‘System Control’ and ‘Strategy Development’ that are closely linked to the solid support during LPS implementation in a construction project. The second level includes two factors, ‘Technique Integration’ and ‘System Standardization’, that are more related to the pre-implementation stage where the use of technology and system should be pre-determined. The third level shows the support from individuals by showing ‘Participant Engagement’ and ‘Participant Awareness’. In contrast, the bottom level indicates greater support outside the project level where the organization tends to show ‘Organization Commitment’ and work closely with ‘External Driver’ to facilitate the implementation of LPS.

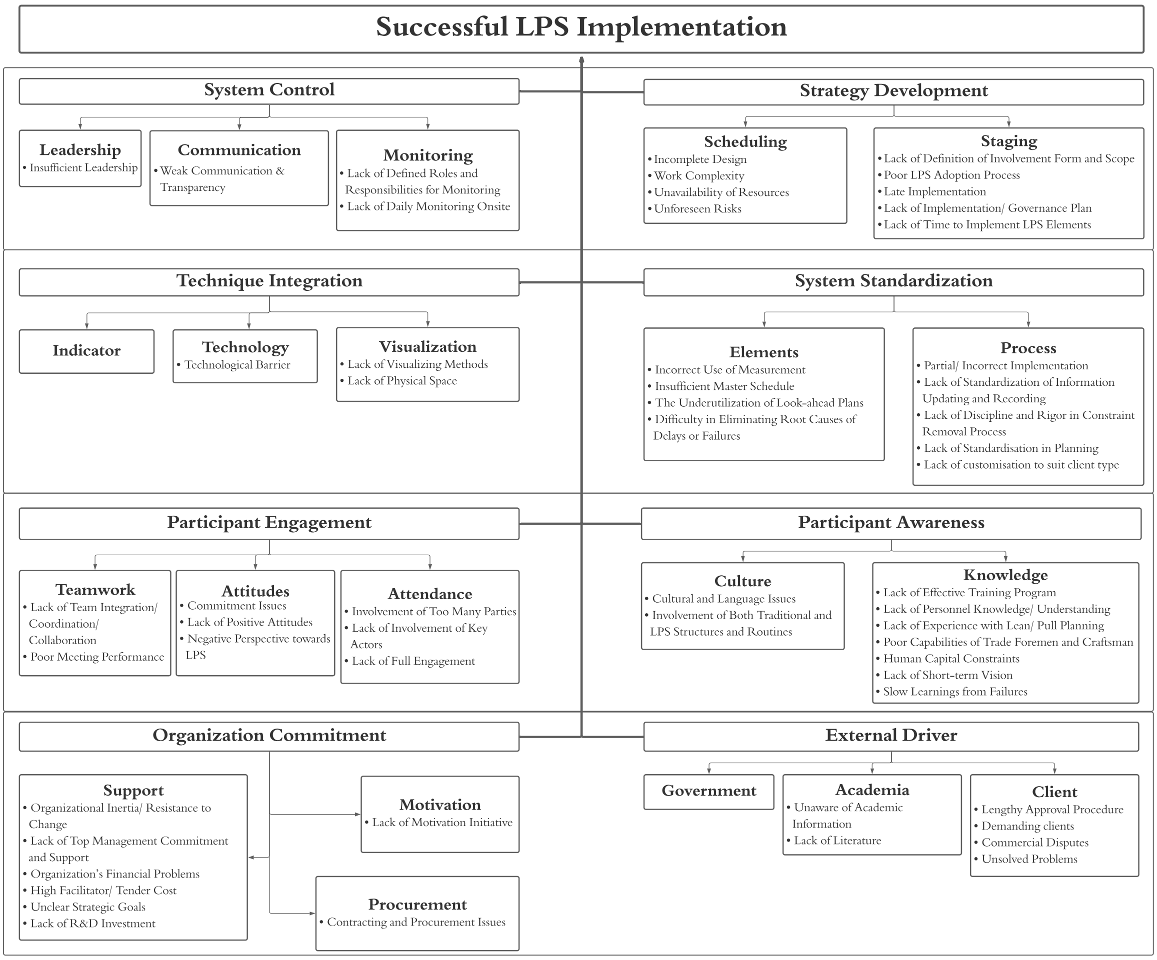

Figure 2. Integrated Framework of Successful LPS Implementation

The developed conceptual framework indicates that to ensure the full benefits of LPS can be achieved during implementation, the *organization*, *project participants* as well as *external parties* should all make a great effort to fulfil the required CSFs and clear all potential barriers. The two factors, 'Organization Commitment' and 'System control' imply a close linkage between full LPS benefits and the effort required from the organization, especially from the management level. The organization definitely plays the most critical role in guiding all the project participants through the entire implementation process by offering effective training programs, providing motivation incentives, and managing resistance to change from end-user level and management level (Ahiakwo et al., 2013; Gao & Low, 2014; Murguia, 2019). As LPS is expected to be implemented in a company to maximize the benefits of continuous improvement, the *organization* should also incorporate LPS into strategic goals and allocate sufficient R&D investment to support the entire transition and develop a culture of collaborative planning within the organization (Hunt & Gonzalez, 2018; Koskenvesa & Koskela, 2012). In addition to those expected commitment and support from the organizational level, the management team, especially the middle management level, are expected to make great commitment to provide sufficient leadership and monitoring strategy to sustain the performance and involvement of LPS participants at project level (Skinnarland, 2012). Greater support is required from the middle manager to the general manager, which is also known as the 'last planner', to ensure the planning process and constraints removal process can be carried out properly when a large number of stakeholders are involved (Kalsaas et al., 2009).

Project participants involved in the LPS planning process should pay more attention to the two factors, which are 'Participant Awareness' and 'Participant Engagement'. These two factors indicate greater involvement and engagement of project participants in the LPS planning process and acceptance of this new culture of collaborative planning. Literature has found resistance to change from the end-user level as a severe barrier facing by current LPS implementation (El-Sabek & McCabe, 2017). Project participants should be encouraged with more open, honest, and transparent attitudes to build trust among the entire team (Daniel et al., 2019). Moreover, project participants are expected to actively engage in the training and LPS meeting to make reliable promising and develop a collaborative plan through negotiation with the entire team (Daniel et al., 2019; Tillmann et al., 2014). To ensure all these expected efforts can be properly devoted by the project participants, it is critical for all participants to have sufficient personnel knowledge and competency in relation to the LPS implementation and collaborative planning (Anand et al., 2019; Fernandez-Solis et al., 2013).

To ensure LPS is successfully implemented with maximum benefits, it is also expected that '*External Driver*', which are the government, academia, and clients, can offer extra support to facilitate the adoption process. The client is expected to make great commitment and support to the LPS implementation through greater involvement in the planning process (Anand et al., 2019; Hamzeh et al., 2016). The government should play the role of the Lean facilitator by forming new policies to suit Lean Construction as well as LPS (Ahiakwo, 2015; Hunt & Gonzalez, 2018). A partnership is expected to be developed between construction companies and academia to build the platform to communicate new findings and development of LPS and, in turn, facilitate the adoption of LPS (Daniel et al., 2019; Hunt & Gonzalez, 2018). Another external driver, which has not yet been identified by existing literature, has been found through the implication of the factor 'Technical Integration'. The existing literature shows that the lack of a compatible technical solution is an ongoing barrier hindering the exchange of LPS-related information and visualization of LPS results (Perez & Ghosh, 2018; Tayeh et al., 2018). Therefore, the development of proper software and technology that incorporate PPC and root cause analysis into the existing tracking system is expected from technology providers to facilitate the implementation of LPS (Gao & Low, 2014; Power & Taylor, 2019).

While the above discussion summarized the required effort from project participants, the organization, and external drivers, it is also critical to remind all the LPS users to pay more attention to the correct use of the LPS system as literature has found incomplete and incorrect use of LPS elements and planning process, which hinders the achievement of full benefits (Perez & Ghosh, 2018). Two factors, 'System Standardization' and 'Strategy Development' have indicated that full adoption of LPS with a standardized implementation process can ensure the full potential of LPS being realized (Hamzeh et al., 2016; Vignesh, 2017). As outlined in Section 2.2, a complete LPS system contains 4 planning levels and different methods and tools in each level (Ballard et al., 2007). Adopting the PBP index, which includes a checklist of 15 LPS tools, is expected to be integrated into the implementation process to assess the level of LPS adoption and ensure LPS elements are properly adopted (Viana et al., 2010). To further ensure the correct use of LPS elements, the organization should hire lean experts until the project team has a robust internal capacity to correctly utilize all the LPS elements and planning process (El-Sabek & McCabe, 2018).

6 Conclusion

Through a systematic review, this developed framework in this research expands on existing best practices of LPS, which provides a better demonstration of the required effort to a successful LPS adoption from project participants, the organization as well as external parties. In addition, this framework has the potential to facilitate full implementation of LPS and allow a smooth integration of LPS into a company's existing operation procedure with defined roles and responsibilities of different project stakeholders and the outlined requirements of a full LPS implementation. This research contributes to the knowledge area and future application of LPS in the field of construction engineering and management. The proposed framework outlines the underpinning of existing best practices and frameworks and reveals newly emerged problems and challenges during more recent implementation. With a proper consolidation of existing empirical evidence, this research generates a solid foundation for further research of LPS adoption in construction projects. In terms of application, the proposed framework can be used by construction companies as a checklist to LPS adoption to investigate the missing operation procedure and responsible personnel in the implementation process. This allows new adapters and existing users to make the correct decision and manage behaviour change of participants in the LPS implementation process at the organizational level. At the same time, extra support from external parties may be requested. Despite the contributions, several limitations need to be highlighted. First, the dataset is limited to journal articles and conference papers in English only. Future research may consider other types of publication. Moreover, future research is expected to validate the conceptual model proposed in this study. It is also worth identifying the relationships between different levels of factors to allow for a more comprehensive understanding of the efforts required.

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Leveraging blockchain for prefabricated construction supply chain management – A conceptual workflow framework

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Abstract

Prefabricated construction is an emerging off-site construction approach that provides significant superiority compared to traditional on-site construction, such as flexibility, safety, environment-friendly, and quickness. However, prefabricated construction development is challenging to establish an efficient supply chain management system. Four aspects need to be improved in the prefabricated construction supply chain management (PCSCM) to popularise the prefabricated construction. (1). Enhancing the information sharing process of PCSCM to fix the information fragmentation issue. (2). Developing the real-time traceability of PCSCM logistics' information. (3). Improving the payment system among PCSCM to ensure the capital flow is fair and on time. (4). Reinforcing transparency of information to increase the trust among all participants in the PCSCM. Blockchain technology can be a promising tool to address these issues since it has been regarded as an information management and sharing platform, contract management system, and means of payment in many other industries such as financial and medical. Blockchain is a distributed ledger with decentralisation, traceability and security features. Nevertheless, the research of blockchain integration in the construction industry is rare due to the low digitisation and automation of construction trades. This study aims to find out how to leverage blockchain for prefabricated construction supply chain management. This research aim is achieved by conducting a systematic literature review. As a result, to solve the issues in PCSCM, a blockchain-enabled PCSCM workflow framework has been proposed in this paper.

Keywords
Blockchain, Supply chain management, Information management, Payment process.

1 Introduction

Supply chain management is of particular importance to prefabricated construction because the management of prefabricated construction supply chain determines the schedule and efficiency of the whole prefabrication project. Also, supply chain management is significant for sectors and industry partners. However, there are many problems in the information sharing among various departments in the management process, such as the opacity of information and the low efficiency of information transmission. Therefore, if governments and industries eager to popularise prefabricated construction, the existing problems in PCSCM must be solved. The current issues of PCSCM are early or late delivery, prolonged construction period, mass stock, especially the lack of real-time information sharing. Moreover, the lack of real-time information sharing leads to more potential problems such as construction chaos, extended project time and increased supply chain costs (Wang et al., 2020).

Blockchain as an emerging technology is a possible way to solve the problems in PCSCM, also a new trend of future technology development. Because blockchain is a distributed and traceable ledger with high security, it can store and share the data or transaction information automatically, which means the blockchain is appropriate to address the problems encountered by PCSCM. According to Iansiti and Lakhani (2017), blockchain provides an open platform initially used for transactions between two parties. Nowadays, it can be used to store and display data (Elghaish et al., 2020). Traditional communication methods of PCSCM rely on phone calls, emails, or faxes (Wang et al., 2020). If the construction industry is eager to transfer from paperwork to digital work, blockchain is an essential technology as the blockchain-based information exchange process is more efficient and safer. Also, blockchain will help coordinate the different stages of the prefabricated supply chain.

The aim of this study is to develop a blockchain-based prefabricated supply chain management framework to improve information management and payment management during the PCSCM process. The specific objectives are reviewing the current PCSCM and finding out how to combine blockchain technology with PCSCM and designing a workflow that contains main steps for establishing the PCSCM framework, which can improve the information sharing, on-time payment and delivery of PCSCM.

This research will contribute to manage the prefabricated construction supply chain. Establish the demand of the existing prefabricated supply couplets management system. The connection between the present prefabricated supply chain management processes with blockchain technology will be clarified to establish a logical prefabricated supply chain management process and framework. In recent years, the proportion of prefabricated structures has increased in the Australian construction industry, and prefabricated structures will be the solution to meet the demand of the construction industry. However, problems in the prefabricated structures supply chain limited the development of the prefabrication industry. The government is looking for ways to solve these problems. We predict that blockchain technology can solve three significant issues in prefabricated structure supply chains due to the nature of blockchain. Because blockchain is essentially a distributed ledger, which can store and transfer information in a secure, non-tempered, traceable and real-time way. Also, blockchain-based smart contracts can automatically process the transaction effectively. More importantly, there is a lack of studies in the field of blockchain applied to supply chains. So, this research will focus on solving the problem and filling the research gap.

2 Literature Review

The prefabricated construction, also known as precast construction, represents a construction method that most construction components are manufactured in a certain location and away from the construction site (Liu et al., 2020). Compared to traditional construction, prefabricated construction has many superiorities, such as flexibility, consistent quality, reduced site disruption, shorter construction time, more safety and environmentally friendly. There are three root causes limit prefabricated construction. First, the manufacture, assembly handling, and moving of prefabricated modular are complicated, and more technical knowledge is required for labours (El-Abidi and Ghazali, 2015). Second, the cost of transportation of prefabricated modular is relatively high and complex compared to standard construction delivery of raw materials because the prefabricated components are usually bulky and hard to be delivered (Jaillon and Poon, 2007). Also, the detour occurs frequently as the road limitation for the vast truck. Third, the current management system for the prefabricated construction supply chain is not advanced enough. Wang et al. (2019) pointed out that the recent research of PCSCM is rare and immature. The first two problems are not related to construction management; therefore, further research on how to optimise the prefabricated construction process is required but will be neglected in this project. More specifically, the PCSCM issues have been inferred by Wang et al. (2020) (1). Information fragmentation. (2). Lack of real-time information. (3). Poor traceability. (4). On-time payment and delivery of prefabricated components. However, the research of integrating blockchain to optimise the PCSCM is rare currently, which indicates the research gap.

2.1 Supply chain management in prefabricated construction

The participants of PCSCM mainly consisted of the supplier of prefabricated components, supplier of delivery service and main contractors that conduct the on-site assembly of prefabricated components (Moon et al., 2015). The general process of prefabricated construction includes the plan, design, raw material transportation, prefabricated, prefabricated components delivery and assembly (Omar et al., 2014). It can be seen that the delivery process plays an essential role in the workflow of prefabricated construction. However, many problems can arise during the logistics process, such as lack of real-time traceability, lack of information sharing, delay in payment and delivery (Wang et al., 2020). As a result, it will be vital to model the framework of prefabricated construction workflow before bringing up further solutions. There are three consecutive tasks been focused on mainly by PCSCM: off-site manufacture, delivery, and on-site assembly of prefabricated modulus, the responsibility of PCSCM are to maximumly cut down the cost within the supply chain (Zhai et al., 2017). Typically, the PCSCM consists of three parties: a prefabricated factory (supplier), a delivery company (supplier) and a construction company (main contractor); the construction company undertake the on-site assembly, the prefabricated company is in charge of the manufacture of prefabricated modulus and the delivery company is responsible for transporting the prefabricated modulus (Jaillon et al. 2009 and Moon et al., 2015). Further, the PCSCM plays a vital role in leading a successful prefabricated construction project as the configuration and arrangement of PCSCM determines whether the expected performance can be achieved (Huang et al., 2005). The PCSCM has not been paid more attention until recent years; it is essentially different from the supply chain management of the manufacturing industry and should be studied individually (Wang et al., 2018). The prefabricated construction supply chain management ability should be high-level since the off-site manufacture and on-site assembly is separate tasks, and the participants should be well managed and coordinated (Han et al., 2017). Enhancing the management ability of the prefabricated construction supply chain is the critical factor to promote the sustainable development of the prefabricated industry (Liu et al., 2020).

Many root causes limit the development of prefabricated construction, include subjective reasons and objective reasons. Wang et al. (2019) and Liu et al. (2020) pointed out that some construction companies refuse to apply prefabricated construction as they do not want to change their workflow to obtain off-the-books income. In an objective aspect, the PCSCM has many issues currently, which may be a barrier to prefabricated construction project performance. More specifically, Liu et al. (2020) stated that the prefabricated components are challenging to store and deliver as they are bulky. Further, the on-site assembly must be on schedule, which requires better management and coordination ability for managers. Technically, the prefabricated components should be maintenance successively without any interruption. Wang et al. (2020) said the information of the prefabricated construction supply chain is fragmented, lack real-time traceability and transparency. In addition, the transaction flow within the prefabricated construction supply chain should be enhanced to ensure a sense of trust and fair among all parties. Schoenwitz et al. (2017) reinforced that although prefabricated construction is an emerging approach, the actual performance is not significantly superior to the traditional construction method since the management ability of PCSCM is weak. Consequently, to let the prefabricated construction be widely adopted, the PCSCM must be optimised.

2.2 Blockchain technology and applications

Satoshi Nakamoto introduced blockchain in 2008 (Nakamoto, 2008). Nakamoto published a paper titled 'Bitcoin: A Peer-to-Peer Electronic Cash System' and developed the first block in 2009, which has since ushered in the Bitcoin era. Bitcoin is the world's first decentralised currency. It is a successful application based on blockchain technology. Blockchain technology allows transactions to occur without a third party (Wang et al., 2017). The three significant features of blockchain in the construction supply chain management field are decentralisation, security and anonymity. Blockchain is an open platform. Therefore, all project participants can access the blockchain. The information displayed in blockchain cannot be edited, deleted or recalled, improving the projects' transparency. Further, data traceability can be achieved during the information sharing process as the blockchain's real-time feature. The use of blockchain can enable enterprises to obtain real-time data and improve data traceability when managing supply chains (Lamb, 2018; Yang et al., 2020). Given the blockchain technology features, it seems feasible to apply blockchain technology to address construction supply chain challenges.

Elghaish et al. (2020) noted that Building Information Modelling (BIM) and blockchain integration could help contracting parties share information securely. Safa et al. (2019) reinforced that the integration of BIM and blockchain technology can improve practicability since blockchain enhances BIM data transparency, and each construction party can track data modification history. Nowadays, the construction industry is experiencing automation and digital innovation to optimise working efficiency and collaboration. Another emerging application to help the construction industry's revolution is the 'blockchain-based smart contract'. Before the concept of the smart contract arose, paper format contracts were used in the construction industry and built trust through reliable intermediaries. However, traditional contracts are expensive due to a third party's hire, which drives people to find a new contracting method without intermediaries' engagement. The earliest smart contract, proposed by Nick Szabo in 1994, is a computer program with auto-execution properties, non-tampered and self-validated (Szabo, 1997). The smart contract comprises functions and state variables, and state variables determine output events regarding logic functions (Bahga and Madisetti, 2016). With the development of blockchain technology in 2008 (Nakamoto, 2008), smart contracts became popular since they could be integrated with blockchain and execute peer-to-peer trends in a secure environment (Mohanta et al., 2018). Das et al. (2020) proposed a blockchain-based smart contract to replace the formal agreement and achieve a safe and transparent auto-payment process. Using smart contracts can increase credibility among all parties and reduce the costs of inviting third parties to participate. Cousins (2018) suggested that once BIM and blockchain are integrated, it can help to incorporate a contract with the BIM system. Consequently, the smart contract can be coded into BIM, and the terms in the contract can be executed automatically.

However, blockchain's cost-saving aspects of various industries may be overestimated (Bloomberg, 2018; Lamb, 2018). Savelyev (2017) stated that smart contracts' costs are not lower than that of ordinary contracts. Still, blockchain remains an emerging concept in the construction management area as construction is an industry with a low digitalisation level.

2.3 Blockchain integration on PCSCM

Blockchain is a distributed ledger technology based on a consensus mechanism. It can also reflect on real-time information; thus, it could introduce blockchain technology to improve supply chain management traceability (Wang et al., 2020; Qian and Papadonikolaki, 2020). Tezel et al. (2020) and Qian and Papadonikolaki (2020) theoretically studied blockchain technology's potential in the construction supply chain management field through expert interviews and data analysis. They noted that blockchain is a significant opportunity to improve the supply chain's trust. Still, it has to be appropriately applied, and blockchain technology will be widely used only if its safety is fully ensured. Beyond the theoretical level, there is some practical research on the blockchain application in supply chain management. Gao et al. (2018) proposed a new supply chain management system called CoC (supply chain on the blockchain) based on a hybrid decentralised ledger, which adopts a novel two-step block building mechanism. Further, an effective storage approach and information defence method were designed to meet supply chain management requirements. Moreover, a prefabricated supply chain management framework concerning blockchain technology (BIMF-PSC) was built by Wang et al. (2020). This model works with a visualised system to provide real-time supply and logistics information. Fitriawijaya and Hsin-Hsuan (2019) proposed applying blockchain to manage the BIM-enabled supply chain. They import supply chain data from BIM into Ethereum, apply the Global Positioning System and Radio Frequency Identification to track supplies and store the real-time information in the blockchain. Consequently, information on the supply chain is real-time and transparent.

Once introducing blockchain technology into the construction supply chain management system, the transmission of supplies can be tracked in real-time. According to Wang et al.'s (2020) research, the on-time delivery of supplies was achieved, and disputes between suppliers and contractors were reduced effectively by implementing blockchain technology into the supply management field. Consequently, blockchain technology can availably integrate fragmented construction supply chain information, laying a solid foundation for the construction industry's digitisation.

Theoretically, blockchain technology can be used for managing fragmented prefabricated supply chain information. However, most studies have not entered proof of concepts. The trial of blockchain application on practical supply chain management is limited, especially in the construction industry. As blockchain is an emerging technology, whether a conservative manager can accept the technology remains an issue (Wang et al., 2020). Further, it will be challenging to integrate huge supply chain information into blockchain and form a comprehensive database since blockchain storage is limited. Wan et al. (2020) noted that one of the most severe barriers limiting blockchain development in construction supply chain management is that different construction parties or firms do not want to share their information due to benefit conflicts. Lastly, once a full-scale supply chain database is built within the blockchain, it will be challenging to prevent the database from revealing and attacking.

2.4 Conceptual framework for blockchain application in PCSCM

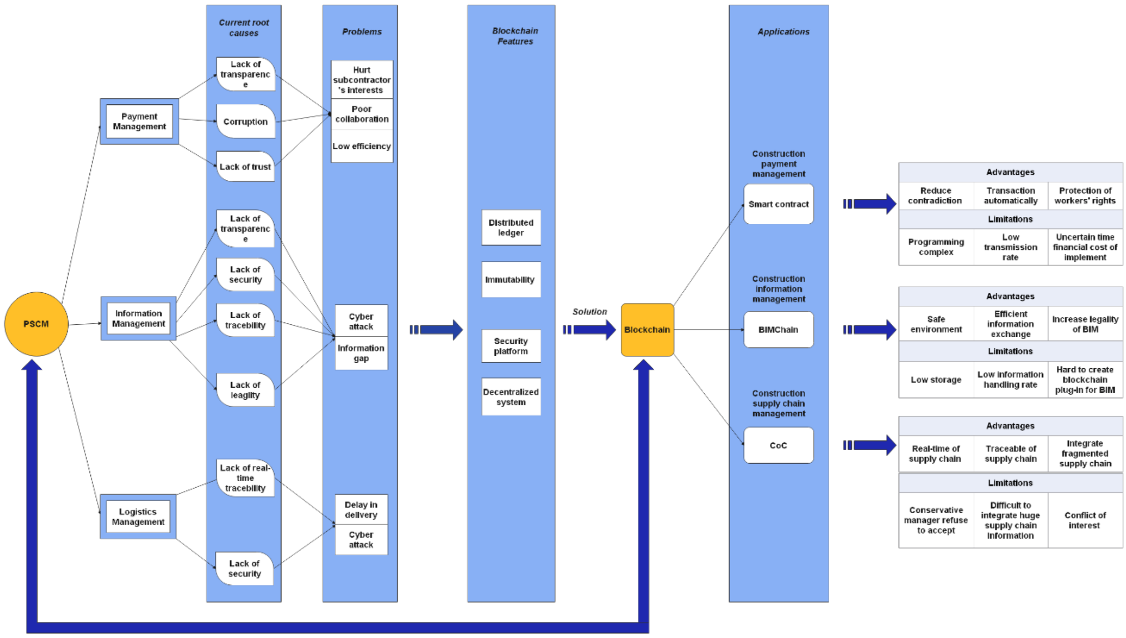

Figure 1. Blockchain integration on PCSCM literature review framework.

This framework represents the thinking and logic in analysing the literature review documents. Its contribution to the knowledge is to clarify what problems can be addressed via blockchain in PCSCM and how to solve them. The current root causes and resulting problems are listed for each management field, representing this study's driving force. Blockchain is a potential solution, given that its features can improve the problems of different management fields. Also, this framework shows three blockchain applications with their advantages and limitations. The prefabricated construction project manager can gain theoretical knowledge of blockchain potentials for improving information sharing and payment management.

3 Research Methodology

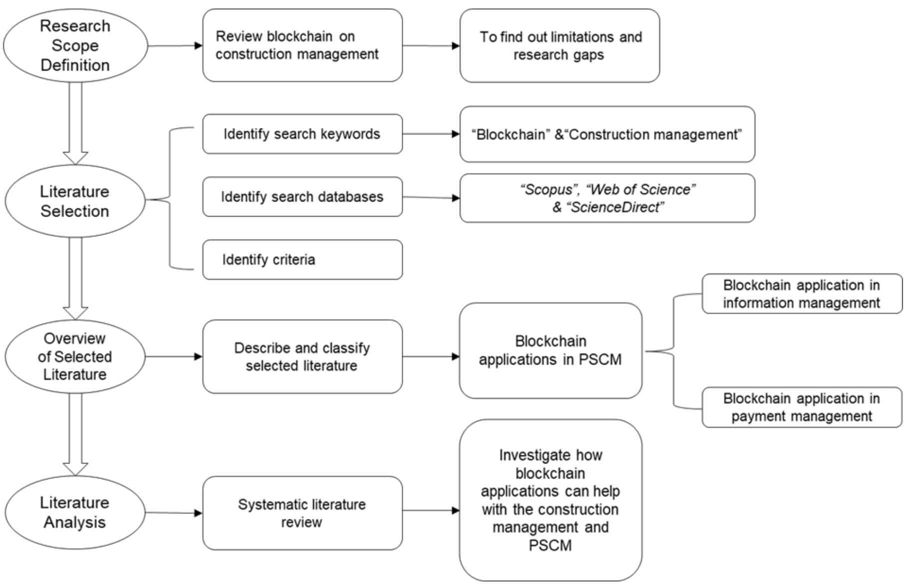

Figure 2. Stage 1 - Systematic literature review.

Conduct the literature review on prefabricated construction, supply chain management, PCSCM and blockchain applications on construction information sharing, payment, and delivery processes. Find out the current research gap, which is applying blockchain to address the problems encountered in PCSCM.

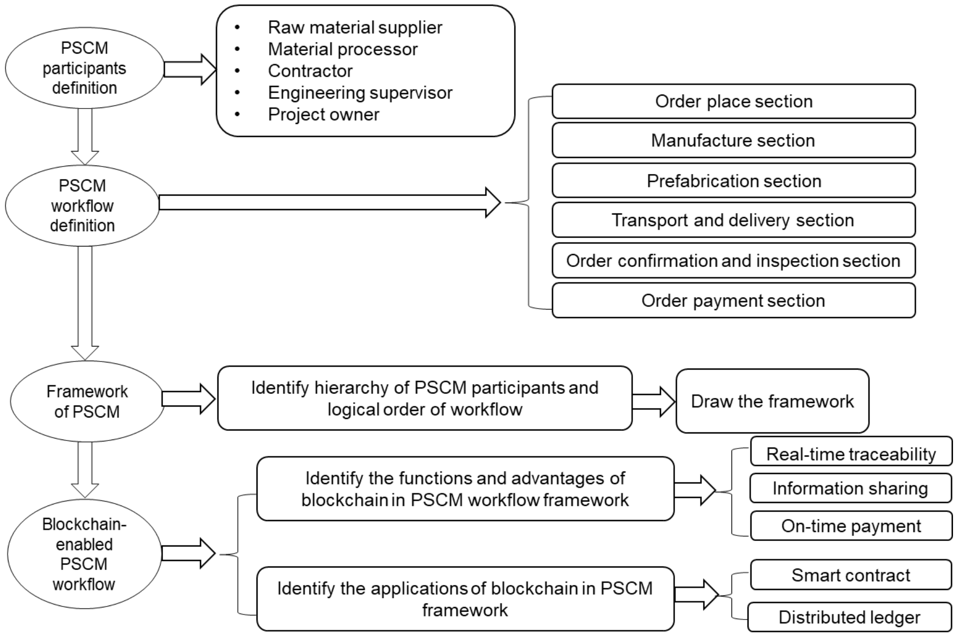

Figure 3. Stage 2 - Blockchain-based PCSCM workflow framework setup.

The framework of integrating PCSCM workflow into blockchain is built in stage 2. This framework indicates the information required to build a blockchain-based PCSCM system and acts as a guideline for utilising the blockchain model. There are two tasks that need to be finalised. First, specify the participants of PCSCM. Second, clarify the workflow of PCSCM.

4 Findings and Discussion

A preliminary framework was developed for the process of the project, which was based on a literature review and combined with the uniqueness and characteristics of this study. After a feasible framework is established, the establishment and development of the project are carried out according to the framework. Later studies will integrate existing enterprise workflows with the framework, building a new framework to make the application more operable. The process of implementing the framework is outlined in the sub-sections below.

As mentioned above, how to integrate blockchain technology into PCSCM is the focus of this study. This study will dig into the application of blockchain technology in supply chain management. It is worth mentioning that the design process is excluded in the PCSCM framework, and the labour (assembly of prefabricated components) is provided by the main contractor. The proposed PCSCM framework has the following scopes:

- Blockchain running sequence and service flow.

- The content and order of work contained in each section.

- Collaboration between blockchain and supply chain

- The scope of the work for the participants in the framework.

- Specific information required for blockchain validation.

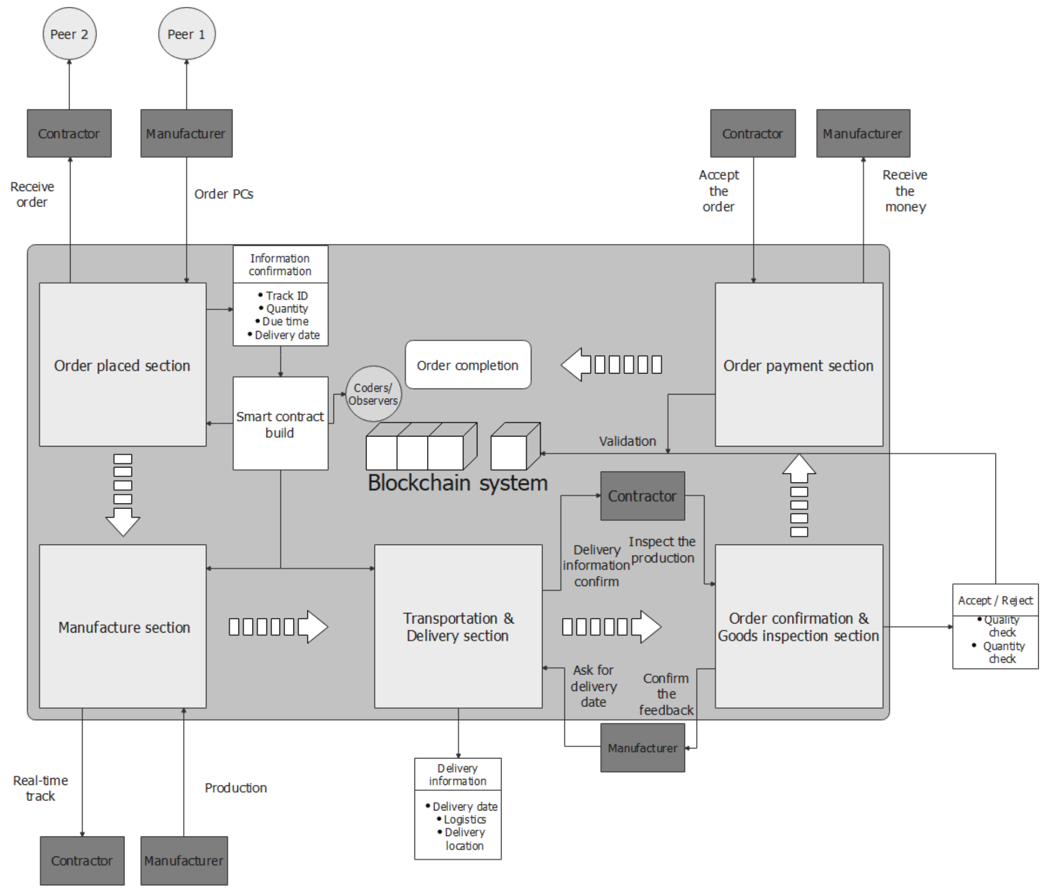

Figure 4. Prefabricated supply chain management framework design.

Stage 1: Order placed section

The contractor puts forward the order to the manufacturer, and both parties sign the contract on the quantity, money, delivery date and delivery quality of the project. Smart contracts are formed by coders who convert written contracts into code that is input into the blockchain. After the smart contract is generated, the coders act as observers to inspect the operation of various aspects of the blockchain. The transaction between the contractors and the manufacturer is performed automatically by a smart contract without the participation of a third party. After the blockchain takes effect, the contractor initiates an order to the manufacturer in the blockchain, and the order is sent to the manufacturer through the blockchain, and the manufacturer checks and confirms the order. Every step will generate a block. All generated blocks cannot be changed or undone. In this step, the customer only needs to send the order in the established framework. The manufacturer only needs to confirm the order. The blockchain automatically validates the order.

Stage 2: Manufacture section

When the manufacturer receives the order, the prefabrication begins in the factory. The information on the prefabrication process will be updated in the blockchain system in real-time. Since it is a private blockchain, only accredited participants can log in to the system to receive real-time information.

Stage 3: Transportation & Delivery section

After the prefabricated component is made, the manufacturer will notify the customer via the blockchain system. And confirm with the customer on the logistics and delivery date. First, the manufacturer initiates a date which the contractor determines. The delivery date is confirmed.

If the customer disagrees with this date, it will refuse. Upon receipt of the rejection, the manufacturer may initiate a new delivery date until a suitable date is confirmed by both parties.

Stage 4: Order confirmation & Prefabricated components inspection section

After the prefabricated components are delivered to the construction place, the contractor will designate personnel to check the quality and quantity of the prefabricated components. If the contractor confirms that the requirements are met, the order will be confirmed in the system and the next stage proceeds. If it does not meet the requirements, the information will be uploaded by the contractor and automatically verified by the blockchain system. According to the verification results, if the order does not meet the requirements, then refuse the order and negotiate according to the contract requirements; If the requirements are met, the contractor's complaint is dismissed and automatically moved to the next stage.

Stage 5: Order payment section

When the contractor confirms the completion of the order, the smart contract automatically transfers the money to the manufacturer's reserved account. The order amount is deposited into the smart contract before the contract is executed, so the payment will be made immediately after the order is completed. Then, the whole order will be completed after this stage.

5 Conclusion

By conducting a systematic literature review about blockchain application on PCSCM, it is found that blockchain is a promising technology to address the lack of information sharing, lack of real-time information traceability issues. There are several research focuses on applying blockchain technology to optimise the information exchange, delivery and payment process and traditional supply chain management system. However, the research of integrating blockchain applications with prefabricated supply chain management is still a gap.

In future research, the approaches of applying blockchain to integrate information and manage contracts will be determined. A blockchain-enabled model will be set to optimise the PCSCM system. There are a few tasks that will be conducting in the future. Firstly, select the most appropriate blockchain platform for PCSCM. Secondly, determine the programming language of the selected blockchain platform. Thirdly, identify blockchain protocols as the principle to simulate the blockchain model. Finally, define the consensus algorithm of the coding process. Through these four tasks, the structure of the blockchain-enabled model can be set. The blockchain-enabled model in PCSCM is going to be validated by cooperating with industries or companies. An interview will be carried out to collect data information of an actual PCSCM project as input to the blockchain-enabled PCSCM model. Furthermore, the case study will prove that the proposed blockchain model can improve efficiency and eliminate the current problems of PCSCM. Also, optimisation of the blockchain-enabled model is carried out in terms of user experience.

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