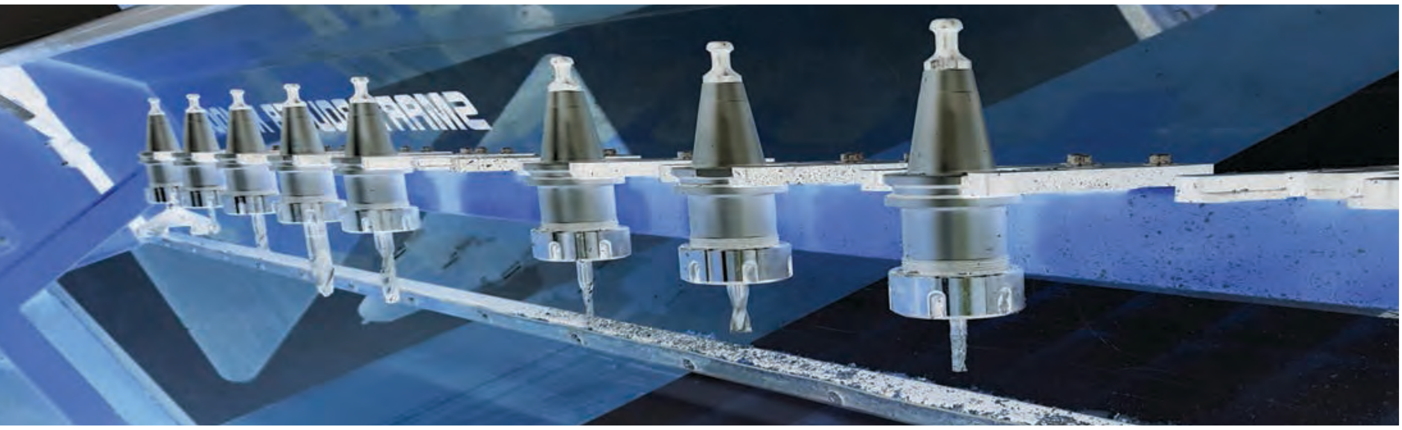
UNIVERSITY OF TECHNOLOGY SYDNEY

FACULTY OF DESIGN / ARCHITECTURE / BUILDING



DIGITAL FABRICATION

SCOPING REPORT 2017

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1.0_EXECUTIVE SUMMARY

Manufacturing, whether medium or high tech, must incorporate new thinking around creativity, design integration together with other aspects of integrated innovation, business analytics and the customer experience.

(Green and Roos, 2012 p. 3)

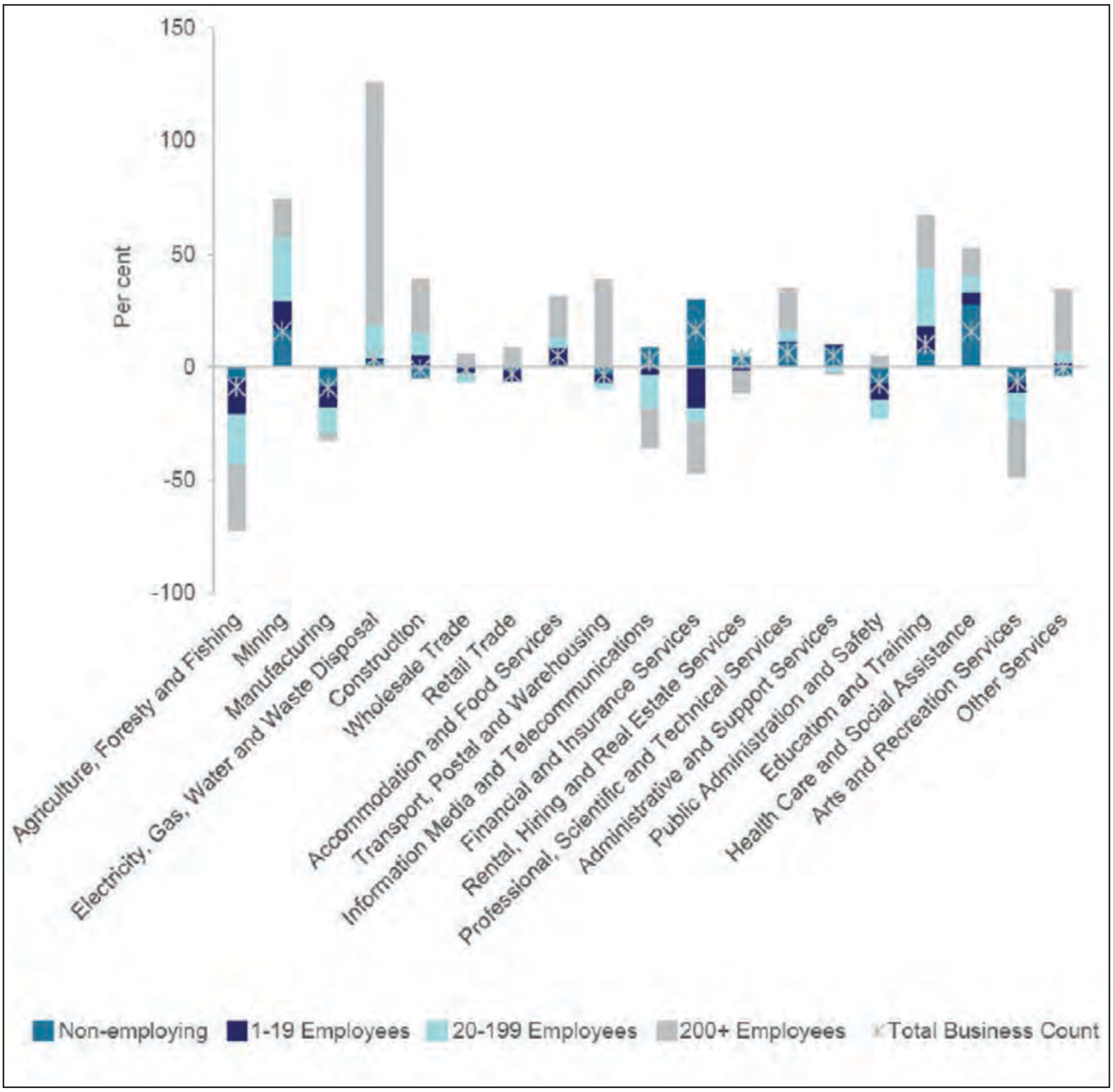
This scoping document gives an overview of the current status of Australian advanced manufacturing. It reveals that cross-sector design industries of architecture and engineering currently have a low level of international globalisation and that Australia does not have a competitive advantage in this industry sector, with foreign ownership increasing rapidly. Within the engineering space, it shows that Australia is at a particular disadvantage, with advancements in communications and design technologies over the past decade facilitating the provision of consulting services from remote (low cost) locations.

The report also reveals that the construction sector is increasingly global. Australia's proximity to Asia provides an opportunity for companies to increase their market in this sector, however, currently Australia does not have a competitive advantage. Other developed nations are already further advanced in their adoption of building information modelling. A lack of training in, and uptake of, new technologies that are widely adopted elsewhere, a lack of innovation in procurement practices, and the failure to move to the onsite assembly of prefabricated components, are now hindering the Australian construction industry's ability to compete internationally.

Collaboration with research institutions is found to assist industry to adapt to the rapidly changing technological environment. The most successful, leading insitiutional research centres are characterised by multiple indusrtry partnerships. Depending upon their size, these institutions either pursue diverse research themes, as in the case of the larger centres, or the limitations of being a smaller competitor are offset through high-end innovative and targeted specialisation.

Funding for research instituions has recently been augmented through the Australian Government's National Innovation And Science Agenda and Industry 4.0 Taskforce. Industry-linked institutional projects are the focus of a range of agile, fast process grant schemes that enable university innovators to collaborate productively in ongoing business partnerships.

Drawing upon a SWOT analysis that focuses upon the bespoke characertisics of the DAB Digital Fabrication Research Group within the current economic context, the document outlines a group plan that synthesises this data into a strategic forward pathway. This pathway is based on the interplay of key themes of brand, stakeholder management, interdisciplinary collaboration and funding resources. It proposes that the curation and application of these themes within specific timeframes will provide the group the capacity to achieve international competitiveness and, in so doing, position UTS at the forefront of this field.



(Swanepoel and Harrison, 2015)

Figure 1: Growth in business counts by firm size class by industry June 2007 to June 2012, per cent

2.0_AUSTRALIAN MANUFACTURING & CONSTRUCTION

The most distinctive feature of Australian manufacturing is its changing role in the Australian economy. In the 1960s, manufacturing accounted for one in every four dollars of nominal gross domestic product. By the early twenty-first century, this had diminished to one in eight, and looks set to decline further as the services sector continues to expand. The direct contribution of manufacturing to today's economy is roughly on a par with its relative share in 1901.

(“Trends in Australian Manufacturing”, p. xix)

2.1_SUMMARY

DECLINE

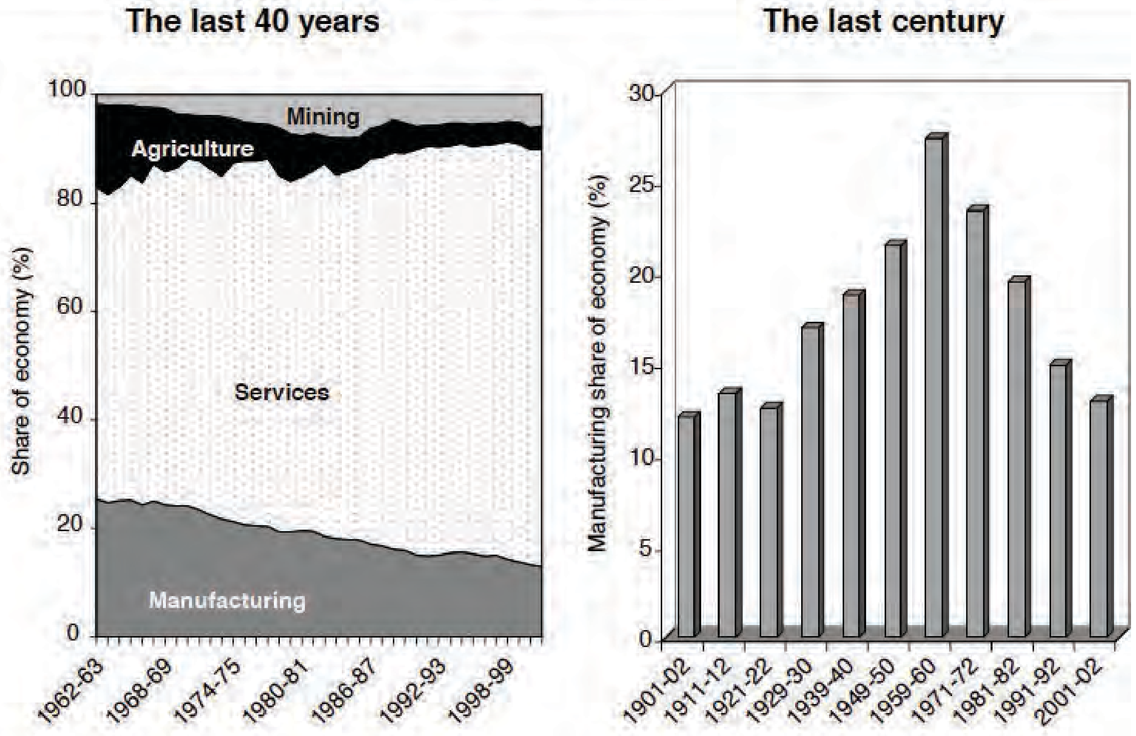
The Australian manufacturing sector has declined over the last forty years due to a higher demand for services as incomes rise; the outsourcing of manufacturing with the high cost of labour; and a fall in the regional dependence on manufacturing. Productivity growth in manufacturing has now stalled, leading to a structural deterioration of the economy. The November 2016 Australian Construction Industry Forum projects a 6% fall in overall building and construction activity. Australia is losing ground to comparable countries and further reforms are needed to boost Australia's productivity levels.

SOLUTIONS

Technological knowledge accumulation has become increasingly important across all sectors of the Australian economy.Manufacturing is increasingly globally oriented with a potential to tap into Asian markets. Also the prefabrication industry has a great opportunity to take advantage of the skills of the automotive sector.

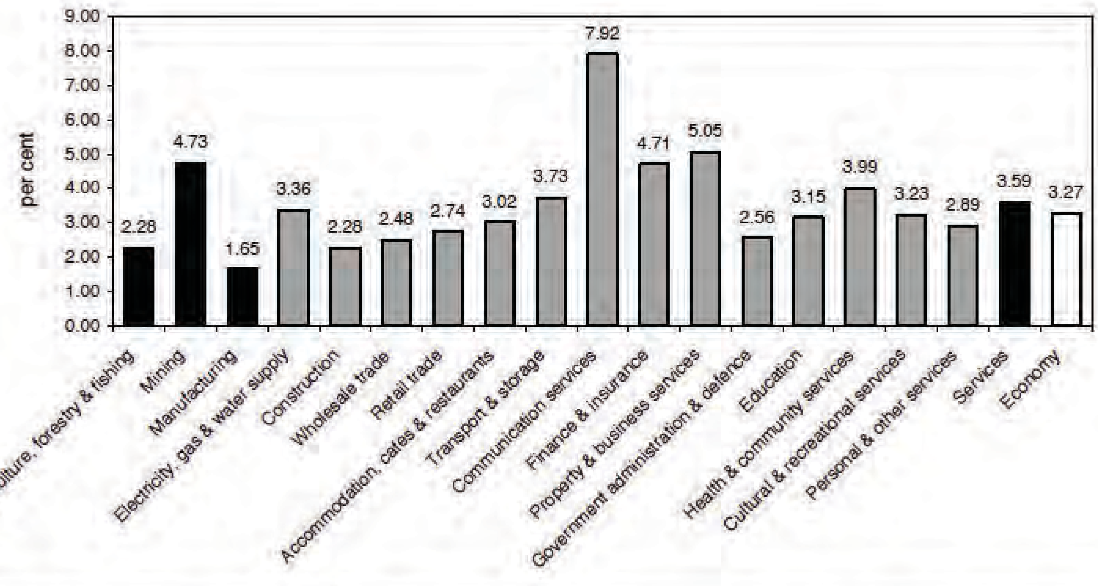
The Australian manufacturing sector will continue to face pressures for change. Its ability to respond to these pressures will determine its future contribution to economic growth.

Manufacturing has declined



Relative growth rates among Australian industries

1974-75 to 2001-02[a]



[a] Annual trend rates of growth over the period were estimated by regressing log real value added against a constant and a time trend. Gross product was measured in constant 2000-01 prices.

Data source: ABS (*Australian System of National Accounts, 2001-02,* Cat. No. 5204.0).

Figure 2: The relative decline and growth of Australian Industries, 1974-2002

2.2_THE DECLINE IN AUSTRALIAN MANUFACTURING

'The most evident symptom of so-called 'deindustrialisation' is the waning importance of manufacturing as an employer… It is certainly the case that the share of total employment accounted for by manufacturing in Australia has fallen markedly over the last forty years — from over one-quarter of employment in 1966-6710 to around 12 per cent in 2001-02.'

("Trends in Australian Manufacturing", p. 32)

KEY POINTS

- There has been a steady decline in Australian manufacturing since the mid 1970's. Productivity growth has now stalled, which amounts to a structural deterioration of the economy behind the substantial gains from the mining boom. Some services once categorised as part of manufacturing have been outsourced and regional dependence on manufacturing has fallen.

- Manufacturing is increasingly globally oriented. Technological knowledge accumulation has become increasingly important across all sectors of the Australian economy over the past 25 years with mining and manufacturing exhibiting the highest growth rates in R&D. Australia has a larger presence in sectors classified as low and medium-low technology

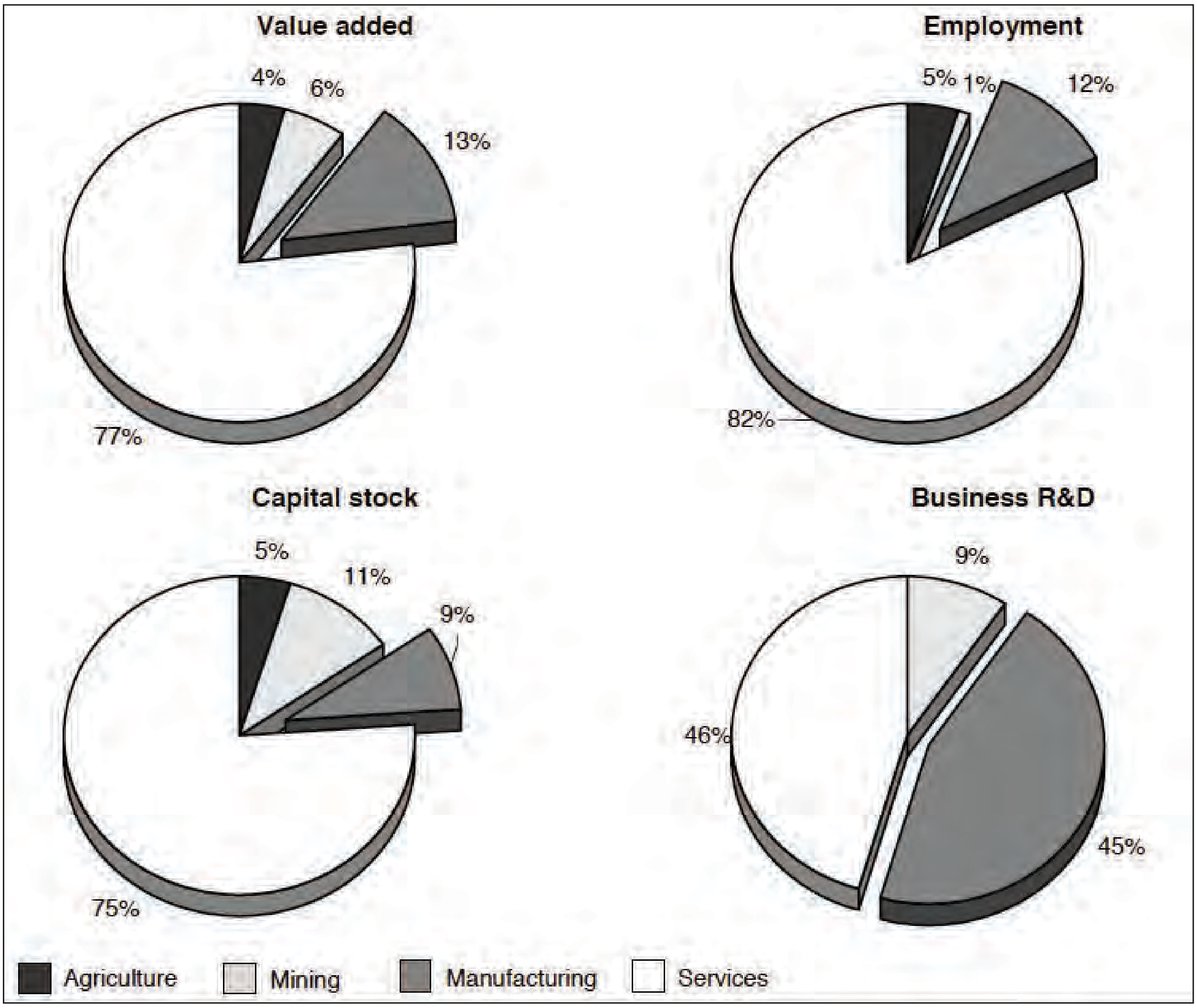


Figure 3: Sectoral contribution of manufacturing to Australian economic activity, 2001-02

2.2.1_MANUFACTURING PRODUCTIVITY 2000

‘The most evident symptom of so-called ‘deindustrialisation’ is the waning importance of manufacturing as an employer… It is certainly the case that the share of total employment accounted for by manufacturing in Australia has fallen markedly over the last forty years — from over one-quarter of employment in 1966-6710 to around 12 per cent in 2001-02.’

(“Trends in Australian Manufacturing”, p. 32)

KEY POINTS

- Manufacturing growth, while strong, has not matched that of the services sector.

- The decline in manufacturing has several causes and implications:
  - Australians’ preference for services as incomes rise.
  - Some services once categorised as part of manufacturing have been outsourced.
  - Regional dependence on manufacturing has fallen.

- Manufacturing is increasingly globally oriented. Exports increased from just over 15 per cent of manufacturing output in 1989-90 to around 24 per cent in 1999-2000.

- Growing R&D intensities reveal that technological knowledge accumulation has become increasingly important across all sectors of the Australian economy over the past 25 years. Mining and manufacturing have exhibited the highest growth rates in R&D.

(Based on Commission Research Paper released on 28 August 2003
(“Trends in Australian Manufacturing”Australian Govt, 2003)

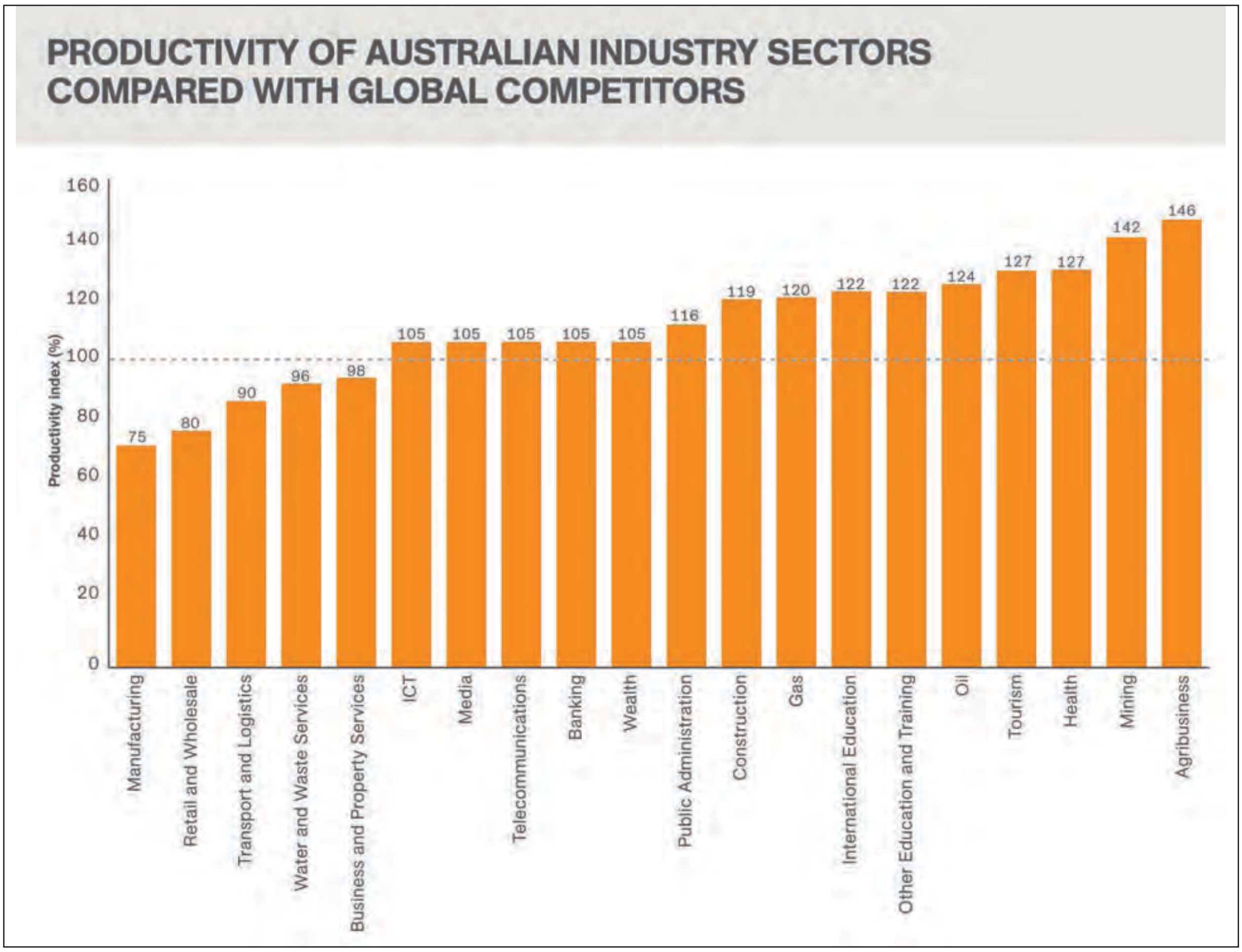


Figure 4: Productivity of Australian Industry Sectors

2.2.2_MANUFACTURING PRODUCTIVITY 2017

‘Productivity growth is a key source of long-term economic growth, business competitiveness and real per capita income growth. It is an important determinant of a country’s living standards and wellbeing.’

(Source: PC Productivity Update April 2016)

KEY POINTS

- Australian manufacturing developed over the 20th century behind tariff protection which promoted infant industries and domestic employment but ultimately stifled innovation and productivity enhancement.

- Productivity growth has now stalled, including in manufacturing, which amounts to a structural deterioration of the economy behind the substantial gains from the mining boom.

- Manufacturing is still predominantly low and medium tech and has more recently encompassed a small high tech sector in ICT and medical technologies.

- Australia is losing ground to comparable countries such as the United States and further reforms are needed to boost Australia’s productivity levels.

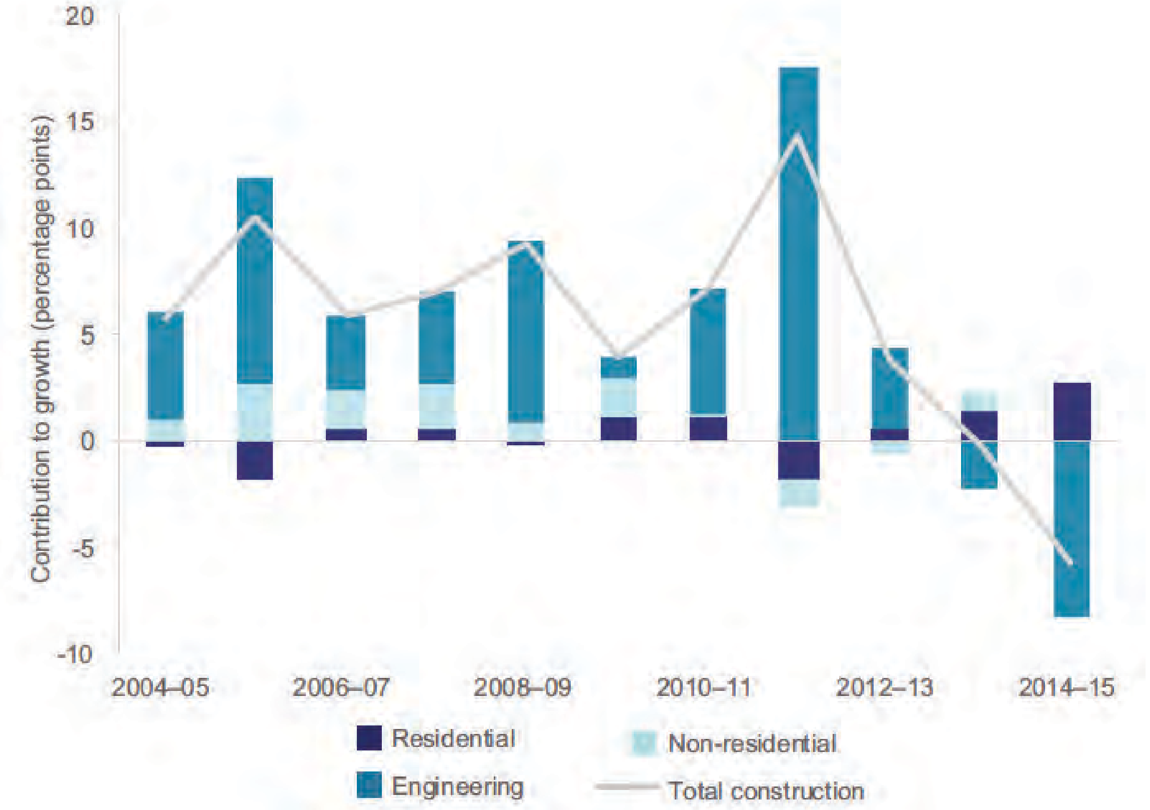
- Australia has a larger presence in sectors classified as low and medium-low technology

(Report of the Non-Government Members, 2012)

Left:

Note: A score of 110 means Australia is 10% more productive than the average productivity of global competitors in the industry.

Sources: Deloitte Access Economics analysis, 2015. Based on data provided in The Conference Board Total Economy Database™, May 2015; Austrade



Source: Thomson Reuters DataStream; ABS cat. no. 8755.0, table 1; ABS cat. no. 8762.0, table 1

Figure 5: Contributions to growth in total construction work, 2005-2015

2.3_THE DECLINE IN AUSTRALIAN CONSTRUCTION

‘Productivity growth is a key source of long-term economic growth, business competitiveness and real per capita income growth. It is an important determinant of a country’s living standards and wellbeing.’

(Source: PC Productivity Update April 2016)

SUMMARY

Activity in the construction sector can be divided into three broad areas: engineering construction, residential building, and non-residential building.

Building construction as a share of total work done in construction fell to an historical low of 38.3% in 2012, followed by an upturn in 2013 and 2014. Engineering construction activity fell by 14.2 per cent in 2014–15, the largest decline since the start of the statistical series. However, residential building activity has been on the rise. Residential building work increased by 10.6 per cent in 2014–15 supported by record low interest rates and high property prices.

Supporting sectors of architecture, engineering and mapping provide a higher proportion of industry value as a percentage of revenue in comparison to the construction sector.

(Australian Industry Report, 2015 “Australian Industry Report 2015”

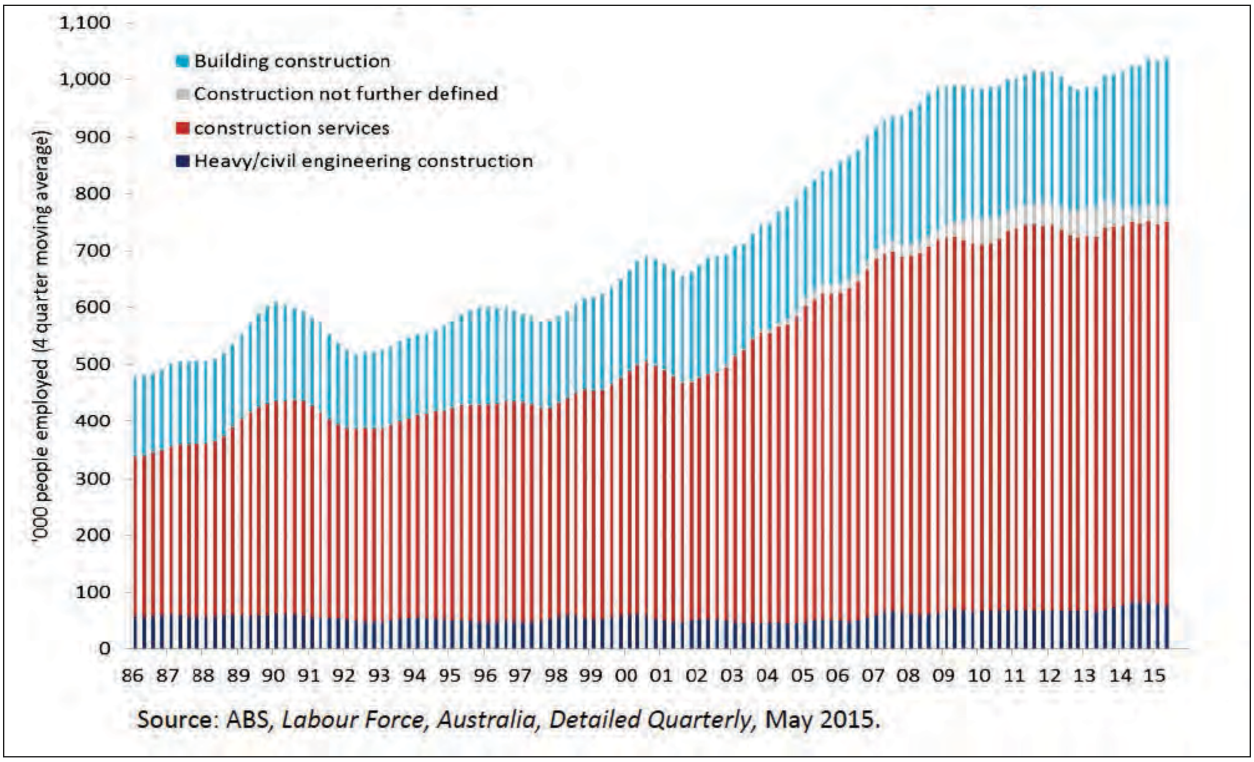


Figure 6: Persons employed in construction by major sector

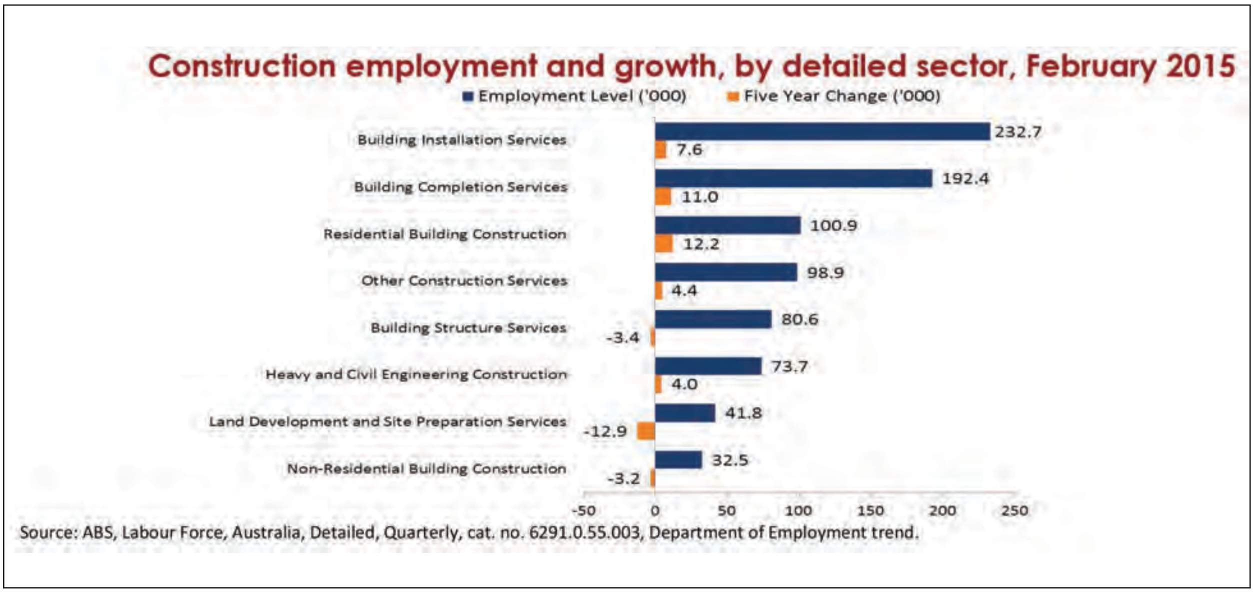


Figure 7: Persons employed in construction by detailed sector

2.3.1_CONSTRUCTION INDUSTRY DELIVERY METHODS

CONSTRUCT ONLY

The most commonly used delivery model for the delivery of infrastructure projects in Australia. Under this model, the design and construction stages are undertaken completely separately, with the project owner preparing the design either in-house or using consultant resources, and a contractor subsequently being engaged to construct the works in line with an agreed program, pre-existing design and other project documentation. This type of model is typically used for both 'minor works' and straightforward 'major works' projects.

DESIGN + CONSTRUCT

Under this delivery model, a contractor is engaged to both design and construct the project works, based on a design brief supplied by the project owner. The contractor either uses in-house design resources to prepare the design or bids as part of a consortium that includes external designers.

CONSTRUCTION MANAGEMENT

Normally used for the construction of buildings, this model involves the project owner engaging the designer and trade contractors directly, whilst also engaging a construction manager to act as its agent and manage the delivery of the construction works on its behalf. The construction manager usually either receives a time-based fee, or is paid a percentage of the cost of the works.

MANAGING CONTRACTOR

Normally used for the construction of large complex buildings, this relationship-style delivery model, based on collaborative principles, involves a head contractor being engaged as the 'managing contractor' to manage the development of the design, coordinate production of construction documentation, enter into contracts and manage the delivery of the works on behalf of the project owner.

Figure 8: Main employing occupations in the construction industry

DIRECT MANAGED

This delivery model involves the project owner directly managing the full delivery of the project works. Under this model, the project owner typically:

- undertakes and coordinates some of the design activities
- is responsible for all preliminaries (e.g. crane hire, site sheds and supervision services) and project management (e.g. scheduling, coordinating, liaising, monitoring and reporting)
- prepares the trade packages, conducts the tenders and selects and pays suppliers and subcontractors
- has control over the quality requirements of the whole of the works.

ECI

ECI is a two-stage relationship-style delivery model generally structured to resemble a project alliance model during the first stage of the contractual arrangement and a D&C model during the second.

ALLIANCE

This arrangement brings together the project owner and one or more non-owner participants or 'NOPs' to work collaboratively to deliver the project, sharing project risks and rewards. It is often used for highly complex projects with uncertain risk profiles that would be difficult to effectively scope, price and deliver under a more traditional delivery model.

PPPs.

PPP delivery models embrace a range of structures and concepts that involve the allocation of risks and responsibilities between the public and private sectors. Typically in a PPP delivery model, a concession makes the private sector operator (concessionaire) responsible for the full delivery of services in a specified area including operation, maintenance, collection, management, construction and rehabilitation of the system. Importantly, the operator is now responsible for all capital investment.

Figure 9: Projected employment growth by construction indusrty sector - five years to 2019

2.3.2_FUTURE GROWTH IN CONSTRUCTION

KEY POINTS

- Manufacturing investment in buildings, structures, plant and equipment is expected to be 5.6% p.a. lower in 2014-15 and 21% p.a. lower in 2015-16, as the demise of the automotive sector and other factors weigh on local manufacturers' investment and expansion plans.
  (Australia's Construction Industry: Profile and Outlook. July 2015, p. 9)

- The November 2016 Australian Construction Industry Forum projects a 6% fall in overall building and construction activity from $220 billion in 2015-16 to $207 billion.

- The availability of capital to finance greater investment will be important to the growth of the manufacturing industry. The recent deregulation of capital markets, in tandem with government-sponsored venture capital schemes, is expected to diversify the range of finance available for potentially profitable investments. The Australian manufacturing sector will continue to face pressures for change. Its ability to respond to these pressures will determine its future contribution to economic growth.

- The Heavy and Civil Engineering Construction sector is projected to record a decline over the five years to November 2019.

2014/15 contracts won, by type of work, $ million								
Rank	Company	Civil Engineering	Commercial	Community	Flats & Units	Industrial	Mining	Grand Total
1	Brookfield Multiplex Constructions	$0	$2,364	$1,991	$1,746	$0	$0	$6,100
2	Laing O'Rourke Australia	$5,081	$273	$340	$0	$325	$0	$6,019
3	John Holland Pty Ltd	$2,690	$166	$704	$0	$159	$0	$3,719
4	Probuild Constructions (Aust) Pty Ltd	$10	$662	$0	$1,602	$0	$0	$2,274
5	BGC (Australia) Pty Ltd	$21	$779	$117	$323	$77	$587	$1,904
6	ADCO Constructions Pty Ltd	$0	$603	$606	$0	$105	$0	$1,314
7	Hutchison Builders Pty Ltd	$21	$341	$224	$572	$16	$0	$1,175
8	Parkview Group (Australia) Pty Ltd	$0	$125	$0	$977	$0	$0	$1,102
9	Hansen Yuncken Pty Ltd	$14	$264	$447	$0	$351	$0	$1,076
10	Mirvac Group	$42	$226	$0	$760	$0	$0	$1,028
11	Built Pty Ltd	$0	$734	$109	$105	$2	$0	$949
12	Downer EDI Works	$442	$14	$0	$0	$0	$480	$937
13	Icon Construction Australia	$0	$76	$43	$770	$0	$0	$889
14	BMD Construction Pty Ltd	$812	$4	$0	$0	$0	$0	$816
15	Kane Constructions Pty Ltd	$13	$54	$573	$45	$109	$0	$793
16	Watpac Constructions Pty Ltd	$10	$62	$408	$199	$18	$86	$783
17	Richard Crookes Constructions Pty Ltd	$0	$14	$153	$527	$65	$0	$759
18	Fulton Hogan Pty Ltd	$640	$0	$50	$0	$10	$0	$700
19	Cockram Construction	$42	$21	$306	$0	$282	$0	$650
20	Pindan Contracting Pty Ltd	$2	$51	$183	$369	$0	$0	$605
Source: HIA Cordell Construction 100 2014/15								

Figure 10: Largest 20 non-residential builders and contractors

2.3.3_STATE OF BUSINESS COMPETITION IN THE CONSTRUCTION MARKET

KEY POINTS

- o A strong expected growth path with the a potential to tap into the Asian markets

- o Industry value added output in the construction and built environment sector is estimated to reach approximately $169bn in FY13. This represents approximately 45 per cent of total industry revenue and is forecast to increase to approximately $187bn by FY18. Supporting sectors of architecture, engineering and mapping provide a higher proportion of industry value as a percentage of revenue in comparison to the construction sector.

- o Exports are estimated to reach approximately $3.2bn in FY13. The largest contributors were construction and engineering consultancy each with $1.4bn. Exports are forecast to grow by approximately 18 per cent by FY18 to$3.75bn. Exports represent less than 1 per cent of industry revenue…Exports are led by key industry players and are focused on construction management services and engineering consultancy services.

(Industry Sectors: Analysis and Forecasting, p. 17)

o Six Australian practices made the world’s top 100 architecture firms of 2015.

- Woods Bagot
- HBO+EMTB
- Cox Architecture
- The Buchan Group
- ThomsonAdsett
- Hayball
- DWP|Suters

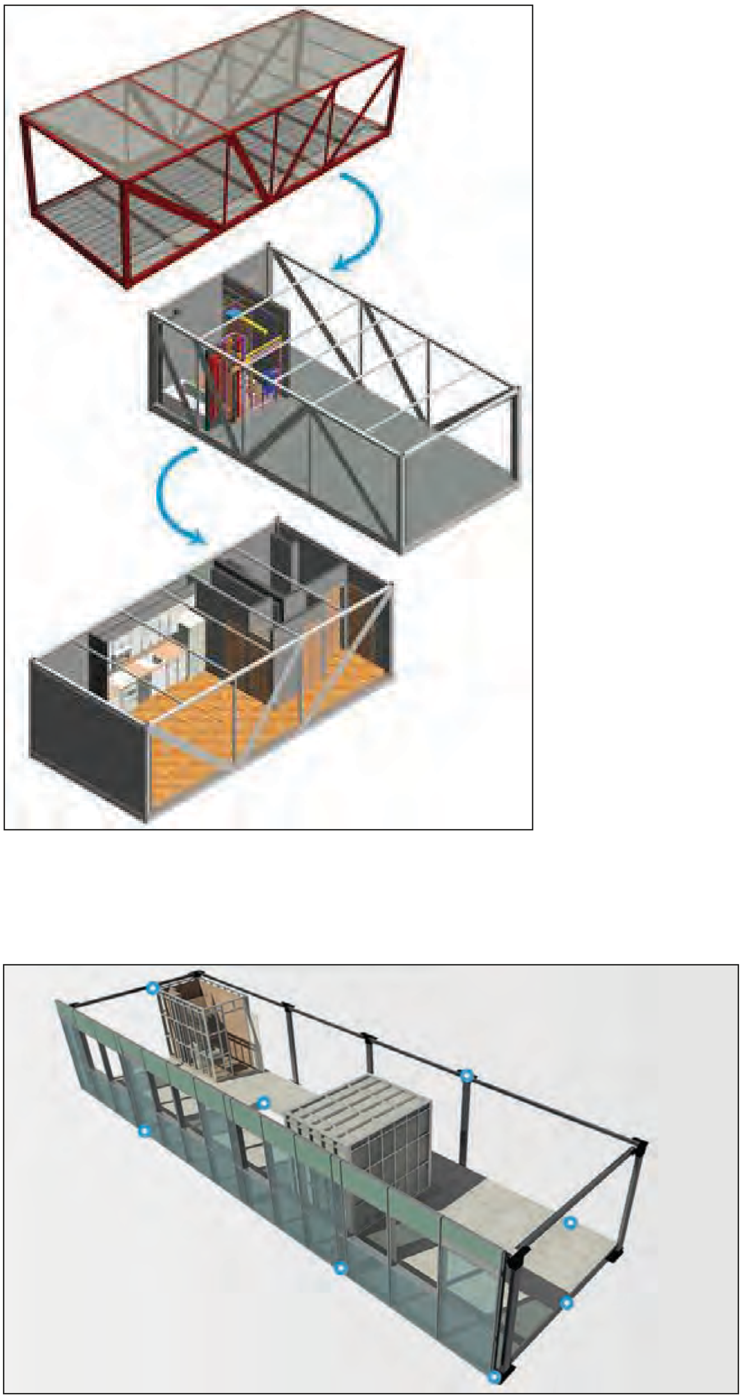


Figure 11: The Hickory Building System Module

2.3.4_PREFABRICATION TREND WITHIN THE AUSTRALIAN BUILDING INDUSTRY

‘Inevitably, the boundaries between manufacturing and other sectors are sometimes blurred, as they may also involve significant transformation of goods…the construction industry transforms raw materials — concrete, metal, wood and wire — into buildings. But since, for the most part, these are made at the site where the output will be used, they are not regarded as part of manufacturing. In contrast, pre-fabricated buildings that are factory-made and transported to a site are included as part of manufacturing. Despite these new industry agglomerations, most statistical data in Australia and other advanced economies are still collected on the basis of traditional industry classes.’

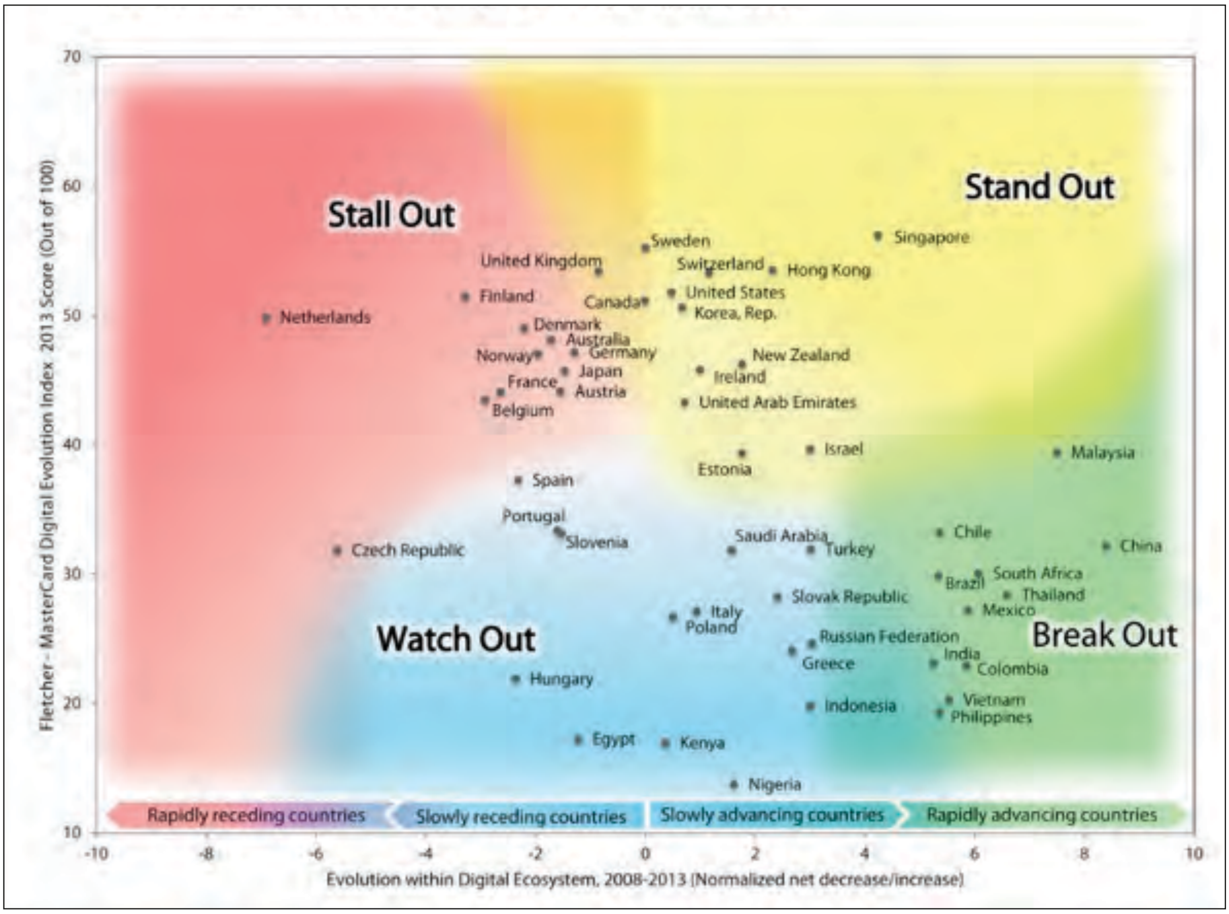
(“Trends in Australian Manufacturing”pp. 3-4)

The recent META PrefabAUS Housing Hub study reveals that prefabrication accounts for only three per cent of housing construction in Australia.

The prefabrication industry has a great opportunity to take advantage of the skills of the automotive sector. The automotive industry could help the prefab industry expand manufacturing plants, utilise new materials and systems, improve assembly lines, and develop automated plant technology that makes off-site construction more efficient.

- construction waste could be reduced by up to 90%
- thermal performance could be increased by over 30%
- neighbourhood disruption, traffic and noise could be reduced by up to 90%
- reduction of energy and water could be used across a project site, with a reduced overall carbon footprint.
- Hickory Building Systems uses innovative, patented structural systems to deliver high-rise construction projects up to 50% faster - reducing construction and financing costs and increasing safety and sustainability.

(http://www.hickory.com.au/what-we-do/#prefabricated-building-systems)



(https://sourceable.net/australia-falling-behind-in-bim-implementation/)

Figure 12: The global implementation of BIM 2008-13

2.3.5_THE STATUS OF BIM IN AUSTRALIA

The purpose of research undertaken by the IBGC in the USA was to create a Digital Evolution Index (DEI) that ranks these 50 nations in relation to their progress or decline in their own journey and evolution into the digital economy. Australia, sits within the category of “Stall Out” – a nation that has previously advanced rapidly only to recently stall or decline in its digital evolution.

- The Australasian Chapter of buildingSMART advocates that “the Australian economy could be better off by as much as $7.6 billion over the next decade by adopting the NBI recommendations.”

Following a report by the Standing Committee on Infrastructure, Transport and Cities released in March 2016 (Report), the Australian Government has become a promoter of BIM within the construction industry. The Report makes ten recommendations, based on the premise that new technologies are transformational and have the capacity to increase productivity in our economy. BIM-specific recommendations of the Report include:

- Recommendation 6 – The Australian Government to form a smart infrastructure task force led by Infrastructure Australia (modelled on the UK BIM Task Group) to act as a coordinator and conduit for the development and implementation of BIM policy nationally. This would include development of industry and product standards, as well as training and education on BIM.

- **Recommendation 7** – The Australian Government require BIM to LOD500 on all infrastructure projects exceeding $50 million in cost receiving Australian Government funding, focusing on tendering mechanisms to facilitate this outcome with an eventual goal of establishing BIM as a procurement standard.

However, the Australian Government has elected not to mandate the use of BIM in Commonwealth funded infrastructure projects, preferring a gradual approach to BIM implementation. State governments across Australia have adopted a similar position. However, the Australian Department of Defence has emerged at the forefront of efforts to incorporate BIM at the Federal procurement level, using BIM to enhance the development and operation of its assets.

Successful Australian projects that have used elements of BIM include:

- Royal Adelaide Hospital Project;
- Moorebank Intermodal Terminal Project;
- Barangaroo development, including Wynyard Walk;
- North West Rail Link;
- Southern Freight Link; Figure 1: BIM and its participants
- Regional Rail Link Victoria;
- South West Rail Link;
- Auburn Stabling Yard;
- New Generation Rolling Stock Stabling, Ipswich;
- Sydney CBD light rail early works;
- Perth Children's Hospital;
- Perth Stadium; and
- Perth Museum.

The UK Cabinet Office BIM Strategy Paper (2011) sets out some of the main benefits of using BIM in the procurement of infrastructure

- 20% reduction in build costs;
- 33% reduction in costs over the lifetime of the asset;
- 47% to 65% reduction in conflicts and re-work during construction;
- 44% to 59% increase in overall project quality;
- 35% to 43% reduction in risk, improved predictability;
- 34% to 40% better performing completed infrastructure; and
- 32% to 38% improvement in review and approval cycles.

("What You Need to Know About Bim in Australia", 2016)

2.3.6_LABOUR

Cross-sector design workplace labour statistics

- o Employment is expected to grow at very low rates or even decline in some sub-sectors (architecture, engineering and specialised design firms)

Construction workplace labour statistics

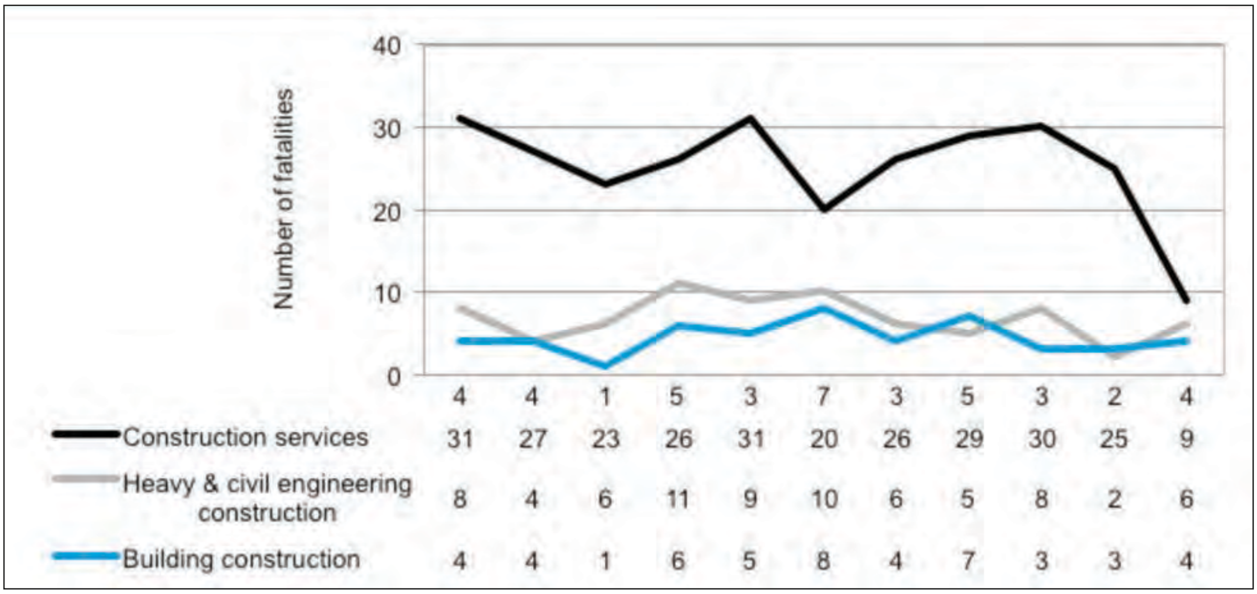
- o Construction provides 8.8% of the national workforce
- o Total employment is forecast to increase by almost 10% between FY13 and FY18

(Industry Sectors: Analysis and Forecasting, p. 15)

Construction labour breakdown (percentage)

- o 65% of construction workers are employed in trade services
- o 26% are in building construction
- o 7% are in heavy and civil construction
- o 2.5% are in general construction services

(Source: ABS, Labour Force Survey, four quarter average, custom data request, 2014)



(http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/fs2010manufacturinginformationsheet)

Figure 13: Fatalities by industry sector, 2003-13

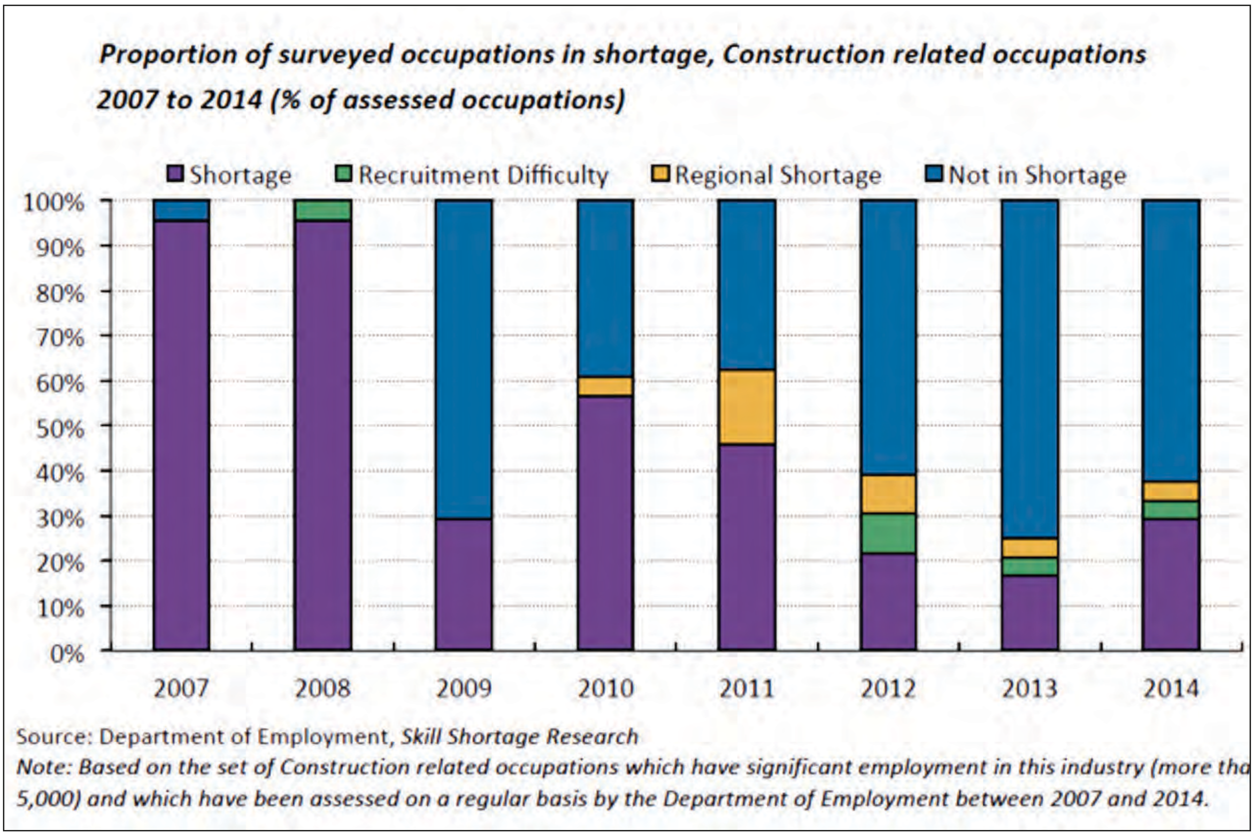


Figure 14: The proportion of construction occupations in shortage, 2007-14

Fatalities by industry sector 2003 to 2013

- 69% of fatalities in the construction industry involved workers in the construction services industry sub-division. The remainder involved workers in heavy & civil engineering construction (19%) and building construction (12%).

Statistics showing availability of labour workforce

Five of the 10 Construction Trades are in national shortage

- Bricklayer
- Stonemason
- Solid Plasterer
- Roof Tiler
- Wall and Floor Tiler

Average construction costs /m2 or m3 in Australia

Construction Type			
Commercial	**Low**	**Medium**	**High**
1-4 level open plan offices, including A/C & lifts, excluding fit out	$1,890	$2,150	$2,590
4-8 level open plan offices, including A/C & lifts, excluding fit out	$2,050	$2,240	$2,720
8 levels and over, including A/C & lifts, excluding fit out	$2,960	$3,170	$3,350
Industrial	**Low**	**Medium**	**High**
High Bay Warehouse, standard config, concrete floor, metal clad	$920	$1,040	$1,130
High Bay Warehouse, standard config, concrete floor, pre-cast concrete wall clad	$1,140	$1,210	$1,360
Retail	**Low**	**Medium**	**High**
Suburban shopping mall area including A/C	$2,280	$2,400	$2,750
Supermarket, including A/C, excluding fit out	$1,470	$1,590	$1,820
Hotels-Motels	**Low**	**Medium**	**High**
Single level boutique motel, including A/C, guest facilities	$3,000	$3,500	$4,750
Single level tavern/hotel, including A/C, excluding loose item fit out	$2,550	$3,100	$3,800

(https://www.bmtqs.com.au/construction-cost-table)

Figure 15: Average construction costs/m^2 or m^3 in Australia

2.3.7_REGULATION

CONSTRUCTION PERMITS IN AUSTRALIA

Procedure

- Verify if a development application is required – 1 day
- File development application with consent authority – 60 days
- Apply for a construction certificate – 21 days
- Apply for approval of building/development plans by Sydney Water Quick Check Agent – 1 day
- Notify City Council of Commencement of work and appoint City Council as PCA – I day
- Receive the commencement of building work inspection – 1 day
- Request and receive connection to water and sewage services – 10 days
- Request the occupation certificate – 1 day
- Receive final inspection by PCA and obtain the final occupation certificate (OC) – 15 days

(http://www.doingbusiness.org/data/exploreeconomies/australia/dealing-with-construction-permits)

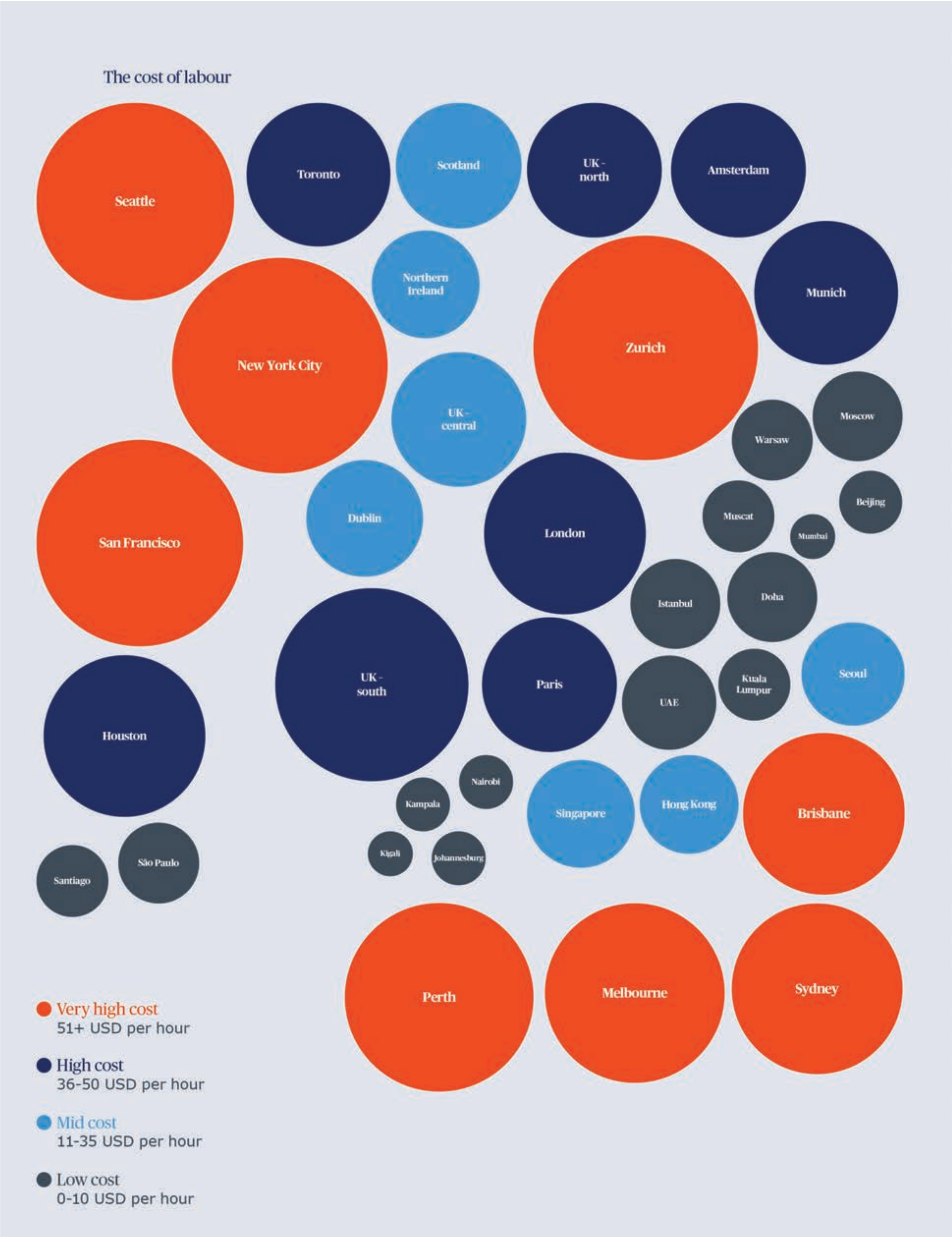


Figure 16: International Construction Costs of Cities: Market Survey 2016

2.4_TRANSFORMING THE CONSTRUCTION INDUSTRY

DIGITAL SOLUTIONS

- **Digital collaboration and mobility**
- **The Internet of Things and advanced analytics**
  - Equipment monitoring and repair
  - Inventory management and ordering
  - Quality assessment - “smart structures”
  - Energy efficiency
  - Safety
- **Innovative construction approaches**
  - Green construction.
  - Cost efficiency
  - Supply-chain agility
  - Improved durability and strength
  - Off-site construction
- **Next-generation techniques**
  - Preassembly
  - 3-D printing
  - Robot-assembled construction

(http://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/imagining-constructions-digital-future)

DIGITAL INNOVATION OPPORTUNITIES

- **Medical Devices**
  Future demand for new technologies and products is expected to grow strongly with low volatility due to increasing community expectations of healthcare

- **Australian automotive manufacturing industry**
  Australian automotive suppliers will move to higher value added products and/or to focus on design and development of products which are then manufactured in lower cost economies.o

- **Transitioning textile manufacturing in Australia**
  The Australian textile industry currently has a manufacturing base which can be transitioned to a successful knowledge-intensive technical textiles sector based on incorporating innovations in material science into fibrous structures. Australia has particular opportunities in fields such as:

    - Healthcare - fibrous tissue engineering scaffolds.
    - Defence – lightweight ballistic and blast protection, low multi-spectral materials and integration of power and sensing into textiles.
    - Water, energy and environment – improved filtration media for the removal of toxic substances from air and water.
    - Mining – stronger and smarter geotextiles for the heavy roads, railways and tailings dams used in the mining industry.

- Biomaterials

- Mining technology services
  (www.abvt.com.au/datasheets/TrendsinManufacturingto2020%20(1).pdf)

3.0_INSTITUTIONAL RESEARCH_
NATIONAL COMPETITION SPACE

Innovation is only likely to occur though if there is support for increased collaboration, training and research into new technologies.

(Industry Sectors: Analysis and Forecasting, p. 16)

3.1_SUMMARY

The most uccessful, leading insitiutional national and international research venues are characterised by at least one of the following:

MULTIPLE INDUSTRY PARTNERSHIPS

- UTS FEIT, Centre for Autonomous Systems
- RMIT Centre for Additive Manufacturing
- Swinburne University of Technology

DIVERSE RESEARCH THEMES

- ETH – Zurich
- ICD UNIVERSITÄT – Stuttgart
- FABLab - University of Michigan
- German Research Centre for Artificial Intelligence

TARGETED AREAS OF SPECIALISATION

- Wyss Institute for Biologically Inspired Engineering - Harvard
- MIT + RADLAB Research and Design Lab

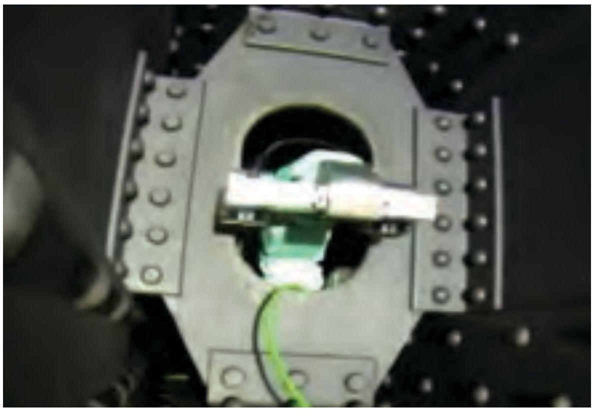
3.2.1_DAB MATERIALS RESEARCH LAB_**UTS**

LOCATION	FACULTY OF DAB, HARRIS ST, ULTIMO
CAPABILITY	o KUKA KR120 HA 6-Axis Robotic Arm [120kg Payload, HA = High Accuracy] + 7metre External Track o ART XR4000 4-Axis Smart Router
RESEARCH	o The development of targeted research themes for this facility are the subjet of this report

3.2.2_CENTRE FOR AUTONOMOUS SYSTEMS_**UTS**

LOCATION	FACULTY OF ENGINEERING + IT, BUILDING 11, BROADWAY
RESEARCH	o Field robotics o Infrastructure robotics: SABRE AUTONOMOUS SOLUTIONS startup - bridge inspection and maintenance, underground mining, water mains condition assessment and stevedoring o Human-centred robotics o Robots in unknown and complex environments (sensing, mapping, motion planning and human-robot interaction o Assistive robotics and human-robot interaction (human models and control) o Manufacturing
WEB	https://www.uts.edu.au/research-and-teaching/our-research/centre-autonomous-systems



3.2.3_PROTOSPACE_**UTS**

LOCATION	BOTANY
CAPABILITY	o Additive manufacturing research and development o Industrial high-end advanced manufacturing o Medium end/desktop additive manufacturing o Traditional subtractive manufacturing
RESEARCH	o Offsite space for large-scale fabrication for UTS staff and students

CAD drawings relatng to the layout and equipment capabilities of this space are included in the Appendix at the end of this report.

3.2.4_CENTRE FOR ADDITIVE MANUFACTURING_**RMIT**

LOCATION	VICTORIA
CAPABILITY	o TRUMPF Trulaser cell 7020 5-axis laser machining centre: o SLM solutions 250HL and 125 HL o Fortus 900 o Objet 350 o Projet 7000 o OKUMA MU-500VII-L Multitasking 5-axis Vertical Machining Centres o OKUMA Multus- Six axis CNC machining Centre o X-ray CT system (GE v/tome/xS)
RESEARCH	o Shape and topology optimisation algorithms o Bio-inspired design o Connectivity between additive manufacturing and industrial design industry
PARTNERS	o Advanced Manufacturing Cooperative Research Centre o Agilent o Anatomics o Australian Nuclear Science and Technology Organisation o AutoCRC o BAE Systems Australia o Chongqing University, China o CSIRO o Defence Materials Technology Centre o Defence Science and Technology Organisation, (DSTO) o Ford Australia o Fraunhofer Institute for Laser Technology, Aachen, Germany o Laser Centre Nord, Hamburg, Germany o Rosebank Engineering o St. Vincent’s Hospital o Weir Minerals o Welding Technology Institute of Australia
WEB	https://www.rmit.edu.au/research/research-institutes-centres-and-groups/research-centres/centre-for-additive-manufacturing

3.2.5_CENTRE FOR ADDITIVE MANUFACTURING_**MONASH**

LOCATION	VICTORIA
CAPABILITY	o Selective laser melting machine (EOS), which is capable of producing high precision and complex, structured parts. o Largest selective laser melting machine(Concept Laser) in the southern hemisphere. o Direct laser deposition machine (Trumpf), which is capable of rapid materials development and large, scale part manufacture and repair. o Hot Isostatic Press (Avure) with unique high temperature and pressure combinations.
RESEARCH	o Material science o Alloy design and processing o Surface engineering o Corrosion and hybrid materials
PARTNERS	o CSIRO o Leading organisations and corporations in the aerospace, rail and advanced manufacturing industries.
WEB	https://platforms.monash.edu/mcam/

The National Additive Manufacturing Collaboration Hub created in conjunction with the CSIRO's Lab 22 and Monash University.

The world's first 3D printed engine

3.2.6_SWARM ROBOTICS LAB_**MONASH**

LOCATION	VICTORIA
RESEARCH	o Swarming and Robustness o Swarms of Climbing Robots o Human Swarm Interaction o Machine Learning & Swarm Robotics o Precise Relative Localization for Robot Swarms operating in 3D space o Distributed SLAM with Swarms of Quad Copters o Novel Approaches for Tracking Flying Swarms of Robots o Advanced Formation Control for Quad Copter Swarms o Swarm Intelligence based Gesture Tracking
WEB	https://www.monash.edu/it/srlab

Quad-copters

3.2.7_UNIVERSITY OF TECHNOLOGY_**SWINBURNE**

Advanced Manufacturing Research Centre, Weihai
Advanced Manufacturing and Design Centre
Factory of the Future
Advanced Technology Centre

LOCATION	VICTORIA	
CAPABILITY	o	3-D Visualisation and Design Studio
	o	Rapid Manufacturing Studio
	o	Advanced Inspection and Machining Studio
	o	Biodevice Innovation Studio
	o	Design for Resource Efficiency Studio
RESEARCH	o	Automation & mechatronics
	o	3D printing
	o	Biomedical devices and medical manufacturing
	o	Electronics manufacturing
	o	Advanced Manufacturing Materials
PARTNERS	o	The Myer Foundation
	o	The Pratt Foundation
	o	Lord Mayor's Charitable Foundation
	o	Truby and Florence Williams Trust

Swinburne University of Technology has entered into a five-year research collaboration with the University of Stuttgart in Germany. Both will work on several different initiatives involving joint research projects in advanced manufacturing, Industry 4.0, innovation in manufacturing and design, and carbon fibre composites to leverage industry and government funding in Australia, Germany and internationally.

WEB	http://www.swinburne.edu.au/research/our-research/

3.2.8_AUSTRALIAN CENTRE FOR FIELD ROBOTICS_ **UNIVERSITY OF SYDNEY**

LOCATION	SYDNEY, NSW
RESEARCH	o ARC Centre of Excellence for Autonomous Systems (CAS) o BAE Systems Centre for Intelligent and Mobile Systems o Centre for Social Robotics o Rio Tinto Centre for Mine Automation
PARTNERS	o Qantas o Horticulture Australia Limited o Toll Holdings o Rio Tinto o DEEDI o Australian Defence Force (ADF) o BAE Systems o Singapore Technologies Aerospace o Iotech o Meat and Livestock Australia o US Office of Naval Research o US Air Force Research Laboratories (AFRL) o US Air Force Office of Scientific Research (AFOSR) o L3-Communications Interstate Electronics o Thales o NSW Roads and Traffic Authority (RTA) o Renault o Komatsu o Leica o Defence Science and Technology Organisation (DSTO) o Iontegrated Marine Observing System o Eglin AFB o Toyota o Australian Plague Locust Commission o Wright Patterson AFB o Patrick Stevedores o Australian Space Research Program o vBrambles Industrial Services o Agency for Defence Development o Electrolux
WEB	http://www.acfr.usyd.edu.au

3.2.9_ROBOTICS AND AUTONOMOUS SYSTEMS_**UNSW**

LOCATION	SYDNEY, NSW
RESEARCH	o agricultural robotics o unmanned aerial vehicles o mobile robotics o navigation
PARTNERS	o Advisian o AECOM o ANSTO o ARUP o Aurecon o Bouygues Construction o Cardno o CPB o GHD o JK Geotechnics o Laing O'Rourke o Macquarie Geotech o Multiplex Ltd o Pells Sullivan Meynink Pty Ltd o Royal HaskoningDHV o RPS Group o SMEC Australia o Taylor Thomson Whitting (TTW) o WSP
WEB	http://www.robotics.unsw.edu.au

3.2.10_THE UNIVERSITY OF WOLLONGONG

LOCATION	NSW
RESEARCH	o Steel Research Hub o Centre For Intelligent Mechatronics Research • Haptics and virtual manipulation • Active suspension control • Steer by wire • Electric cars • Robotic assisted rehabilitation for stroke patients
PARTNERS	o BlueScope o OneSteel (represented by Arrium) o Australian Steel Institute o Bisalloy o Cox Architects o Lysaght o Stockland

The Steel Research Hub has a cash ($5.3M) and in-kind ($6.475M) commitment from the Australian steel industry over five years.

WEB	http://eis.uow.edu.au/manufacturing/index.html

3.2.11_INSTITUTE FOR FUTURE ENVIRONMENTS_ **QUEENSLAND UNIVERSITY OF TECHNOLOGY**

LOCATION	QUEENSLAND	
RESEARCH	o	Australian centre for robotic vision projects
	o	Agricultural robotics
	o	Robotics and neuroscience
	o	Field robotics
	o	Mining robotics
	o	Aerial robotics
	o	Medical robotics
	o	General robotics and autonomous system
PARTNERS	o	Australian Association for Unmanned Systems
	o	ARS Electronica
	o	Australian Research Council
	o	Boeing Research & Technology Australia
	o	Civil Aviation Safety Authority
	o	CRC Plant Biosecurity
	o	CRC SI
	o	CSIRO
	o	Ergon Energy
	o	ETH Zurich
	o	Kansas State University
	o	MathWorks
	o	Northrop Grumman
	o	Qld Government
	o	RMIT University
	o	Telecom Bretagne
	o	Thales
	o	rpde
	o	University of Stuttgart
WEB	https://www.qut.edu.au/institute-for-future-environments	

3.2.12_UNIVERSITY OF QUEENSLAND

LOCATION	QUEENSLAND
CAPABILITY	o 3-D Visualisation and Design Studio o Rapid Manufacturing Studio o Advanced Inspection and Machining Studio o Biodevice Innovation Studio o Design for Resource Efficiency Studio
RESEARCH	o Aerial robotics o Biorobotics o Mining applications

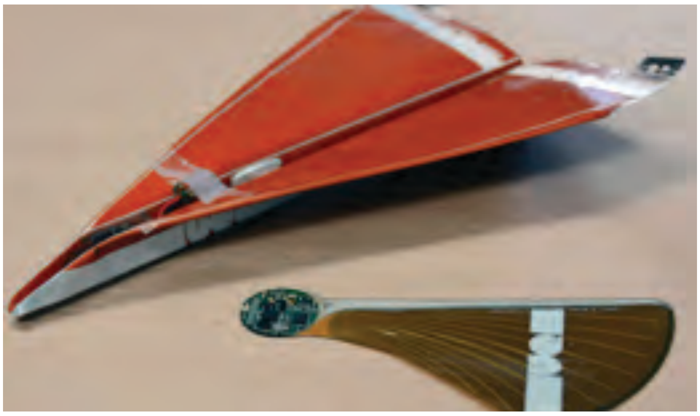
PARTNERS

A list of UQ's industry partners can be found in the Appendix at the end of this document.

2017 Funded Linkage Projects

- $450,000 for a research project to develop strategies to mitigate silica scaling at coal seam gas water treatment facilities.
- $555,000 to understand the reactions taking place during the recovery of base-metal and precious minerals. The project will develop new technologies to achieve mineral separation and metal extraction more efficiently and economically.
- $195,000 to support improved extraction and utilisation of Australia's iron ore resources.

WEB	http://www.robotics.uq.edu.au



Aero-electro-mechanical system for easily-deployable environmental sensing

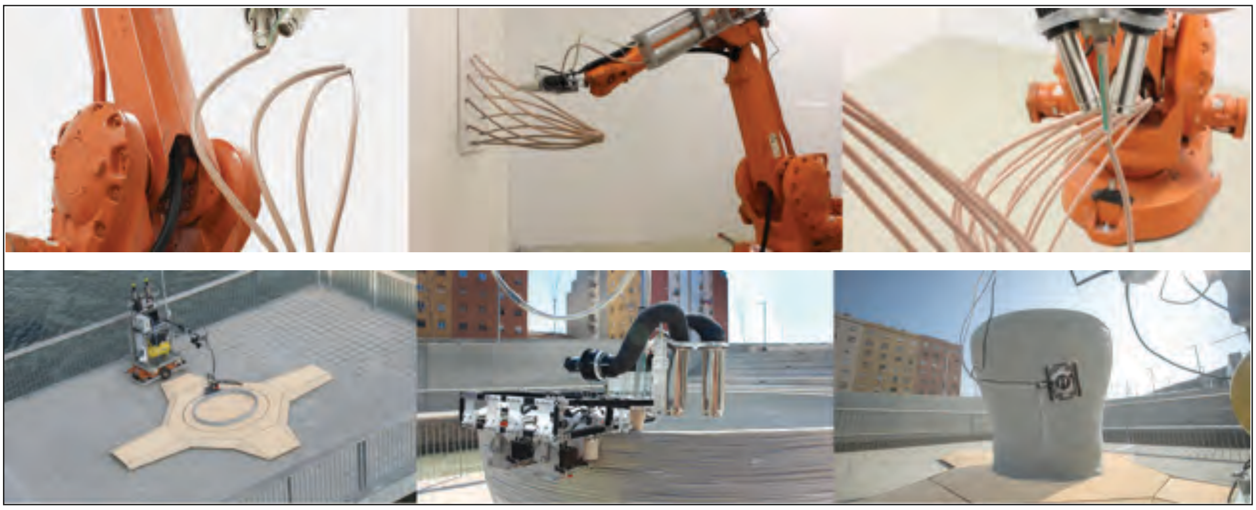
3.2.13_BOND UNIVERSITY

LOCATION	QUEENSLAND
CAPABILITY	o Trotec laser cutter with an 800x1100 bed size o Dimension uPrint 3d printer with a 200x200x200 build area and 2 Maker-Bot 3d printers o ART CNC Router with a 500x2400x250 bed size o ABB 2.8m Robotic Arm on a 4m track
RESEARCH	o Australian centre for robotic vision projects o Agricultural robotics o Robotics and neuroscience o Field robotics o Mining robotics o Aerial robotics o Medical robotics o General robotics and autonomous systems
PARTNERS	o AECOM o Andresen O’Gorman Architects o Bates Smart Architects o Coast Arc o CRAB Studio o DBI Design o degenhartSHEDD o Gold Coast City Art Gallery o Gold Coast City Council o ML Design o Philip Follent Architects o Pratt Institute o Ranger Design o Soheil Abedian o Sunland Group Limited o Tokyo University of Art
WEB	https://bond.edu.au/about-bond/facilities-services/teaching-facilities/fabrication-laboratory

4.0_INSTITUTIONAL RESEARCH_ INTERNATIONAL COMPETITION SPACE

4.2.1_FAB LAB_**INSTITUTE FOR ADVANCED ARCHITECTURE OF CATALONIA**

LOCATION	SPAIN
CAPABILITY	o Large scale laser cutter Multicamm 2000 o Large scale milling machine o 3 axis Precix 11100 Series o Large scale milling machine o 3 axis ShopBot o Precision milling machine Monofab ARM 10 o Vinyl cutter GX-24 Camm Servo o Laser cutter Epilog XT Legend 36 75w o Laser cutter Trotec Speedy 400
RESEARCH	o Self-sufficiency o Solar house o Fab Lab house o Large scale 3d printing o Intelligent cities o Internet of things o Responsive architecture o Fab textiles
WEB	https://iaac.net/fab-labs/fab-labs-bcn/



TOP: Anti-gravity additive manufacturing
BOTTOM: Small robots printing large-scale structures

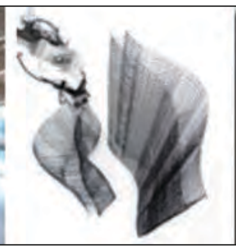
4.2.2_ATROPOS | REDEFINE MANUFACTURING | +LAB_ POLITECNICO MILANO

LOCATION	ITALY
RESEARCH	o Continuous fibre composites: glass, basalt, carbon, polyaramides and bamboo
WEB	http://www.piulab.it

4.2.3_NATIONAL CENTRE OF COMPETENCE IN RESEARCH (NCCR) DIGITAL FABRICATION_**ETH ZURICH**

LOCATION	SWITZERLAND
RESEARCH	o On-site robotic construction o Mesh mould metal o Robotic lightweight structures o Jammed architectural structures o Complex timber structures o Robotic fabrication laboratory o Spatial wire cutting o Mobile robotic tiling o The sequential roof o YOUR software environment o Aerial construction o Rock print o Smart dynamic casting o Topology optimization o Iridescence print o Robotic foldings o Mesh mould o Acoustic bricks o Tailorcrete
WEB	http://www.dfab.ch/about/introduction/


The sequential roof


Mesh mould


Onsite robotic construction


Smart dynamic casting

4.2.4_ICD UNIVERSITÄT_**STUTTGART**

LOCATION	GERMANY
RESEARCH	o Synthesis of space, structure and climate in integrative computational design processes o Morphogenetic design experiments o Hygroscope: meteorosensitive morphology • fibrous surface • membrane morphologies • paper strip morphologies • adaptive pneumatic shelters o Material systems • wood/steel/ concrete • fibre composites • membranes • pneumatics • aggregates
WEB	http://icd.uni-stuttgart.de

A list of current ICD projects and funding bodies is included in the Appendix at the end of this report.

4.2.5_DFKI_GERMAN RESEARCH CENTRE FOR ARTIFICIAL INTELLIGENCE

LOCATION	GERMANY
RESEARCH	o Knowledge Management o Cyber-Physical Systems o Multilingual Technologies o Plan-Based Robot Control o Educational Technology Lab o Interactive Textiles o Robotics Innovation Center o Innovative Retail Laboratory o Institute for Information Systems o Embedded Intelligence o Smart Service Engineering o Intelligent Analytics for Massive Data o Intelligent Networks o Agents and Simulated Reality o Augmented Vision o Language Technology o Intelligent User Interfaces o Innovative Factory Systems **Kaiserslautern** • Knowledge Management • Augmented Vision • Innovative Factory Systems • Integrated Communication Systems **Saarbrücken** • Innovative Retail Laboratory • Institute for Information Systems • Agents and Simulated Reality • Language Technology • Intelligent User Interfaces **Bremen** • Robotics Innovation Center • Cyber Physical Systems **Berlin** • Project Office for Language Technology • Intelligent User Interfaces
WEB	https://www.dfki.de/web/intelligent-solutions-for-the-knowledge-society?set_language=en

4.2.6_FABLab_**UNIVERSITY OF MICHIGAN**

LOCATION	USA
CAPABILITY	o 3D Printers o 7-Axis Robot o CNC Knitting Machine o CNC Router o CNC Waterjet o Laser Cutters o Zünd Knife Cutter o Digitizer
RESEARCH	o Research Through Making (RTM) Program • catenary slumping - Specimen • stereotomic vault construction - La Voûte de LeFèvre • Incremental Sheet Metal Forming Methods
WEB	https://taubmancollege.umich.edu/labs-workshops/digital-fabrication-lab

4.2.7_WYSS INSTITUTE_**UNIVERSITY OF HARVARD_GSD**

LOCATION USA

RESEARCH

- o Phase-Separating Liquid Gated Membranes
  - A filtration technology selectively processing complex material flows, precisely separating liquids, gases and solids without clogging and with significant energy savings
- o Programmable Robot Swarms
  - Autonomous artificial swarms of robots for search and rescue missions, construction efforts, environmental remediation, and medical applications
  - 4D Printing of Shapeshifting Devices
  - 3D-printed hydrogel composite architectures that change shape over time for use in smart textiles, soft electronics, medical devices, and tissue engineering.

WEB https://wyss.harvard.edu/

4.2.8_INSTITUTE FOR CRITICAL TECHNOLOGY AND APPLIED SCIENCE_**VIRGINIA TECH**

LOCATION	USA
RESEARCH	o Innovation-based Manufacturing • Implementation of Self-Healing Approach for Smart Assembly Systems o Additive Manufacturing • Complex Cellular Castings o Renewable Materials o Sustainable Water o Cognition and Communication o National Security

CENTER FOR AUTONOMOUS SYSTEMS (VACAS)

- o Advanced vehicle guidance and control
- o Advanced sensing and navigation
- o Advanced mobility and actuation
- o Emerging Technologies

WEB	http://www.ictas.vt.edu/

4.2.9_SCI-ARC_**SOUTHERN CALIFORNIA INSTITUTE OF ARCHITECTURE**

LOCATION	USA
RESEARCH	o Robot house o Fabrication shop
WEB	https://sciarc.edu/institution/facility/

5.0_NON-INSTITUTIONAL RESEARCH

5.1.1_RADLAB - RESEARCH_DESIGN LAB

LOCATION USA

PARTNERS

Add, Inc
Aero Designs
Aesop
AgaMatrix, Inc
Ann Beha Architects
ARIAD Pharmaceuticals
Arrowstreet, Inc
Artaic, LLC
Behnisch Studio East, Inc
Boston Balloon Events
Boston Dynamics
Boston Furniture Collaborative
Boston University
Cambridge Seven
CChange Investments, LLC
Christian Kerez
Coppiardi Cases
CW Keller & Associates
dECOi Architects
East Boston Playhouse
Epstein Joslin Architects
Golden Architects, Inc
Gradient Corporation
Gund Partnership
Halvorson Design Partnership
Harvard University GSD
Harvard Museums of Science & Culture
Hood Park LLC
Howeler + Yoon Architecture
IDEO
Innosight Consulting, LLC
JHDrum Associates
Kiinde
Kennedy & Violich Architecture
Kosmo Studios
Lavallee Brensinger Architects
Leers Weinzapfel Associates
MBTA
MIT Center for Advanced Urbanism
MIT Dept of Architecture
MIT Dept of Biology
MIT Dept of Mathematics
MIT Lincoln Laboratory
Mobile Fitness Systems
Mullen – Boston
Museum Design Associates
Myco Rehab, LLC
NADAAA
NBBJ Architects
New Balance Athletic Shoe, Inc
Northeastern University
Novokinetics, LLC
Oasys Water
Ocean Spray Cranberries, Inc
One North Boston, LLC
OneVision Resources
Oudens Ello Architecture
Paperless Parts
Paul Lukez Architects
Phase(n)
Phillips Design Group
Piano Craft Guild Associates
Pomeroy Co, Inc
Renaissance Group
Reverse Architecture
RMA Architects
Sasaki Associates, Inc
Schneider Electric
Sea-Dar Construction
Shanghai Paramount Real Estate Development Company
Shepley Bulfinch
Sourcentra, Inc
Stephen Stimson Landscape Architects
Tiax, LLC
Tsoi / Kobus & Associates
Ubiquitous Energy
Warner Bros. Pictures Inc.
Wellington Management
William O'Brien Jr, LLC
Xitome Design

WEB http://radlabinc.com/

5.1.2_BEITES + CO

LOCATION	TORONTO, CANADA
RESEARCH	o Robot integration o material simulation & validation o aluminum composite material o glass fibre reinforced polyester resin o shape memory polymer: responsive architecture
WEB	http://beites.co/

5.1.3_GUY MARTIN DESIGN

LOCATION	LOS ANGELES
WEB	http://www.guymartindesign.com/

5.1.4_digifabTURINg

LOCATION	ITALY
RESEARCH	o inFORMed Clay matter
WEB	https://digifabturing.github.io/LandingPage/

5.1.5_CARACOL DESIGN STUDIO

LOCATION	ITALY
RESEARCH	o Parametric drawing executed by a kuka robot - each drawing is the graphic expression of a math function in which a grid of parallel lines is deformed by virtual attractor points o concrete printing
WEB	http://www.caracolstudio.it/

6.0_RESOURCES/FUNDING CONTEXT

“Australia should see the fourth industrial revolution as an opportunity. If we establish a broad-based capability to use global engineering and manufacturing platforms based on advanced materials, the often spruiked access by our SME’s to global supply chains are more a reality now than they have been at any time in the past”

Jeff Connolly, Chair of the Prime Minister’s Industry 4.0 Taskforce

6.1_SUMMARY

The principal current funding resources and opportunities available to digital fabrication reserach are defined by the following:

- **THE NATIONAL INNOVATION AND SCIENCE AGENDA**
  The National Innovation and Science Agenda will deliver $36 million between 2016-19 to assist international innovation and science engagement and to Build strong regional linkages in the Asia-Pacific.

- **THE INNOVATIVE MANUFACTURING COOPERATIVE RESEARCH CENTRE**
  The IMCRC runs from 2016 to 2022 with $40 million in Commonwealth funding available for industry projects to match dollar for dollar industry cash contributions.

- **INDUSTRY 4.0**
  The Australian Government's Industry 4.0 Taskforce and Platform Industrie 4.0 from Germany have signed a cooperation agreement to cooperate in developing modern manufacturing sectors across five work streams.

- **AUSTRALIAN GOVERNMENT FUNDING/GRANTS**
  The most immediately applicable grants to the DAB Digital Fabrication Research Group are **Linkage Project Grants and Discovery Project Grants with the ultimate goal of establishing an ARC Centre of Excellence.**

6.2_ADVANCED MANUFACTURING INITIATIVES

The 2017-18 Budget provides over $100 million in new funding to boost innovation, skills and employment in advanced manufacturing. The funding includes $47.5 million for a new Advanced Manufacturing Growth Fund, building on the existing $155 million Growth Fund that helps industry diversify into other high value sectors ahead of the wind-down of car manufacturing.

6.2.1_THE INNOVATIVE MANUFACTURING COOPERATIVE RESEARCH CENTRE

http://www.imcrc.org/

KEY POINTS

- Key enabling and innovative manufacturing technologies including additive manufacturing (3D printing), nanotechnology, micro and nano electronics, photonics, advanced materials, advanced manufacturing systems, simulation, augmented reality and a range of lifecycle management (PLM) technologies.
- IMCRC runs from 2016 to 2022.
- $40 million in Commonwealth funding available for industry projects to match dollar for dollar industry cash contributions.
- Essential Participants in the IMCRC contribute at least $500K in cash over the term of IMCRC.
- Applications are to be created and submitted by a lead industry participant using the templates available at http://www.imcrc.org/new-research-projects.html
- Projects are reviewed initially by the IMCRC Innovation Investment Committee (IIC) which can approve projects up to $1m in cash value.
- IMCRC invites new project applications from industry for projects up to $6 million total cash investment.

KEY PROJECT ASSESSMENT CRITERIA REQUIRE THAT A PROJECT:

- is industry led, delivers clear manufacturing outcomes, and involves innovative and advanced manufacturing.
- demonstrates genuine collaboration, including with SMEs, and also with Growth Centres and other CRCs;
- creates opportunities to access global supply chains;
- delivers wider / multiplier benefits to Australian manufacturing;
- contributes to the sector transformation and sustainability;
- requires high quality research with Universities, CSIRO and/or other research organisations in Australia, and facilitates PhD student scholarships;
- has a clear IP utilisation / commercialisation plan (note that IMCRC does not own Project IP – ownership is determined between the industry and research participants where it can most effectively be commercialised);
- has a clear business innovation and transformation plan and/or Industry 4.0 adoption plan (IMCRC is developing diagnostics, education and training materials and methodology to facilitate this);
- has a defined return on research investment, with both manufacturing and commercial outcomes.

6.2.2_THE NATIONAL INNOVATION AND SCIENCE AGENDA

RESEARCH

http://www.innovation.gov.au/audience/researchers-and-universities

GLOBAL INNOVATION STRATEGY

The Global Innovation Strategy outlines existing and new initiatives and support for international innovation and science engagement. It can be viewed at industry.gov.au/innovation/Global-Innovation-Strategy. Under the National Innovation and Science Agenda the strategy includes $36 million invested over four years to:

- Establish five ‘Landing Pads’ in global innovation hotspots to support entrepreneurial Australians. Landing Pads provide market-ready startups with a short-term (90 day) operational base where they can access entrepreneurial talent, mentors, investors and a wider connected network of innovation hubs.

- Provide seed funding to assist Australian businesses and researchers to collaborate with international businesses and researchers through the Global Connections Fund.

- Provide funding to assist Australian businesses and researchers to collaborate with global partners on strategically focused, leading-edge research and development projects through the Global Innovation Linkages programme.

- Build strong regional linkages in the Asia-Pacific through the Regional Collaborations Programme which will support multi-partner activities that facilitate greater science, research and industry collaboration in delivering innovative solutions to shared regional challenges.

OPPORTUNITIES FOR WOMEN IN SCIENCE, TECHNOLOGY, ENGINEERING AND MATHS

An investment of $13 million over five years to encourage more women to choose and stay in STEM research, related careers, startups and entrepreneurial firms, including:

- o Supporting the expansion of the Science in Australia Gender Equity (SAGE) project to include more Australian science and research institutions.
- o Establishing a new group of 'Male Champions of Change' focused on STEM-based and entrepreneurial industries.
- o Partnering with the private sector, community groups and educational organisations to foster interest in STEM and entrepreneurship amongst women.

INNOVATION CONNECTIONS: CONNECTING INDUSTRY TO INNOVATION INFRASTRUCTURE

The Innovation Connections programme:

- o provides access to Innovation Facilitators so businesses can access Australia's innovation infrastructure, including in regional areas

- o makes matched grants available to support graduate and postgraduate researchers placements in businesses

- o makes matched grants available to support business researchers to be placed in publicly funded research organisations

- o identifies opportunities to access research and development and testing facilities and develop specialised training options by working more closely with the vocational education and training sector.

BUSINESS

(http://www.innovation.gov.au/audience/business)

INNOVATION CONNECTIONS PROGRAM:

- o provides access to Innovation Facilitators so businesses can access Australia's innovation infrastructure, including in regional areas

- makes matched grants available to support graduate and postgraduate researchers placements in businesses
- makes matched grants available to support business researchers to be placed in publicly funded research organisations
- identifies opportunities to access research and development and testing facilities and develop specialised training options by working more closely with the vocational education and training sector.

INTANGIBLE ASSET DEPRECIATION

This initiative provides businesses with:

- A new option to self-assess the tax effective life of acquired intangible assets that are currently set by statute. This will better align the tax treatment of the asset with the actual number of years the asset provides an economic benefit.
- The option to continue using the existing statutory effective life of the asset.

INCREASING ACCESS TO COMPANY LOSSES

- The current 'same business test' will be relaxed and a more flexible 'similar business test' will be introduced.
- More businesses to will be able to access prior year losses when they have made changes to their operations, such as entering into new transactions or business activities. This will encourage entrepreneurship by allowing loss-making companies to seek out new opportunities to return to profitability.
- Under the 'similar business test' companies will be able to access losses where their business, while not the same, uses similar assets and generates income from similar sources.

6.2.3_VICTORIA'S FUTURE INDUSTRIES_ CONSTRUCTION TECHNOLOGIES DISCUSSION PAPER AUGUST 2015

There is a long-run trend away from artisan-based work undertaken in situ to projects involving the assembly of components fabricated elsewhere known as 'off-site construction'. New IT systems are being deployed to improve design and management of the construction process, as well as the operational efficiency of the building once completed. Expectations of higher levels of environmental performance has focused more attention on design quality and the impacts of products specified, creating demand for smart and green projects.

OPPORTUNITIES AND CHALLENGES KEY POINTS

- Greater uptake of technologies will improve productivity
- Building Information Modelling will increase overall efficiencies
- Off-site construction will deliver productivity gains
- Victoria can be a centre of excellence for off-site construction
- Capitalising on Melbourne's status as the world's most liveable city
- Melbourne's liveability profile can build export opportunities
- Victoria is a showcase for smart construction
- Further adoption of new materials will improve the sector's performance
- Industry and research partnerships will increase technology uptake
- Victoria has the proven ability to commercialise construction technologies
- A technology friendly regulatory environment could improve competitiveness

The full version of this paper is included in the Appendix at the end of this report.

6.2.4_THE ADVANCED MANUFACTURING GROWTH CENTRE

https://www.amgc.org.au/Category?Action=View&Category_id=45#team

---

The Advanced Manufacturing Growth Centre is a membership-based, not-for-profit organisation which supports the development of a world-leading advanced manufacturing sector in Australia.

ACTION PLAN **R+D PRORITIES**

- Robotics and automated production processes
- Advanced materials and composites
- Digital design and rapid prototyping
- Sustainable manufacturing and life-cycle engineering
- Additive manufacturing
- Sensors and data analytics
- Materials resilience and repair
- Bio-manufacturing and biological integration
- Nano-manufacturing, micro-manufacturing and precision manufacturing
- Augmented or virtual reality systems

ADVANCED MANUFACTURING GROWTH CENTRE COLLABORATION HUBS

- The National Carbon Fibre and Composite Manufacturing Collaboration Hub in Geelong, Victoria, created in conjunction with Deakin University and the CSIRO Fibres of the Future Laboratory.
- The National Additive Manufacturing Collaboration Hub in Clayton, Victoria, created with the CSIRO's Lab 22 and Monash University.
- Manufacturing Futures Research Institute at Swinburne University of Technology

PARTNERS

Thales, Quickstep, The Dow Chemical Company, Siemens, Bosch, Swisse, Laing O'Rourke, SPEE3D, University of NSW and the CSIRO,

The full version of the Action Plan document is included in the Appendix at the end of this report.

6.2.5_INDUSTRY 4.0

INDUSTRY 4.0 - GERMANY

RESEARCH THEMES

- The Smart Factory
- The Real Environment
- The Economic Environment
- Human Beings and Work
- The Technology Factor

DESIGN PRINCIPLES

- **Interoperability**
  The ability of machines, devices, sensors, and people to connect and communicate with each other via the Internet of Things (IoT) or the Internet of People (IoP).
- **Information transparency**
  The ability of information systems to create a virtual copy of the physical world by enriching digital plant models with sensor data.
- **Technical assistance**
  The ability of assistance systems to support humans by aggregating and visualizing information comprehensibly and the ability of cyber physical systems to physically support humans.
- **Decentralized decision**
  The ability of cyber physical systems to make decisions on their own and to perform their tasks as autonomous as possible.

INDUSTRY 4.0 - AUSTRALIA

The Prime Minister's Industry 4.0 Taskforce in Australia and Platform Industrie 4.0 from Germany have signed a cooperation agreement to cooperate in developing modern manufacturing sectors across five work streams.

- reference architectures, standards and norms
- support for small and medium sized enterprises (SMEs)
- Industry 4.0-Testlabs
- security of networked systems
- work, education and training

A document explaining INDUSTRIE 4.0 and 'Smart Manufacturing for the Future' is included in the Appendix at the end of this report

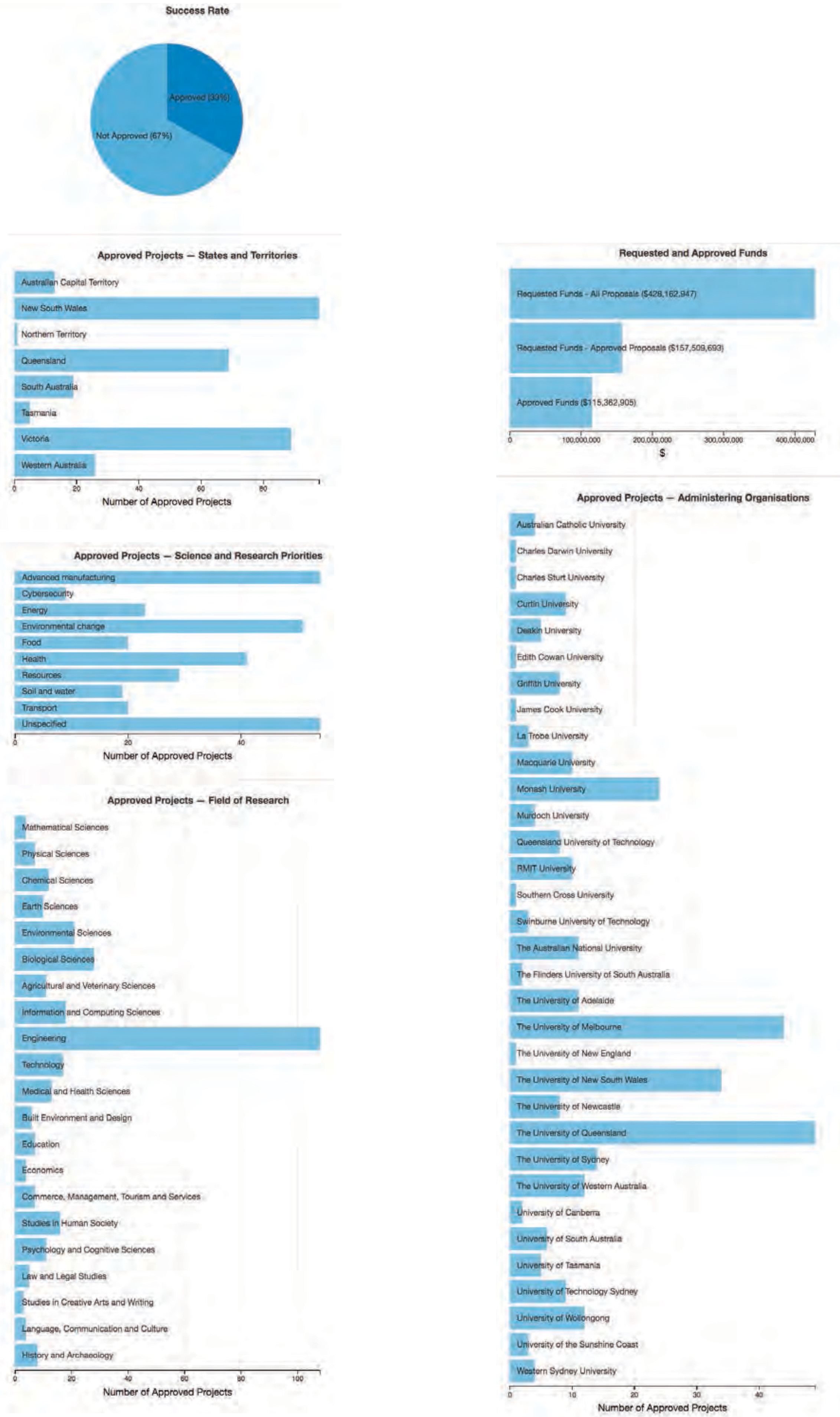


Figure 17: Approved ARC Grants 2016

6.3_AUSTRALIAN GOVERNMENT FUNDING/GRANTS

GRANTS

ARC/ NHMRC

http://www.arc.gov.au/grants-dataset-information

The ARC's Linkage funding schemes aim to encourage and extend cooperative approaches to research and improve the use of research outcomes.

- **Linkage Projects**
  http://www.arc.gov.au/selection-report-linkage-projects-2016
  The Linkage Projects scheme provides funding to Eligible Organisations to support research and development (R&D) projects. From 1 July 2016, the ARC commenced accepting proposals under the Linkage Projects scheme on a continuous basis and (2017 round) proposals can be submitted at any time up to 19 December 2017.

- **Discovery Projects**
  http://www.arc.gov.au/selection-report-discovery-projects-2017
  These can be undertaken by individual researchers or research teams.

- **Industrial Transformation Research Program**
  http://www.arc.gov.au/selection-report-industrial-transformation-training-centres-2017
  The priorities for Industrial Transformation Research Hubs for funding commencing in 2017 and Industrial Transformation Training Centres for funding commencing in 2017 include Advanced Manufacturing.

- **Discovery Early Career Researcher Award**
  http://www.arc.gov.au/selection-report-discovery-early-career-researcher-award-2017
  The scheme provides funding for early-career researchers in both teaching and research, and research-only positions.

Field of Research category	Number of proposals Approved#	Partner Organisation contributions (cash & in-kind) over project life (approved proposals)
Mathematical Sciences	1	*
Physical Sciences	2	$1,188,442
Chemical Sciences	3	$1,669,399
Earth Sciences	4	$4,125,347
Environmental Sciences	4	$3,138,014
Biological Sciences	8	$8,334,414
Agricultural and Veterinary Sciences	2	$783,185
Information and Computing Sciences	4	$2,771,640
Engineering	34	$20,868,805
Technology	6	$4,564,820
Medical and Health Sciences	3	$1,025,945
Built Environment and Design	1	*
Education	3	$2,051,250
Economics	1	*
Commerce, Management, Tourism and Services	1	*
Studies in Human Society	2	$999,026
Psychology and Cognitive Sciences	4	$3,115,259
Law and Legal Studies	1	*
Language, Communication and Culture	2	$749,968
History and Archaeology	3	$1,409,289
Total	**89**	**$58,513,889**

Figure 18: Proposed data by Field of Research category for Linkage Grants 2016

- **Linkage Infrastructure, Equipment and Facilities**
  http://www.arc.gov.au/selection-report-linkage-infrastructure-equipment-and-facilities-2017
  Funding for research infrastructure, equipment and facilities to eligible organisations.

- **ARC Centres of Excellence**
  http://www.arc.gov.au/selection-report-arc-centres-excellence-funding-commencing-2017
  ARC Centres of Excellence are prestigious foci of expertise through which high-quality researchers maintain and develop Australia's international standing in research areas of national priority.

- **Special Research Initiatives**
  The Special Research Initiatives (SRI) scheme provides funding for new and emerging fields of research and builds capacity in strategically important areas. Applications for SRI funding may be submitted only when invited by the ARC by means of a call for proposal(s) for funding.

INDUSTRY DRIVEN FUNDING

- TechVouchers (NSW) - matched funding up to 15k from the NSW Govt.
- Innovation Connections - matched funding up to 50k from the Govt.
- AMSI internships - going forward (2017) similar to TechVoucher Scheme TBC. Total project value ~ up to max 30k
- Minimum Viable Product - MVP (NSW) - matched funding up to 25k from the NSW Government

OTHER WAYS TO ENGAGE

- Tenders
- Philanthropy & other grants – see researchprofessional.com - anything from 1k travel to $XX
- City of Sydney Grants - between 20k -80k + partner contributions
- Contract research
- Scholarships
- PhD students
- Easy access IP

Priority area	Proposals considered	Proposals approved	Success rate (%)	Approved funds (over project life)
Advanced Manufacturing	42	19	45.2	$7,045,981
Cybersecurity	6	4	66.7	$1,097,000
Energy	17	8	47.1	$2,726,000
Environmental Change	15	7	46.7	$3,113,537
Food	25	7	28.0	$3,029,000
Health	39	11	28.2	$3,211,498
Resources	17	12	70.6	$4,826,385
Soil and Water	11	3	27.3	$1,967,074
Transport	7	2	28.6	$985,000
None selected	46	16	34.8	$6,142,992
Total Proposals	**225**	**89**	**39.6**	**$34,144,467**
Total Proposals within Science and Research Priorities	**179**	**73**	**40.8**	**$28,001,475**
Percentage within Science and Research Priorities (%)	**79.6**	**82.0**		**82.0**

Figure 19: Approved funding for Linkage Projects 2016 by Science and Research Priority

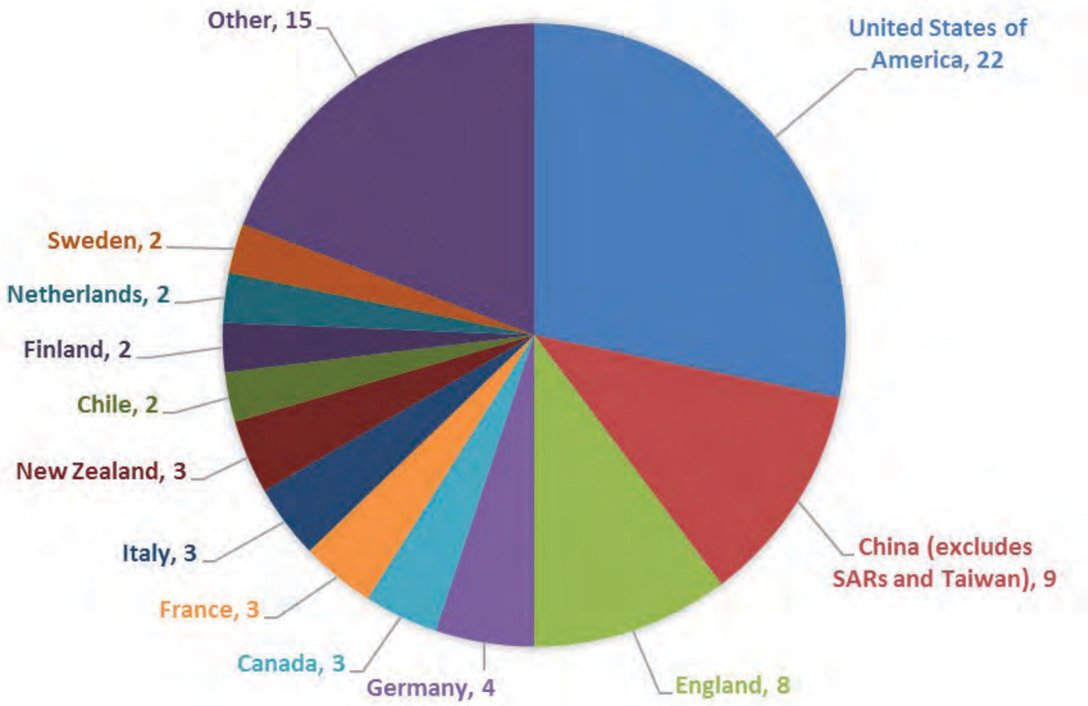


Figure 20: Instances of international collaboration on approved proposals in Linkage Projects 2016

Science and Research Priorities	Proposals considered	Proposals approved	Success rate (%)	Approved funds (over project life)
Advanced manufacturing	506	113	22.3%	$45,109,499
Cybersecurity	126	14	11.1%	$5,011,000
Energy	178	33	18.5%	$12,075,000
Environmental change	450	75	16.7%	$30,379,256
Food	148	13	8.8%	$5,374,400
Health	479	71	14.8%	$24,969,721
Resources	123	17	13.8%	$5,864,760
Soil and water	110	20	18.2%	$8,638,488
Transport	88	13	14.8%	$4,986,000
Unspecified	1332	261	19.6%	$92,252,528
Total	**3540**	**630**	**17.8%**	**$234,660,652**
Total within Science and Research Priorities	**2208**	**369**	**16.7%**	**$142,408,124**
Percentage within Science and Research Priorities (%)	**62.4%**	**58.6%**		**60.7%**

Figure 21: Approved funding for Discovery Projects 2017 by Science and Research Priorities

ARC Centres of Excellence Title	Centre Director	Administering Organisation	Total approved funds over project life
ARC Centre of Excellence for All Sky Astrophysics in 3 Dimensions	Prof Lisa Kewley	The Australian National University	$30,300,000
ARC Centre of Excellence of Australian Biodiversity and Heritage	Prof Richard Roberts	University of Wollongong	$33,750,000
ARC Centre of Excellence for Climate Extremes	Prof Andrew Pitman	The University of New South Wales	$30,050,000
ARC Centre of Excellence for Engineered Quantum Systems	Prof Andrew White	The University of Queensland	$31,900,000
ARC Centre of Excellence for Gravitational Wave Discovery	Prof Matthew Bailes	Swinburne University of Technology	$31,300,000
ARC Centre of Excellence in Exciton Science	Prof Paul Mulvaney	The University of Melbourne	$31,850,000
ARC Centre of Excellence in Future Low-Energy Electronics Technologies	Prof Michael Fuhrer	Monash University	$33,400,000
ARC Centre of Excellence in Population Ageing Research	Prof John Piggott	The University of New South Wales	$27,250,000
ARC Centre of Excellence for Quantum Computation and Communication Technology	Prof Michelle Simmons	The University of New South Wales	$33,700,000

Figure 22: ARC Centres of Excellence 2017 proposals approved for funding

Australian Government
Australian Research Council ARC Grants

Lead Investigator Name	Project Id	Administering Organisation	Project Summary	Total Funding Amount ($)	Funding Commencement Year	Scheme
Bharat Dave	DP110102625	The University of Melbourne	This project on adoption of digital fabrication technologies by Australian architecture practices …	169,000	2011	Discovery Projects
Jon McCormack	FT170100033	Monash University	This interdisciplinary project aims to open the way for the next generation of manufacturing …	937,422	2017	ARC Future Fellowships
Robert Elliman	DP0343308	The Australian National University	Silicon's pre-eminence in high-speed digital electronics does not extend to optoelectronics where …	290,000	2003	Discovery Projects

Figure 23: ARC Grants for digital fabrication

7.0_UTS DIGITAL FABRICATION SWOT ANALYSIS

STRENGTHS

- Leaders in the field
- Strong track record of research and industry consulting
- Successful external funding across UTS
- Strong national and international network and connections to key international experts
- International MOU with Michigan
- Ongoing personal collaborations (ARC centre for excellence + Monash University)
- Academic credentials (PhD's)
- Track record of collaborative projects
- Location of research environment (city centre, high profile)
- Investment by university
- High profile research groups for collaboration within UTS (CAS - Centre for Autonomous Systems)
- UTS has a strong mandate from the VC to proliferate itself as a 'university of technology'

OPPORTUNITIES

- Protospace – potential cross-collaborative working environment
- Botany space – 1:1 prototyping and testing environment
- Clear innovation agenda by federal government: National Innovation and Science Agenda
- Research is aligned with 3 of 9 federal research priorities (advanced manufacturing, resources, energy)
- Changes in building codes and regulations create an opportunity for innovation
- Government initiative concerning Industry 4.0 (retraining of existing sector)
- Linkage grant schemes – applied research with industry partners (ongoing application opportunities – agile and fast process)
- AUS changing demographics: population, housing demand, infrastructure, built environment
- Changing context for business – globalisation competitiveness and the need to combat different business parameters within Australia
- National reputation for innovation and high quality goods and output
- Opportunity to launch a new partially objective and technological research culture

WEAKNESSES

- Unknown / immature brand
- Weak, but improving, overall reputation of UTS as a technology university
- Immature researchers (no silverback – no ARC grant yet)
- Research focused workload (too much teaching load)
- Lack of bodies (RA's, TA's, Tech's,)
- Academic credentials (2 major players without PhD's)
- No University seed funding for interdisciplinary research projects
- Access to workshop facilities – pay-to-use model, control of machines …
- University uses a pay-to-play model = high associated costs for research work
- No emerging "star" researcher in the major emerging construction trends
- Resistance of industry for uptake of novel or advanced technologies
- Lack of geographic critical mass
- Fragmentation/duplication of research in this field – individuals not groups
- Research group doesn't have priority-assigned equipment or staff
- Lack of expansion space
- Space allocation focus on generic need, rather than on specific needs of specialized research
- No designated communications person
- No designated KTT person

THREATS

- Industry traditionally unwilling to engage in research
- Low risk tolerance in related industry
- Minimal funding in this area
- Constrained rules of current funding programmes
- Federal budget (20% cut to education, and general cuts to research)
- Statistic rule of funding to Medicine 50%
- Lack of an integrated programme for advanced digital training of trades and workers
- Clear competitors from other institutions (big fish in a small pond: RMIT, UQ)
- No academic authority over the support network for on-going work
- Coming to the party late – many industry collaborations have already been formed
- No clear leadership in architecture
- Currently no clear strategy to foster technology in the department

8.0_STAKEHOLDER + PARTNERSHIP ANALYSIS

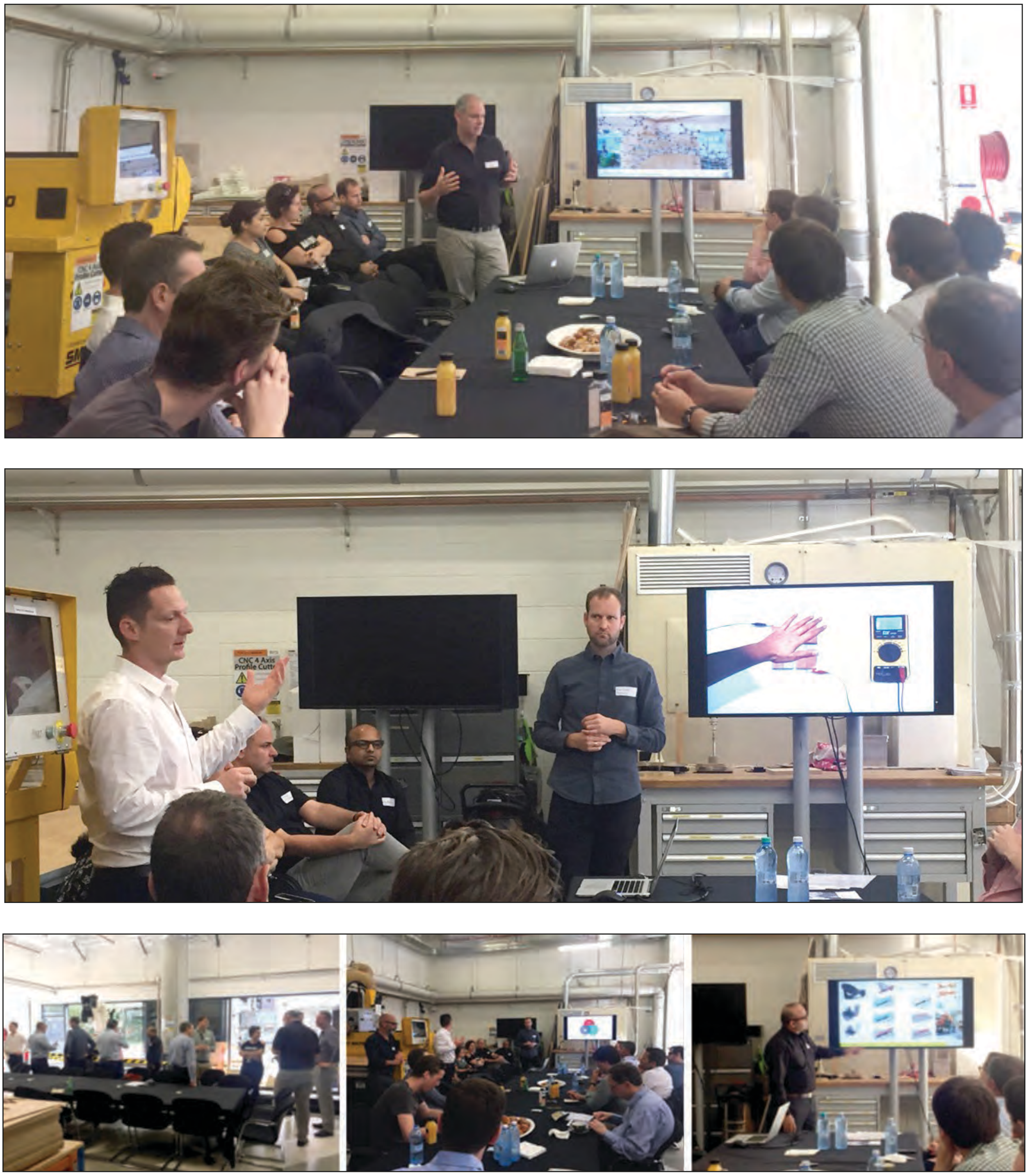


Figure 24: Industry breakfast 23/11/16 – Robotics Lab, DAB, UTS.
Top: Russell Loveridge – ETH;
Centre, left to right: Tim Schork, Nimish Biloria and Iain Maxwell.

8.1_STRATEGIC ENGAGEMENT WITH INDUSTRY_ **STAKEHOLDERS AND PARTNERS**

INDUSTRY BREAKFAST 23/11/16 – ROBOTICS LAB, DAB, UTS

An industry breakfast was held with a view to engaging potential partners in more efficient construction and manufacturing solutions using digital fabrication techniques developed by DAB at UTS. This was done with the intention of initiating an ongoing series of industry engagements that underpin the trajectory of research undertaken in DAB, both in terms of technical leadership and advice as well as funding support.

An outline of the issues and concerns that arose from this meeting follows:

External Attendees

- Craig Allchin - LEND LEASE Development
- Timothy Devlin - MIRVAC Development
- Brian Mariotti - SAJC Architects
- Alexander Mohr - Munichre Insurance
- Rodney Paesler - Scott Carver Architects
- Mitchell Page - COX Architects
- Adam Williams - LEND LEASE Development

8.1.1_HOW WILL PARTNERS BE ENGAGED?

WHAT IS THE INCENTIVE?

- Architecture is evolving and Australia needs to be an equal player in the global market
- Technology will have a strong role in the future of construction
- Australian construction firms want to be seen as part of an innovation culture
- Efficient solutions for onsite logistics issues
- UTS is building a new initiative and team to position itself at the forefront of digital fabrication

WHO AND WHAT IS THE TEAM?

- Local researchers (existing + new positions)
- Extended researchers (U Michigan, Kassel, RL)
- A strong team brand is needed
- Ongoing team administration and marketing needs to be implemented (quarterly industry breakfasts; management of invitee database; monthly newsletter)

WHAT IS THE AMBITION?

- Enabling a new potential to be realised in construction in the Australian market
- Establishing a responsive framework for the construction industry
- Creating more efficient, sustainable building solutions

WHAT IS THE INVOLVEMENT?

- Advice and insights about industry challenges and issues
- Advice and insights into industry labour and business context
- Funding partnership

8.1.2_WHAT DO PARTNERS WANT TO ACHIEVE?

- COMPETITIVE PLACEMENT
  Future partners want to be competitively placed in the market – the ETH example has shown that up-front investment in DF technology very quickly becomes cost neutral in a project. This allows the investor to run a niche business where they are the sole bidder in a growing market. Other competitors can then invest in DF technology with a different advantage to spread the capacities over a competitive network.

- FLEXIBILITY
  Companies want more flexibility from BIM between design and structure. This interface becomes disjointed between project stages with the different subcontractors.

- LOGISTICS + ASSEMBLY
  Companies want a system of onsite material logistics where BIM is coupled to methods of assembly.

- LOGISTICS + MOVEMENT
  Companies want an efficient logistics solution to the vertical + horizontal movement of material to and from sites.

- DIFFERENTIATED MATERIALS
  Companies want a system that can provide differentiated materials, such as mixed aggregate in concrete. This means less material on the construction site and therefore less embodied energy.

- GOVERNMENT INCENTIVES
  Companies want to tap into the Government incentives for having a carbon neutral site.

- STRATEGIC METHODS
  Companies want to find new strategic ways to lower ratio of building to inhabitable volume. New approaches to the development of strong, lightweight buildings using digital fabrication techniques can reduce material mass and therefore the onsite amount of carbon/embodied energy.

9.0_GROUP PLAN OUTLINE

9.1_SUMMARY

BRAND/IDENTITY
The DAB Digital Fabrication Research Group requires a coherent, visible brand to progress future industry partnerships, government funding and to attract future PhD researchers

STAKEHOLDER MANAGEMENT
The sub-consultants are the culture-changers and therefore a primary target group.

INTERDISCIPLINARY COLLABORATION
Create inter-faculty connections that lead to new test and experimentation platforms.

FUNDING RESOURCES
Internal UTS funding is needed for the first 12 months while the group is evolving.

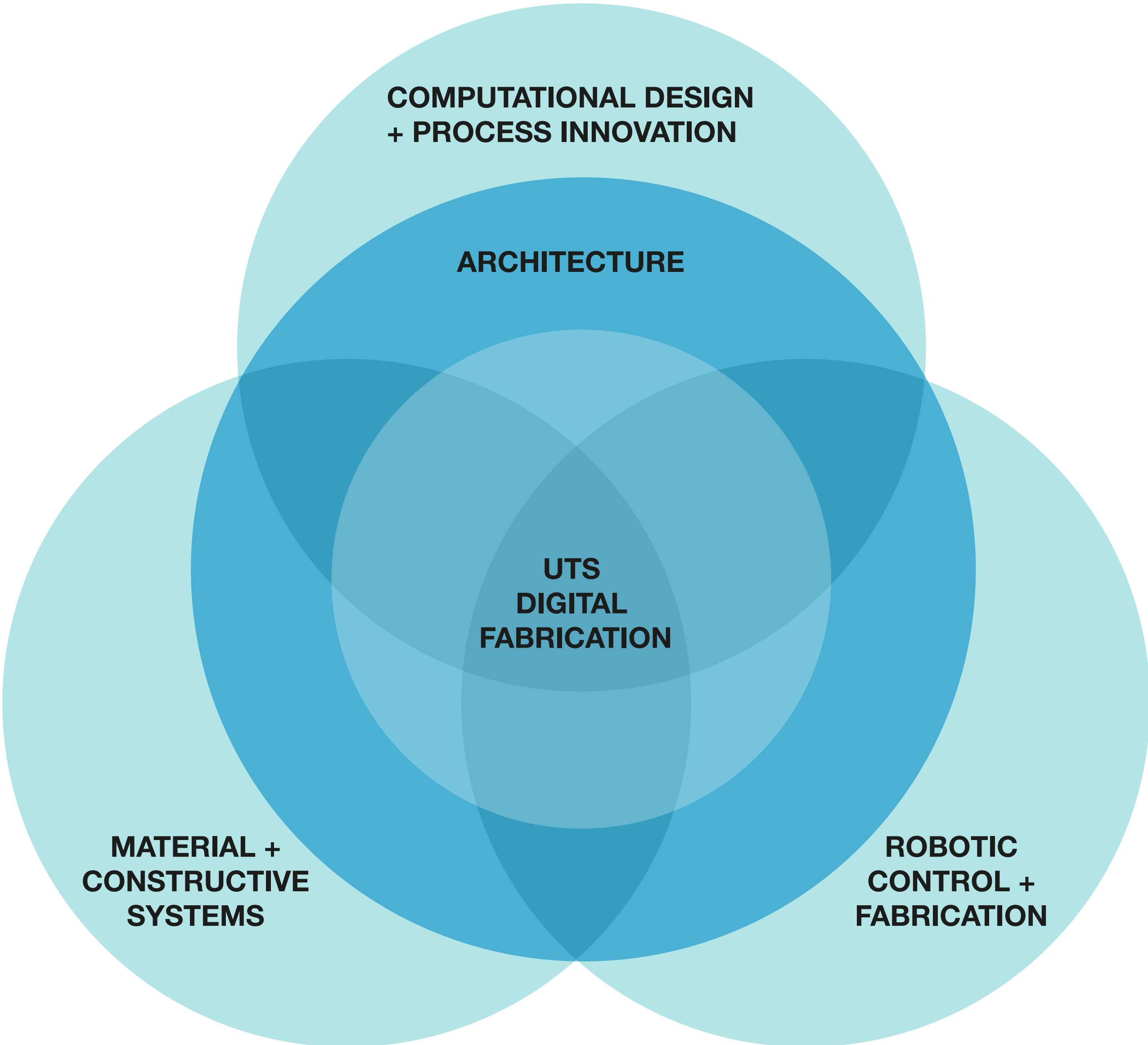


Figure 25: Venn diagram of institutional and industry positioning of the DAB DF Research Group (adapted from Russell Loveridge's NCCR model)

9.2_GROUP IMPLEMENTATION_ **TIMINGS/TACTICS/APPROACHES**

The following points reflect issues discussed in the Advanced Fabrication Research Workshop between 21st November – 25th November 2016 and relate to the implementation and ongoing development of a DAB Digital Fabrication Group.

GROUP REPRESENTATION/IDENTITY

- The DAB Digital Fabrication Research Group (DFRG) requires a coherent brand to progress future industry partnerships, government funding and in order to attract future PhD researchers. The brand needs to reflect the unique capabilities of UTS, and specifically, DAB.

- The brand will represent incoming researchers (Nimish Biloria and Tim Schork) plus the existing capabilities of existing staff members (Dave Pigram, Iain Maxwell) and Dane Vooderhake).

- There is also a need to establish an industry advisory group. Russell Loveridge (NCCR) will act in a consultative capacity regarding the implementation and management of this.

- The DFRG needs to be perceived as a key player in ‘innovation culture’.

GROUP/STAKEHOLDER MANAGEMENT PROCESS

- The DFRG needs to have someone in a role specifically devoted to the day-to-day management the group. This includes attending to the diverse requirements of administering the group’s brand identity and its developing relationship with external industry partners.

- In industry it is the sub-consultants who are the culture-changers and therefore this is a primary target group.

- The principal strategic driver for the group is COMMUNICATION:
    - 1:1 meetings with industry
    - City of Sydney
    - Liaise with potential industry partners via a monthly newsletter
    - Targeted recruitment of partners via quarterly industry breakfasts

TIMELINE

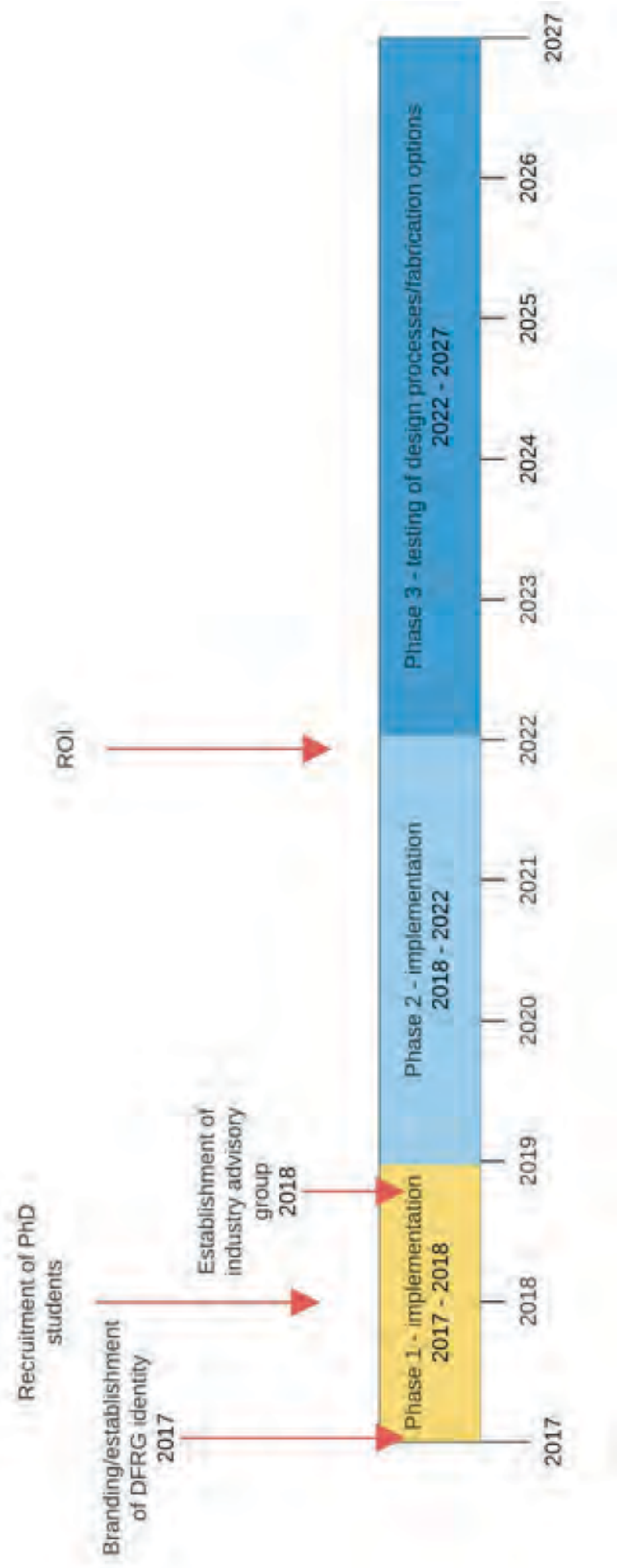


Figure 26: Proposed timeline for implementation of DAB Digital DAB Digital Fabrication Research Group

INTERDISCIPLINARY COLLABORATION

- Group production is interdependent within UTS - there are multiple interdisciplinary opportunities for collaboration, networks and cluster development.

- Create inter-faculty connections that lead to new test and experimentation platforms.

- Implement “boundary-crossing” skills of teamwork, communication, creative thinking and problem-solving.

FUNDING RESOURCES

- Internal UTS funding is needed for the first 12 months while the group is in its early establishment phase.

- Resources such as government grants and industry partnership funding can then be considered for projects/student training to change the culture over time.

- Industry partners can be approached to leverage funding as part of their corporate social responsibility.

10.0_REFERENCES

10.0_REFERENCES

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Scoping Report prepared by Dr Linda Matthews
https://www.uts.edu.au/dr-linda-matthews

11.0_APPENDIX

11.0_APPENDIX

This appendix contains a comprehensive and detailed account of the results relating to the three series of practical tests undertaken in support of this thesis.

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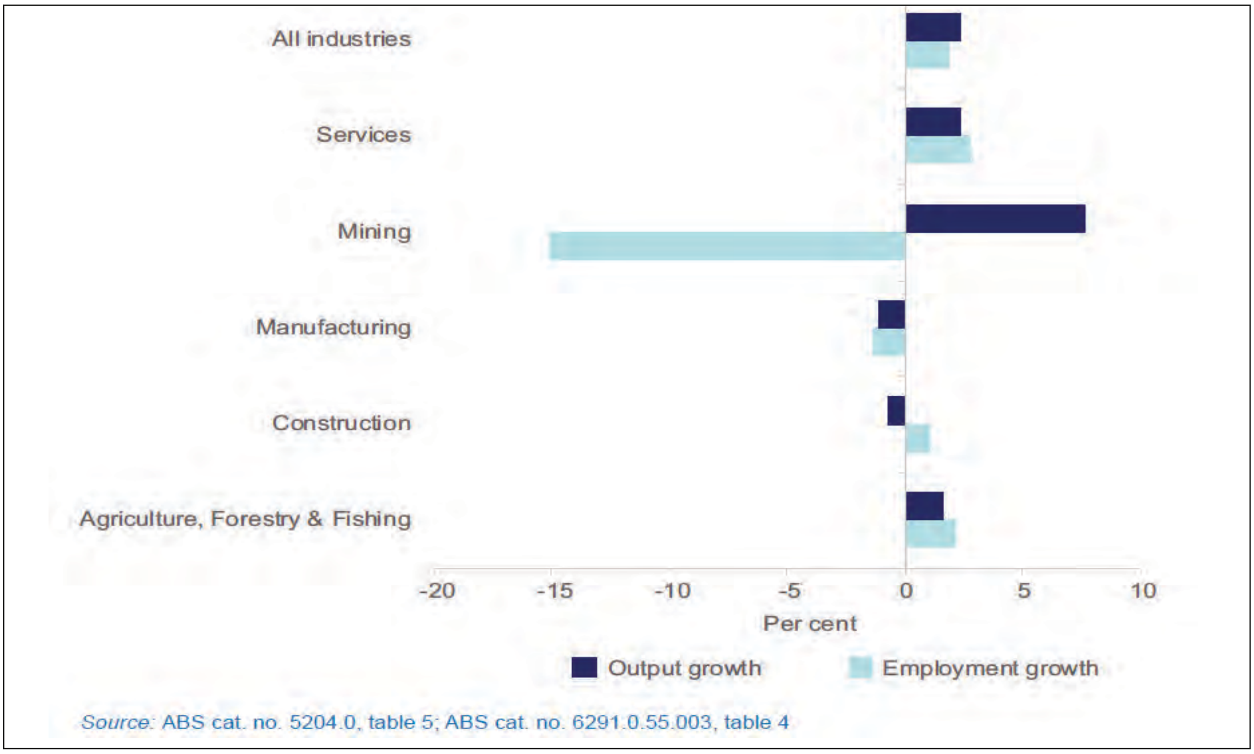


Figure A1: Growth in output and employment by industry 2014-15

2.3 THE DECLINE IN AUSTRALIAN CONSTRUCTION

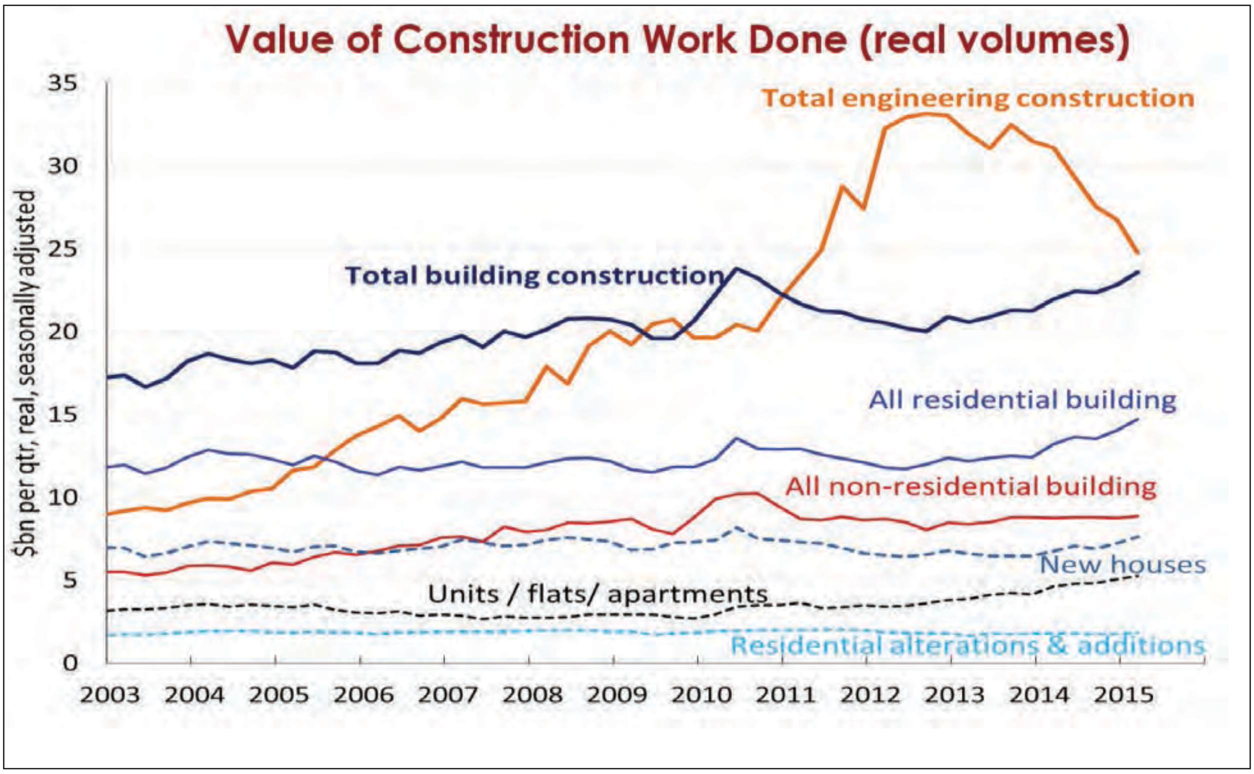
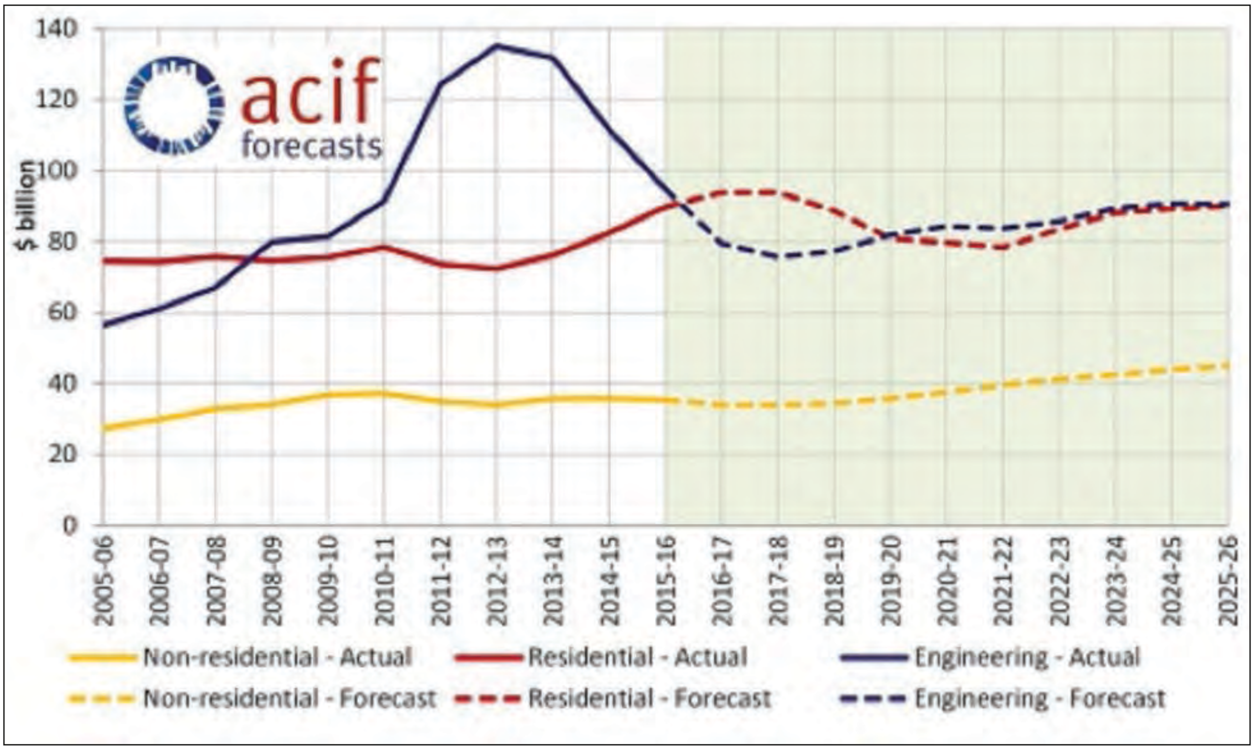


Figure A2: Value of construction work done 2003-15

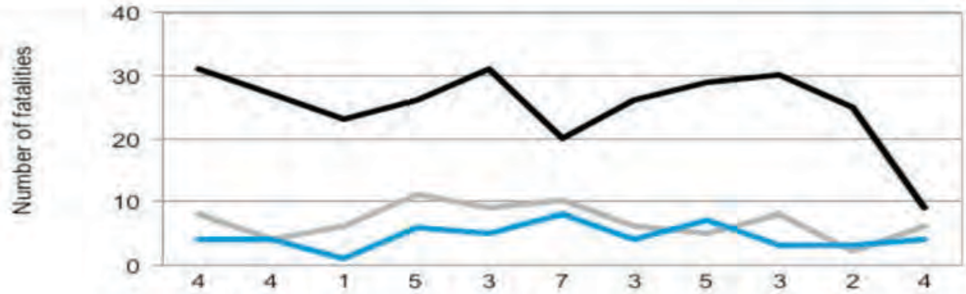
2.3.2 FUTURE GROWTH IN CONSTRUCTION



("New Acif Forecasts: Post-Boom Falls - and Rises", 2016)

Figure A3: Construction industry forcast 2005-26

2.3.6 LABOUR



	4	4	1	5	3	7	3	5	3	2	4
Construction services	31	27	23	26	31	20	26	29	30	25	9
Heavy & civil engineering construction	8	4	6	11	9	10	6	5	8	2	6
Building construction	4	4	1	6	5	8	4	7	3	3	4

Figure A4: Worker fatalities in construction industry 2003-13

Trends in manufacturing to 2020

A foresighting discussion paper

Future Manufacturing

Industry Innovation Council




Date: 30 September 2011

For more information, or to comment on the paper, please contact:

Manager

Future Manufacturing

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Canberra ACT 2601

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Future Manufacturing Industry Innovation Council
Discussion paper:
Trends in manufacturing to 2020

Executive summary

Australian manufacturing is a diverse and vibrant industry that plays a significant role in the economy. The industry employs close to one million people and its of total industry gross value-add was 10 per cent in 2010-11. In addition, manufactures accounted for one-third of Australian exports. Manufacturing is also an important driver of innovation in industry – being responsible for a quarter of research and development among businesses.

The industry is faced with both challenges and opportunities. Some of these are shorter term 'shocks', while others are longer term trends. Some, such as globalisation, ageing workforce and the small size of the Australian domestic market have been recognised for some time. Others are more recent, including requirements for low carbon production, the impact of terms of trade and the associated rise in the exchange rate of the Australian dollar. Global 'megatrends' resulting from population growth, economic growth, urbanisation, peak resources and societal changes are contributing both opportunities and threats over the medium term.

Technology, such as information and communication technologies and emerging technologies, is also driving 'disruptive' changes, providing major opportunities and challenges in product and production innovation which will enable the Australian manufacturing industry to respond positively to the challenges and opportunities.

A robust manufacturing sector of the future requires firms that are not only technologically sophisticated, but are also agile, adaptive, and efficient. This is only possible in firms that are knowledgeable, innovative and well managed, and which have access to skills as well as capital. Such assets provide the absorptive capacity needed by successful firms to embrace new knowledge, technology and innovative practices to increase productivity and competitiveness.

Thus, the resilience or robustness of Australian manufacturing lies in firms that:

- recognise that to succeed in the high value-add, low volume products in which they are likely to have a competitive advantage, they must bundle products and services to *sell solutions*, rather than simply tangible products;
- have the capability to identify, design, develop, make and sell products and services that *are in demand*;
- operate with high efficiency and productivity, allowing them to *optimise the use of their capital* – human, intellectual and material;
- have the ability to maximise leverage from *strong and sustainable partnerships* through local and global supply chains; and that
- *seek markets in emerging growth economies*, both by partnering in global supply chains, and by meeting demands from their growing middle classes for high value-add niche products, rather than low cost commodities.

Finally, there is often a tendency to view the innovation needs of an industry through a sectoral lens. A more system-wide approach to building an innovation system is required. Policies and programs that support the development of knowledge, skills, competencies and capabilities that can be effectively translated *across* industry sectors are likely to contribute to the future robustness of Australian manufacturing.

Background

The Future Manufacturing Industry Innovation Council (Future Manufacturing Council), in collaboration with the Department of Innovation, Industry, Science and Research, and the CSIRO Future Manufacturing Flagship, prepared this discussion paper on trends in manufacturing to 2020 at the request of the Enterprise Connect Manufacturing Advisory Committee.

The paper describes Australia's manufacturing industry as it is currently and discusses a number of emerging issues and trends that are affecting, and are expected to affect and influence, Australian manufacturers in the period leading up to 2020 and possibly beyond.

The paper collates informed views of a cross-section of stakeholders including industry, the R&D community, innovation advisory bodies, unions and the public sector.

The paper is intended to invite and provoke debate and discussion among relevant stakeholders on the implications of these, and potentially other, emerging issues on the future of innovation-driven, high value-add manufacturing in Australia.

Future Manufacturing Council

The Future Manufacturing Council is one of a number of Industry Innovation Councils established by the Australian Government.

The Council's focus is on innovation-intensive, high technology, high value-add, high-skill, export-orientated manufacturing. While its primary role is to advise the Minister for Innovation, Industry, Science, and Research, the Council is also championing innovation in manufacturing and helping to build connections between and collaboration with other innovation initiatives and organisations.

The Council has defined a vision for Australian future manufacturing:

> *A future manufacturing industry that provides innovative products and related service solutions to domestic and export markets in innovative ways, builds and retains its highly skilled workforce and is a vital enabler of highly productive and competitive Australian manufacturing.*

To that end, to establish priorities for its work, the Council has formulated a ***Strategic Roadmap for 2010 – 11***, which is at page 38.

Defining manufacturing

Manufacturing, for the purposes of the paper, is defined as including product development, innovation and commercialisation, design, production, manufacturing services and support. This is succinctly defined by the University of Cambridge's Institute for Manufacturing in its 2006 paper *Defining High Value Manufacturing*[1]:

> *…the full cycle of activities from research and development, through design, production, logistics and services, to end of life management…*

[1] http://www.ifm.eng.cam.ac.uk/cig/documents/DefiningHVM.pdf

Innovation, for the purposes of this paper, is defined as

> *… the implementation of new or significantly improved products, operational processes, marketing methods or organisational methods in business practice, workplace organisation or external relations. These innovations can be new to the firm/educational institution, new to the market/sector or new to the world.* [2]

The Council considers that Australia's manufacturing future lies in innovation-intensive, high technology, high value-add, high-skill, export-oriented manufacturing, rather than commodity products. These technologies also have the potential to benefit 'traditional' manufacturing.

> **Importance of 'low-tech' industries**
>
> It should be remembered that innovation-intensive processes are also a critical part of so-called low tech industries. For example, the development of a hard, wear-resistant coating for mining equipment that exhibits a longer life than the current weld overlays would be of enormous benefit. Increasing efficiencies by reducing down time for improved production is desirable and lucrative. … These low hanging fruit from what is perceived as low tech should not be ignored but actively encouraged. In fact it is proposed that successes in low tech ventures would have a more dramatic impact on the bottom line than a specialized, high-tech venture.[3]

Why is manufacturing important to the economy?

Recent experience with the Global Financial Crisis (GFC) highlighted the importance of maintaining the full spectrum of manufacturing capability in the broad economy. Evidence from Germany, Switzerland and other high value-add manufacturing countries in Europe demonstrates that business culture and economic policy settings have kept manufacturing a strong contributor to economic production, productivity and employment. This enabled Germany to survive the GFC much better than other leading developed economies. The US Chicago Manufacturing Renaissance[4] is advocating a similar approach of a manufacturing sector closely aligned with broader society, and especially education.

[2] OECD definition at: http://www.oecd.org/document/10/0,3746,en_2649_33723_40898954_1_1_1_1,00.html

[3] Professor Christopher Berndt of Swinburne University of Technology, comment on draft of the document

[4] http://www.chicagomanufacturing.org/

Importance of a diverse manufacturing industry

It is very difficult to establish and develop new and innovative industries in isolation from the rest of the industrial ecosystem. For example, in scaling up start-up businesses that will hopefully become future SMEs and ultimately successor industries, there is a need to cost effectively access many ancillary capabilities such as pressure vessel and furnace manufacture, fabrication, chemical analysis, electronics, drafting etc. These ancillary industries, while not necessarily 'high tech', can only exist where there is a deep and long term market for their services that will justify their establishment in a specific location. Their competitive advantage is through their relationship with customers, quality and agility.[5]

Profile of Australian manufacturing

Australia's manufacturing industry is diverse. It comprises industries ranging from those producing relatively low value-added commodity products such as some foods and beverages, and other simply transformed manufactures, to high precision, high value-add products including automotive and aerospace components, machine tools, medical devices, electronics, scientific instruments, advanced materials and pharmaceuticals.

Australia's manufacturing industry has grown steadily in absolute terms over the last decade, albeit at a slower rate than other sectors of the economy. The comparative growth of the industry sectors within manufacturing has not been uniform; Australia's manufacturing industry is characterised by change and diversity (see Table 1).

[5] Dr George Collins, Chief Executive Officer, CAST Cooperative Research Centre

Table 1: Industry gross value added of key industry sectors and manufacturing subsectors, and their growth rates.

	2000–01 ($b)	**2009–10 ($b)**	**2010–11 ($b)**	**Year on year % change 2009–10 to 2010–11**	**Average annual compound growth rate (%) 2000–01 to 2010–11**
Agriculture	**24.0**	**28.4**	**34.0**	**19.7**	**3.6**
Mining	**95.8**	**121.1**	**117.7**	**–2.8**	**2.1**
Services	**613.4**	**844.3**	**866.9**	**2.7**	**3.5**
Manufacturing consisting of:	**103.4**	**110.9**	**111.9**	**1.0**	**0.8**
Food, beverage and tobacco products	22.5	23.7	23.4	–1.2	0.4
Textile, clothing and other manufacturing	8.1	4.6	4.3	–6.8	–6.1
Wood and paper products	8.1	7.4	7.3	–2.3	–1.0
Printing and recorded media	5.4	4.5	4.5	0.2	–1.8
Petroleum, coal, chemical and rubber products	21.0	19.7	19.9	1.4	–0.5
Non-metallic mineral products	3.9	5.7	5.5	–3.1	3.6
Metal products	18.3	23.0	25.2	9.7	3.2
Machinery and equipment	18.2	22.3	21.9	–2.1	1.8

Source: ABS Cat. No. 5206.0.

Historical trends

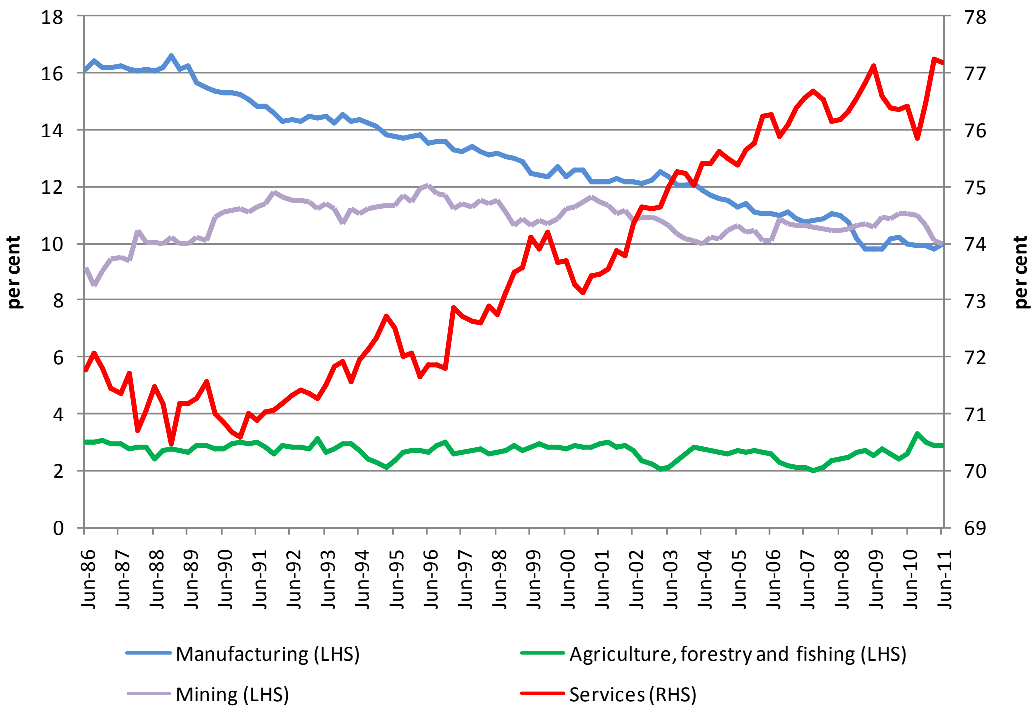
The Organisation of Economic Cooperation and Development (OECD)[6] notes that economic development in OECD economies has long been characterised by a gradual process of structural change. In the initial stage of economic development, agriculture typically accounts for the bulk of GDP and employment, as is still the case in many developing countries. In later stages of economic development, the share of agriculture in total industry value-added and employment typically declines, while the manufacturing sector grows more rapidly as economies industrialise. In recent years, many OECD economies (such as the United States, the United Kingdom, Japan, Germany and France) have experienced a decline in the share of manufacturing in overall employment and output, with a concurrent rise in the share of services.

[6] OECD 2006, *The changing nature of manufacturing in OECD economies*, OECD Directorate for Science, Technology and Industry working paper.

Australia's manufacturing sector, while growing in absolute terms over the past 25 years, has declined as a share of total industry gross value added (GVA)[7]. As can be seen in Chart 1 below, services sector GVA has increased rapidly over the past 25 years, outpacing all other sectors. Mining sector GVA has been increasing faster than manufacturing sector GVA, with both sectors now contributing a similar amount to the economy.

Over the past 25 years, the manufacturing sector's share of total industry GVA has declined from 16 per cent in the year to the June quarter 1986 to 10 per cent in the year to the June quarter 2011. In contrast, the mining sector's share of total industry GVA has increased from 9 per cent in the year to the June quarter 1986 to 10 per cent in the year to the June quarter 2011. The services sector remains the key contributor to the economy, with a percentage share of 77.3 per cent in the year to the June quarter 2011 (see Chart 1).

Chart 1: Industry gross value added, June quarter 1986 to June quarter 2011



Source: ABS Cat. No. 5206.0, quarterly data.

In absolute terms, the number of employed persons in the manufacturing sector has declined over the past 25 years, while employment in the services sector has increased rapidly over the same period. Since the onset of the mining boom, the number of persons employed in the mining sector has also increased rapidly, although off a low base. Despite the rapid increase in mining sector employment during the commodity boom, the manufacturing sector still contributes almost five times that of the mining sector to total employment. Manufacturing currently employs almost 1 million people (8.5 per cent of the workforce) and mining, over 200,000 people (1.9 per cent of the workforce).

[7] Total Industry GVA is equal to GDP minus *Taxes less subsidies on products, ownership of dwellings* and *Statistical discrepancy*

Manufacturing employment by subsector

As at the September 2011 quarter, manufacturing employment stood at 945,600 people, a net fall of -5.4 percent through the year from 999,400 people in the September 2010 quarter. Over the past 10 years, from September 2001 to September 2011, manufacturing employment has declined by 86,300 people or at an average annual rate of -0.9 per cent (see Table 2). The long-term decline in manufacturing employment reflects higher levels of labour productivity and capital deepening.

By industry subsector, trends in manufacturing employment vary. Through the year to September 2011, subsectors such as primary metal, and beverage and tobacco product have led the bulk of employment gains following the GFC. However, when employment growth is examined over the past 10 years, from September 2001 to September 2011, only food, beverage and tobacco product, and primary metal and metal product have experienced an increase in employment (see Table 2). All other manufacturing subsectors have experienced a decline in employment over the period. Once again, this trend in employment decline is consistent with higher productivity and capital deepening in the manufacturing sector.

Table 2: Manufacturing Employment by industry subsector (000's persons)

Industry	**Sep-2001**	**Sep-2010**	**Sep-2011**	**Year on year % Change**	**Average annual growth from Sep-2001 to Sep-2011**
Manufacturing, nfd	28.3	78.8	72.2	**-8.4%**	9.8%
Food Product	172.3	204.4	196.0	**-4.1%**	1.3%
Beverage and Tobacco Product	22.1	22.4	29.8	**32.8%**	3.0%
Textile, Leather, Clothing and Footwear	80.1	48.6	37.7	**-22.4%**	-7.3%
Wood Product	42.9	38.9	35.9	**-7.8%**	-1.8%
Pulp, Paper and Converted Paper Product	28.0	21.9	14.4	**-34.2%**	-6.4%
Printing (including the Reproduction of Recorded Media)	52.1	60.8	38.2	**-37.2%**	-3.0%
Petroleum and Coal Product	13.8	6.6	11.3	**70.7%**	-2.0%
Basic Chemical and Chemical Product	49.5	39.7	39.6	**-0.3%**	-2.2%
Polymer Product and Rubber Product	45.7	32.7	31.6	**-3.5%**	-3.6%
Non-Metallic Mineral Product	46.0	36.2	37.5	**3.8%**	-2.0%
Primary Metal and Metal Product	64.7	84.6	94.5	**11.6%**	3.9%
Fabricated Metal Product	82.5	56.6	54.9	**-3.2%**	-4.0%
Transport Equipment	104.8	86.1	80.7	**-6.2%**	-2.6%
Machinery and Equipment	121.7	122.5	110.1	**-10.1%**	-1.0%
Furniture and Other	77.4	58.4	61.2	**4.8%**	-2.3%
Total Manufacturing	1,031.9	999.4	945.6	**-5.4%**	-0.9%
Total- all industries	9,043.9	11,208.3	11,344.7	**1.2%**	2.3%
Manufacturing share	11.4%	8.9%	8.3%		

Source: ABS Cat. No. 6291.0.55.003 (original, detailed quarterly)

Manufacturing employment by state/territory

Victoria accounts for the largest share of manufacturing employees in Australia (31.8 per cent) followed by New South Wales (29.3 per cent) and Queensland (18.3 per cent) (see Table 3).

Table 3: Manufacturing employment by state, May 2011

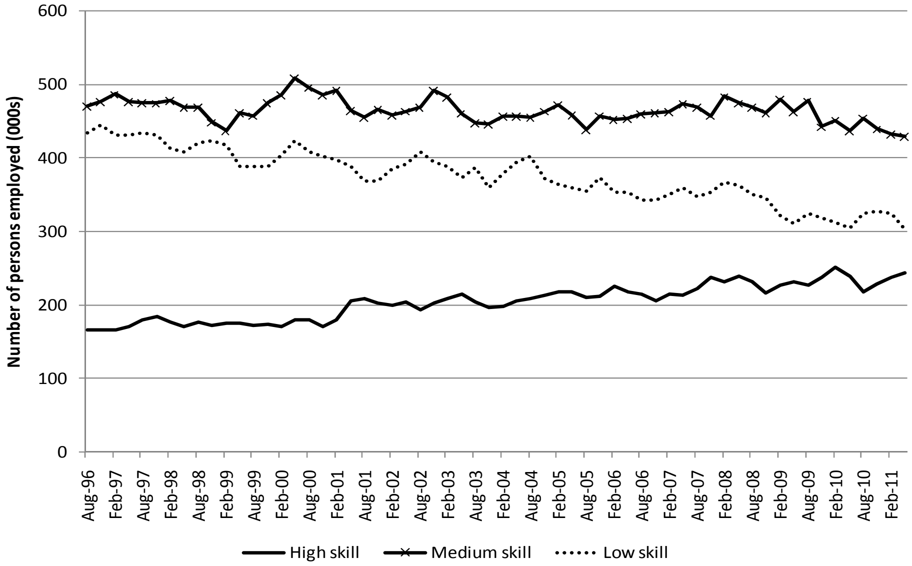
	000s persons	Manufacturing % share of total state/territory employment	State/territory % share of total manufacturing employment in Australia
New South Wales	285.9	8.0	29.3%
Victoria	310.0	10.8	31.8%
Queensland	178.6	7.6	18.3%
South Australia	82.2	10.0	8.4%
Western Australia	92.5	7.5	9.5%
Tasmania	21.0	8.9	2.2%
Northern Territory	3.1	2.7	0.3%
Australian Capital Territory	2.9	1.4	0.3%

Source: ABS Cat. No. 6291.0.55.003 (original, detailed quarterly)

Manufacturing employment by occupation

In May 2011, 25 per cent of employed persons in the manufacturing industry were classified as 'high skilled', up from 19 per cent in the corresponding period ten years earlier (see Chart 2). This general increase in high skilled workers is concurrent with a general decline in lower skilled workers in the manufacturing industry. Managerial knowhow, workforce skills and innovation capabilities are important for improving competitiveness in the face of structural change and cyclical and other short term shocks.

Chart 2: Manufacturing employment by occupation



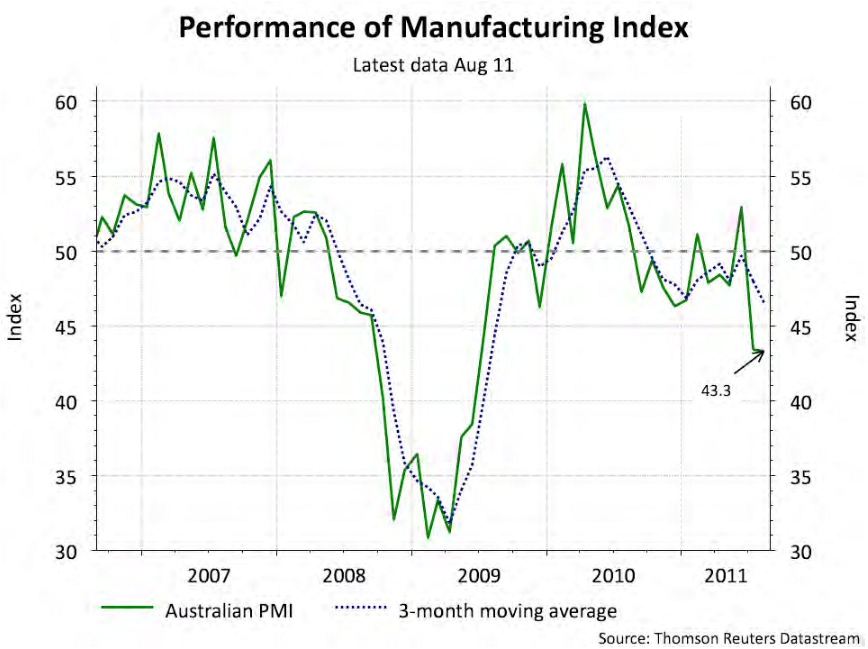
Source: ABS Cat. No. 6291.0.55.003

Note: High skill includes managers and professionals. Medium skill includes technicians and tradespersons, community and personal service workers, clerical and administrative workers and sales workers. Low skill includes machinery operators and drivers and labourers.

Manufacturing performance

The Australian Industry Group/PricewaterhouseCoopers Performance of Manufacturing Index (PMI) fell marginally by 0.1 index points to 43.3 in August (see Chart 3). The index remains below the 50 level which separates expansion from contraction. Survey respondents cited reduced domestic demand, the strong Australian dollar, increased foreign competition, high interest rates, uncertainty surrounding proposed carbon pricing and renewed weakness in the global economy as factors affecting the sector.

Chart 3: PMI index for August 2011



Manufacturing's contribution and linkages in a diverse economy

Like all industries, the manufacturing sector has strong linkages to other sectors in the economy. ABS supply-use data show that re-inputs from the manufacturing sector account for 40.5 per cent of intermediate industry inputs to manufacturing. The services and mining sectors also provide significant inputs to manufacturing. The manufacturing sector provides $161.5 billion of inputs to other sectors in the economy (see Tables 4 and 5).

Table 4: Industry inputs to manufacturing ($ billion, current prices)

	2006–07	% share
Agriculture, forestry and fishing	23.8	9.6
Mining	50.7	20.4
Manufacturing	100.7	40.5
Services	73.5	29.6
Total industry inputs to manufacturing	248.7	100.0

Table 5: Manufacturing inputs to industry ($ billion, current prices)

	2006–07	% share
Agriculture, forestry and fishing	7.9	3.0
Mining	12.1	4.6
Manufacturing	100.7	38.4
Services	141.5	54.0
Total manufacturing inputs to industry	262.2	100.0

Source: ABS Cat. No. 5209.0.55.001, Final release 2006–07 tables

Accurate measurement of the manufacturing sector

Part of the difficulty in preparing this paper, and indeed, in analysing the manufacturing industry in general, is measuring its actual size and hence the economic and social impacts of the sector.

Successful, growing manufacturing firms do much more than make products. They offer both manufactured goods *and* services to provide a *solution* to the client's needs. The services provided in such cases can be either explicit, such as pre and after sales service of a product, or embedded in the solution – or both. Those manufacturing firms that bundle their services with product offerings are more sustainably successful than others that do not.

Business models these days are often bundles of services which package a manufactured product or range of products and these may not be counted as manufacturing in the ABS data. In other words the size of manufacturing and related skills is significantly understated.[8]

For statistical purposes, an industry is a grouping of business units that are mainly engaged in undertaking similar economic activities. With these points in mind, official statistical classifications and attendant data collections should be revised to reflect the spectrum of value-add provided by manufacturers.

[8] Professor Roy Green of the University of Technology Sydney, comment on draft of the document

Trends to 2020 ... and beyond: Issues and opportunities for Australian manufacturing

Since the 1980s, manufacturing in Australia has undergone substantial structural change influenced by a number of factors including trade liberalisation, removal of industry protectionist policies and economic regulation of markets, falling transportation costs and improved information and communications technology (ICT).

Moving towards 2020, Australia’s manufacturing industry will be confronted with new opportunities and challenges resulting from the convergence of factors external and internal to Australia. Some are shorter term economic and/or environmental shocks, while others are longer term periodic trends.

The current strong global demand for Australia's resources, particularly from China and India, has driven the terms of trade to record levels with the consequential rising and volatile exchange rate. And, the effects of the GFC continue.

Australia's workforce demographic is changing, while Australia and other countries are experiencing the maturity of changes resulting from the widespread application of ICT. The impact of structural adjustments resulting from ICT will continue.

Emerging global megatrends will influence and shape the future of Australian manufacturing. These include increasing resource scarcity and climate change, urbanisation and increased affluence, people on the move, divergent demographics and the economic growth of developed and developing nations such as Brazil, Russia, China and India (BRIC) with consequential market demand and competition.

The scarcity of many natural resources (such as petroleum, rare earths, readily-accessible metals), calls for greater environmental sustainability and the growing importance of a low carbon economy are giving rise to the emergence of leading edge of 'Sixth Wave' innovations. The innovations include biomimicry, green chemistry and green nanotechnology, whole system design, industrial ecology, greater resource productivity, sustainable energy and satellite technologies.

Australia's manufacturing industry has responded positively to the challenges and opportunities that have faced it since the 1980s to now. It has transformed itself by adapting and repositioning itself to engage in higher value-added activities and become more outward focussed – increasing exports and reaching into global markets. The success and continued prominence of manufacturing in Australia’s economy will depend on appropriate responses from business and government to the new and emerging challenges and opportunities. These responses will include leveraging innovation to drive increases in productivity, sustainability and global competitiveness, and integrating into increasingly complex global supply chain markets.

Terms of trade driving value and volatility of the Australian dollar and structural changes in the economy – an upside to manufacturing and associated downstream industries

The rising demand for Australia's resources is driving Australia's terms of trade higher. This and other global financial market movements are driving higher currency exchange rates and volatility. In turn, there are consequential structural changes in the economy.[9]

[9] Sydney Morning Herald. 4 May 2011. *$A staying high: ANZ* - http://www.smh.com.au/business/a-staying-high-anz-20110503-1e6tg.html#ixzz1R6tFElQM

Some economists predict this situation will continue for the foreseeable future, and this can be expected to will bring about altered usage patterns of inputs and consumption. For some time now, this has made Australian manufactured exports generally less competitive in the global marketplace. This is particularly so for those who compete on price rather than value for money.

In these conditions, trade-exposed manufacturers will be pressed to establish a competitive advantage in order to survive. Innovation provides solutions where it leads to reduced costs, increased productivity, and new or more appealing products and services. Conversely, a strong Australian dollar may support manufacturing industries with links to Australia's natural resource endowments.

However, an upside to the strength of the resources sector is the creation of high-wage jobs for Australians, and innovative, high value-add products and services to mining and associated firms both here and abroad.[10] Opportunities exist in exploiting downstream markets in the mining sector by supplying traditional goods and services or carving out niche markets. Examples include the manufacture and/or the provision of mining equipment and instrumentation, software, explosives, energy systems, transportation equipment and services, scientific research services through to personal protective technologies for miners.

Adding value to Australia's minerals

Australia has the world's largest reserves of titanium ore, as well as the technological know-how to turn ore into high value added manufactured metal products. There is a very wide range of high-end uses for titanium, including medical implants and aerospace components.

Today, most of our titanium ore is shipped overseas, and brought back after processing. Based on current mining and export volumes, it is estimated Australia has 90 years of this resource remaining. However, the value of titanium alloy metal in the world market is 100 times greater than that of titanium ore. CSIRO is developing technology to convert ore to titanium metal alloy. If Australia were to grow a local industry that converted its ore to alloy metal, it could maintain its current value of exports and effectively extend its natural ore resource by a factor of 100 (90 years to 9,000 years)[11].

As promising as these facts are, they raise the question of why commercial investment in such activities occurs elsewhere but not in Australia.

A strong exchange rate is likely to benefit industries naturally protected from import competition, especially by reducing import costs; although globalisation seems to reduce the range of what were once considered 'naturally protected' sectors.

In addition, a strong exchange rate may offset to some degree, the costs of imported capital and other items that are used by trade exposed manufacturing industries. This may

[10] Australasian Institute of Mining and Metallurgy, 2006. Submission to House of Representatives Inquiry into the state of Australia's manufactured export and import competing base now and beyond the resources boom. http://www.ausimm.com.au/content/docs/state_aust_manufactured_export.pdf

[11] http://minister.innovation.gov.au/Carr/Underthemicroscope/Pages/default.aspx

have a positive impact on capital deepening, productivity and the competitiveness of Australian manufacturing industries. A less positive possibility is for firms to rely on 'off-the-shelf' imported innovation, rather than developing proprietary intellectual property with the potential to provide a competitive advantage.

One response to a high-value, fluctuating currency is for Australian firms to draw on the opportunities presented by free trade agreements. These allow Australian industry to 'offshore' the low value adding, high labour content aspects of production, while keeping high value adding onshore. However, such strategies must be dealt with on a case-by-case basis. For example, the Scania Group considers that as long as the total cost of labour does not exceed 15 per cent of their cost base, the disadvantages of offshoring outweigh the advantages[12].

Other options for responding to currency fluctuations are for Australian firms to make use of financial instruments such as currency hedging and pricing their traded products and services in other foreign currencies. Financial innovation is therefore a valuable accompaniment to technology, management and organisational innovation.

Interdependency of manufacturing and associated services

To compete globally, firms need to provide innovative solutions and services that exploit revenue streams other than those arising from simple production.

Sell solutions – products bundled with value-adding services

The ability of manufacturing firms to provide solutions, rather than simple items of production, and the growing role of manufacturing services and support is of increasing importance.

Such behaviour is evidence of Australian firms transforming themselves from just a manufacturer or service provider to a total package problem-solver for their customers.

It is a smart move to add services to products because it is less risky to develop new services than new products. Services have ever-expanding boundaries and are not constrained by what the product can be first seen to do. A firm that provides services does not have to retool or invest in expensive and untried technologies.

The move made by Australian firms to 'selling solutions' is a competitive response so that they can succeed in an increasingly volatile and globalised business environment of cheaper products, shorter product cycles, faster business imitations and saturated markets.[13]

The capacity and willingness of firms to implement, manage and enforce appropriate intellectual property protection will also be vital to their success.

[12] Roos, Professor Göran. 14 July 2011. Presentation to the chairs of the Innovation, Industry, Science and Research portfolio's innovation bodies.

[13] Kennedy, Narelle. 22 August 2002. *Manufacturing New Competitive Strategies*. Australian Business Foundation

Technological advances

Research and development has underpinned the development of innovative and higher value-added products and services which have been a source of competitive advantage for many Australian manufacturing industries. It has also been vital to the development of new production processes that have lowered manufacturing costs, improved quality and driven economies of scale. Such developments also offer opportunities for Australian innovators to license their technology for both domestic and overseas use. Conversely, manufacturers may also choose to adopt and adapt existing technologies from domestic and overseas sources to introduce new production processes and/or products which add value, lower costs and raise productivity.

The ability of firms to be aware of and exploit disruptive technology, technological advances and world's best innovation practices will be key to ongoing success.

Key enabling technologies such as nano technology and biotechnology, rapid prototyping and additive manufacturing are expected to support the development of new and improved manufacturing industries and higher value-added products, together with improved production processes. These are likely to increasingly play a prominent role in enabling such mass customisation. Such technologies also provide the opportunity for low volume manufacturing without relatively expensive set up costs, potentially allowing the localisation of manufacturing – as opposed to off-shoring to locations where economies of scale can be otherwise achieved.

Increasingly, ICT-enablement is allowing manufacturers to adapt and exploit new technological product and service offerings, opening new opportunities and pathways to competitiveness and wealth creation for Australian manufacturers[14] [15]. Over the last decades digital computing, communications and the ICT revolution have had a profound impact across manufacturing industries, shifting them towards more agile, just-in-time processing, high-performance manufacturing, and accelerated introduction of new products. As we head towards 2020, the convergence of nanotechnology, biotechnology, cognitive and neuroscience with ICT is expected to cause similar disruptive changes[16].

Increasingly manufacturers will need to leverage the power of knowledge networks and digitised manufacturing technologies such as computer integrated manufacturing (CIM) that allow flexible manufacturing of multiple product lines and do it without necessarily increasing their manufacturing footprint. While the need is recognised, there is currently a significant gap, and hence an opportunity to develop the design and production systems to address it.

Advances in CIM and the ability to move large amounts of information through broadband networks will in many cases enable manufacturing companies to operate remotely from the location of production or of markets. This potentially reduces the geographical constraints on manufacturing and allows Australian companies to operate more effectively through global supply chains.

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[14] Pricewaterhouse Coopers, 2009. The future of UK manufacturing: Reports of its death are greatly exaggerated, http://www.pwc.co.uk/eng/publications/the_future_of_ manufacturing.html

[15] Davies, A., Brady, T., et al, 2003. Delivering Integrated Solutions, University of Sussex, SPRU – Science and Technology Policy Research, Centre for Research in Innovation Management, Engineering and Physical Sciences Research Council, Imperial College.

[16] Australian Business Foundation. April 2011. Manufacturing Futures – A paper by the Australian Business Foundation for the NSW Business Chamber

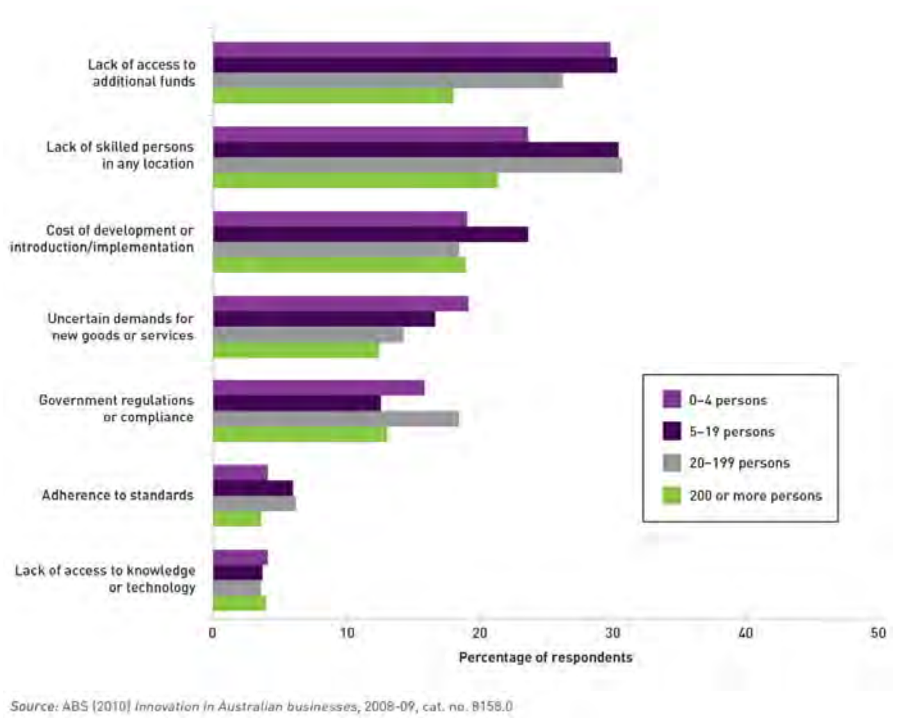
The National Broadband Network will be a key piece of infrastructure that will allow for process improvements within manufacturing firms. For example, it will facilitate the uptake and use of CIM across all aspects of the manufacturing process, resulting in productivity gains at the firm level. CIM will improve efficiencies across the supply chain, as well as enabling the rapid prototyping and product customisation mentioned elsewhere in this paper.

Related to CIM are other computer-enabled, networked technologies such as smart grids, mini-grids and building management systems which offer both increased efficiencies in their application, and opportunities for developers and manufacturers as the global economy adopts these technologies.

Increasing skills requirements for precision, high value-add manufacturing

A highly skilled, well managed workforce, combining an appropriate mix of leadership, professional, technical and trade skills is essential for Australian manufacturing industries to innovate, adopt improved technologies and remain globally competitive in the future. Chart 4 illustrates that the lack of access to skilled employees is a major barrier to innovation.

Chart 4: Barriers to innovation for innovation-active Australian businesses 2008-09



Source: Chart 3.5 from the *Australian Innovation System Report 2011*

Highly skilled jobs continue to be created as Australian manufacturing responds to the productivity and competitiveness challenges by investing in capital equipment that embodies ICT and enables computer-aided design, computer integrated manufacturing and digital additive manufacturing. As firms package value-added services with their manufacturing solutions, highly skilled service jobs will be created. Many of these jobs will be office-type jobs. These types of jobs will be more attractive to the tertiary trained staff they require. That said, Australia's precision manufacturing jobs have attractive work environments.

An ageing Australian workforce could contribute to future declines in manufacturing employment due to natural attrition. The consequential loss of both formal and tacit knowledge held by those highly skilled employees will also pose problems for firms.

Competition in the labour market for skilled employees and trainees is intense. Many new entrants to the workforce are pursuing careers outside manufacturing industry. Consequently, the ability of firms and the industry as a whole to market manufacturing as a viable and rewarding career path will be vital to recruiting new generations of employees.

The lead time between action to increase levels of training and people actually taking up positions in industry is in the order of years. Education and training of the workforce at the firm level is therefore a strategic issue for the long term survival of the firm. This will require firm managers to fully appreciate human resource management issues and be aware of training assistance that is available.

Hence, recruiting or training employees with the necessary skills to embrace and implement technological advances and continuous innovation will be increasingly important for the success of manufacturing firms.

There is strong anecdotal evidence that Australia is not training sufficient people with necessary trade or professional skills, leading to the need to recruit skilled workers from overseas. At the more fundamental level, Skills Australia has indicated that 43 per cent of the Australian workforce has literacy problems and 47 per cent has numeracy problems[17]. While this might not be the case for high value-added manufacturers, it is important to note that approximately 50 per cent of workers in the manufacturing sector do not have a vocational qualification.[18]

To address this, firms need to consider appropriate in-house training, succession planning and mentoring so that skills are not lost. Industry involvement with the education system and a greater commitment to in-the-workplace training, including apprenticeships, will also be important in ensuring employees have relevant skills and experience.

Productivity growth

Productivity is a measure of the ratio of inputs, such as labour, materials and capital to the production of outputs in the form of goods and services. Growth in productivity is essential for the competitiveness and viability of Australian manufacturing industries in the domestic and global markets, and for sustaining long term increases in Australia's national income and standard of living. The OECD report, *Australia: Towards a Seamless National Economy, 2010* noted 'Australia needs to boost productivity to return to long-term sustained growth...'

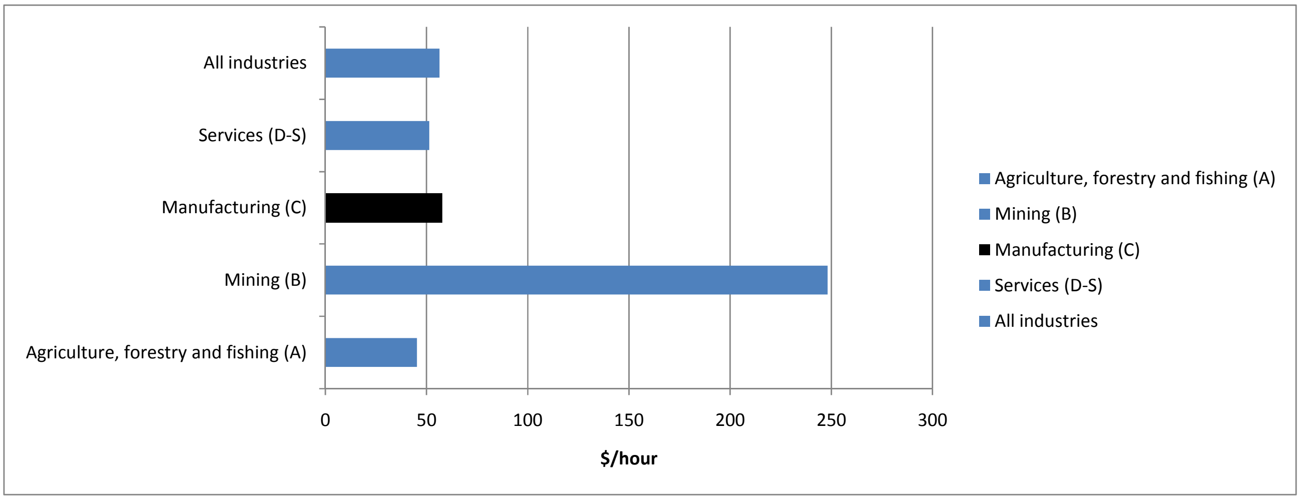
[17] Skills Australia .2010. Australian Workforce Futures - A National Workforce Development Strategy. http://www.skillsaustralia.gov.au/PDFs_RTFs/WWF_strategy.pdf

[18] David Pettigrew, QMI Solutions Ltd

As one measure of productivity, labour productivity is measured as industry gross value added per hour worked. Labour productivity in the manufacturing industry grew at an average annual rate of 1.8 per cent from FY 2000-01 to FY 2010-11. This compares to the labour productivity for all industries, which grew at an average annual rate of 1.2 per cent for the same period.

Chart 5 shows that in FY 2010-11, manufacturing labour productivity was above the average for all industries and was the second only to, and lagging behind, the mining sector.[19]

Chart 5: Labour productivity, FY 2010-11



A 2011 report from the Grattan Institute indicated that Japan and a collective of European nations experienced negative growth in labour productivity in manufacturing between 1990-2000 and 2000-07.[20]

However, despite growth in labour productivity, the competitiveness of the Australian manufacturing sector declined compared to Europe and the USA as Chart 6 shows:

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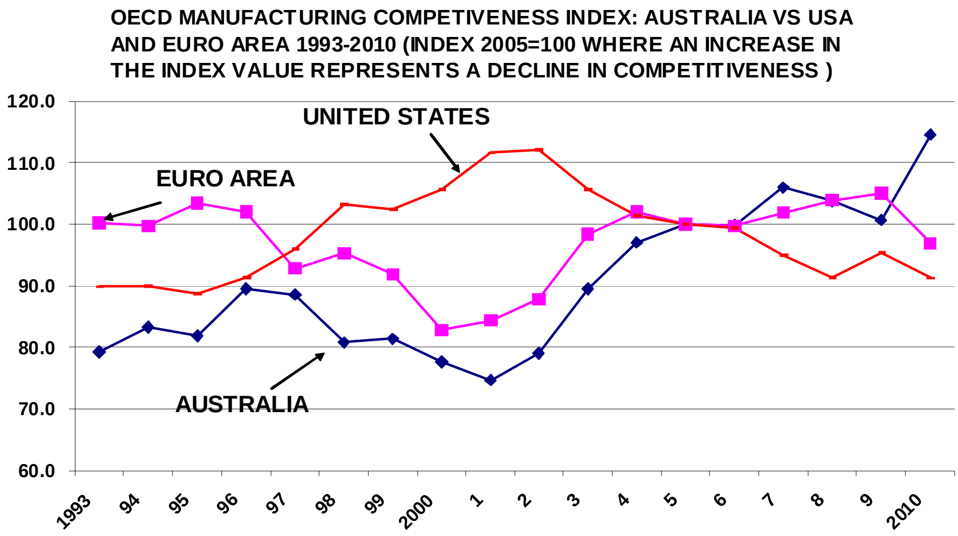
[19] Labour productivity values are DIISR estimates derived from ABS Cat no 5206.0 and ABS Cat no 6291.0.55.003, and expressed as financial year averages.

Note: Sectors grouped according to ANZSIC 2006 and services sector includes ANZSIC Divisions D-S.

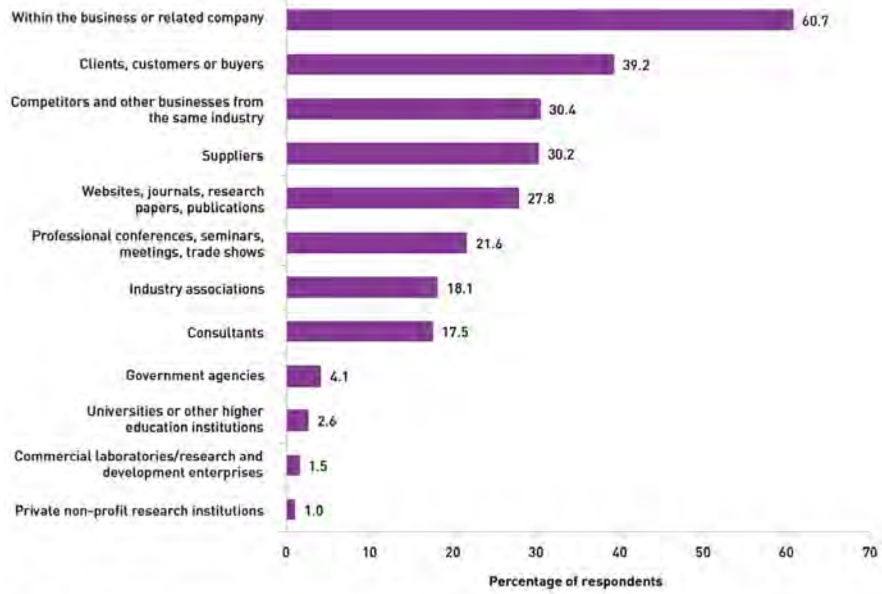
[20] Eslake, S. 2011. *Productivity*, paper presented to the annual policy conference of the Reserve Bank of Australia 15-16 August 2011.

Chart 6: OECD Manufacturing Competitiveness Index: Australia vs USA and Euro Area



Innovation is recognised as a driver of productivity and is an important factor in achieving the Australian Government's productivity agenda. Many studies on innovation have found that up to 40 per cent of innovation ideas come from customers. Chart 7 (source Chart 4.1 from the *Australian Innovation System Report 2011*[21]) illustrates sources of ideas or information for innovation-active Australian firms in 2008–09.

Chart 7: Sources of ideas or information for innovation-active Australian firms, 2008-09



Source: ABS (2010) *Innovation in Australian Business 2008–09* cat. no.8158.0

Innovation goes beyond the development and implementation of new or significantly improved products. It includes the implementation of new or improved operational

[21] Department of Innovation, Industry, Science and Research. 2011. *Australian Innovation System Report 2011.* http://www.innovation.gov.au/AISReport

processes, marketing methods or organisational methods in business practice, workplace organisation or external relations. These innovations can be new to the institution/firm, new to the market/sector or new to the world.[22]

Many firms, especially SMEs, view productivity and competitiveness as simply cost-reduction exercises, i.e. short-term actions. However, cost reduction and importantly the reduction of waste in all its forms is a strategic issue and needs to be integrated with technology, human capital and innovation in order for long-term productivity improvement to be sustained. For example, implementation of new systems and processes such as computer integrated manufacturing and lean manufacturing can significantly improve firm productivity.

Ensuring that firms identify and implement world's best practice in management, process and product innovation will be vital to success of manufacturing into the future. The leadership group in each firm is responsible for soundly judging their firm's business environment – the external challenges and opportunities – and their firm's strengths and weaknesses. With this information the leadership group must then make appropriate business decisions on what actions to take that will ensure the longer-term sustainable competitiveness of the firm. This has to be followed through with an implementation plan that achieves the firm's strategic objectives.

While new product and service innovation are seen as significant drivers of productivity, insufficient knowledge of human-capital management remains a major barrier to productivity gains for many companies. Human-capital management is necessary for firms to make appropriate, strategic decisions on the investment and best use their assets.[23]

The *Management Matters in Australia* report of 2009 by Professor Roy Green identified the contribution of management skills to firm productivity. It benchmarked Australian management practices against 15 other countries using 18 management criteria. Australia was ranked slightly above the average at 6th place, but behind other advanced economies. The report rated the management practices of Australian firms '…as only moderately above average when benchmarked globally'. In this respect, the report noted that many of our firms are being outperformed by the best of our competitors in China and India. The report noted that while Australian businesses do well in managing operations, there was significant scope for consistent and sustained improvement in key areas such as people and strategic management. The report's evidence indicates that while companies may offer innovative products, services or solutions, there is potential for improved productivity returns from investment in the people skills of managers and the associated culture change.

The lack of productivity growth in the wider economy has recently been highlighted as a barrier to success for many Australian firms. Given the challenges facing manufacturers described in this paper, the ability of Australian manufacturing to raise productivity sustainably will be vital to success in the medium to long term.

Ensuring that firms identify and implement world's best practice in process and product innovation will be vital. Management and organisational innovation will be necessary precursors to realising world's best practice. Furthermore, to be competitive, firms will need to ensure that any gains in productivity are made in line with the principles of 'green

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[22] See also, the OECD definition at: http://www.oecd.org/document/10/0,3746,en_2649_33723_40898954_1_1_1_1,00.html

[23] *Gearing for growth – future drivers of corporate productivity.* A report from the Economist Intelligence unit (2011).

growth'. From this perspective, 'resource productivity', that is, how efficiently and sustainably manufacturers utilise materials, energy and water inputs, can be expected to become increasingly important.

Sustainable growth

Policy framework conditions in Australia and foreign markets

Government policy framework conditions and regulations will be an important driver in the competitive success of domestic firms through to 2020. In particular, policies that create an environment in which firms can grow are essential. In this respect, consistency of government policy settings is a recurring theme raised by industry in Australia and overseas. Investment is most likely to occur in an environment of reasonable certainty, and government must balance the conflicting challenges of providing a stable policy framework, while being flexible and responsive to changing economic and social conditions.

In this respect, initiatives such as the Government's *Industry Innovation Councils* are an important contribution to building an innovation culture in Australia. The Councils are charged with providing strategic advice on innovation priorities to the Minister for Innovation, Industry, Science and Research, championing innovation in industry, and building connections and collaboration across Councils and with other innovation initiatives. By increasing the flow of information and ideas across the various 'silos' in society, better policy, programs and regulation, and better use of these initiatives by industry and the research community can be expected.

A supportive regulatory environment is essential for the proper functioning of society and sustainable economic growth. The challenge for government is to deliver effective and efficient regulation that addresses an identified problem and benefits to the community, taking account of the costs.[24]

Such outcomes are a particular challenge in federal systems, with a tendency for regulation to be either duplicated across levels of government, or subtly inconsistent between jurisdictions – adding to business costs in both cases. Hence, regulation reform has been a focus of the Council of Australian Governments for some years.

Given these challenges, effective engagement between government and industry stakeholders can address the potential for problems created by regulation. It ensures mutual understanding of the problem, alternative options to address it, potential administrative and compliance mechanisms, and associated benefits, costs and risks. It also facilitates greater transparency in regulatory processes. This can improve accountability as well as address issues concerning regulatory failure, such as regulatory capture, rigidity, market uncertainty and inability to understand policy risk. [25]

Hence, firms' understanding of the regulatory environment in which they operate is an important factor in maintaining and improving their competitiveness. This extends to their awareness of the regulations – tariff and non-tariff barriers – applying in potential export markets.

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[24] Office of Best Practice Regulation. Accessed 5 Sep 2011. http://www.finance.gov.au/obpr/proposal/handbook/1-productivity-and-regulation.html

[25] Office of Best Practice Regulation. Accessed 5 Sep 2011. http://www.finance.gov.au/obpr/proposal/handbook/1-productivity-and-regulation.html

Environmental regulations – securing a social licence to operate and compete in increasingly greener markets

The recognition of a changing climate, the increasing scarcity of some key natural resources, and the need to adapt to a carbon-constrained future, has resulted in increased demand by consumers and governments for sustainable products and services. Some national governments, such as in Europe and South Korea, are responding to these emerging trends with growth and innovation policy frameworks and strategies.

Green growth means fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies. To do this, it must catalyse investment and innovation which will underpin sustained growth and give rise to new economic opportunities.

Environmental regulations and their enforcement are becoming increasingly stringent in both Australian and global export markets. For example, in all parts of Australia, governments are increasing landfill levies. These levies will continue to put pressure on both manufacturers and retailers to make and sell products with less packaging or with greater recyclability.

Product stewardship in Australia

Australia consumes over 1.5m tonnes of largely hydrocarbon-based plastics annually, of which less than 20 per cent is recycled. Product stewardship regulation has been successfully implemented in various parts of Europe, while the Australian Government launched product stewardship programs for rubber tyres and computer screens under its *National Waste Management Policy* of 2010. In June 2011 landmark product stewardship legislation was passed in the Australian Senate. The scheme aims to increase television and computer recycling rates from the current 10 per cent to 80 per cent by 2020-21. It is likely that in the future, other product classes will be included and a regulatory impact statement is currently being prepared on a range of measures to address packaging waste and litter, including container deposits, with public consultation expected to begin later this year.

This growing trend in environmental regulations, both in Australia and overseas markets expands the traditional role of the manufacturer to include the responsible disposal of products at the end of their service life.[26]

High-value market opportunities will exist for those proactive manufacturers that understand and reduce their environmental footprint of their products and production processes. High value products and services will be differentiated from their competitors on the basis of whole-of-life – that is the innovation, design, production and end-of-life management.

The recent release of the *Building Products Life Cycle Inventory* developed by the Building Products Innovation Council (a private sector body) provides an example of how

[26] http://www.environment.gov.au/minister/farrell/2011/mr20110615.html

manufacturers can develop the necessary knowledge to reduce the life cycle impacts of their products.[27]

Sustainable products and services cover the entire spectrum from low to high value-added outputs. The 'green jobs' created by these emerging markets will require a workforce with an increased understanding of and training in sustainability principles and competitiveness.

Operating in a resource constrained world – 'doing more with less'

There is mounting evidence that many natural resources are reaching their peak in terms of availability at either reasonable cost or quality. This includes non-renewable minerals and fossil fuels. Many of the high-grade ore deposits that underpin the success of the Australian minerals industry are now depleting or experiencing declining grades and quality.[28] There is scarcity of fresh water resources relative to demand[29] and energy demand is forecast to rise throughout the world in the coming decades.

In the book *The Sixth Wave - how to succeed in a resource limited world*[30], the authors suggest economic growth will eventually be decoupled from resource consumption and waste production. Resources will be valued and priced on the basis of a shift in assumptions from 'resources are cheap and plentiful' to 'resources being seen as scarce and valuable'.

Competition for materials will put pressure on manufacturers to make the best use of available resources and to respond by improving the efficiency of production. From a manufacturing perspective there will be a need to closely examine the effective use of virgin feedstock, the selection and availability of substitute or alternative feedstock, the re-use of waste or unused material and the need to give due consideration to energy and water efficiency during the manufacture of products. 'Cradle to cradle' will become the norm.

A report produced by the UK manufacturers’ organisation, EEF Limited, in conjunction with Barclays Commercial Bank suggests that businesses spend around 5 per cent of turnover on waste, including unused materials, defects, energy and water, and points out that 90 per cent of materials used in production do not find their way into the final product.[31]

Resource efficiency can and should occur at both product and processing levels in the manufacture of commodities such as chemical or feedstock material and the production of both simple and elaborate manufactures. For example:

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[27] http://www.bpic.asn.au/LCI

[28] Mudd, G M, 2009, The Sustainability of Mining in Australia: Key Production Trends and Their Environmental Implications for the Future. Research Report No RR5, Department of Civil Engineering, Monash University and Mineral Policy Institute, Revised - April 2009.

[29] UN, 2006. Coping with water scarcity: A strategic issue and priority for system-wide action. United Nations Thematic Water Initiatives, New York.

[30] Moody, James Bradfield and Nogrady, Bianca. 2010. The Sixth Wave - How to Succeed in a Resource Limited World

[31] http://www.greenwisebusiness.co.uk/news/report-calls-on-manufacturers-to-increase-resource-efficiency-320.aspx

- Improved chemistry technology, enabling manufacturers to carry out simple and complex chemical transformations faster, more efficiently, with fewer processing steps, while offering reduced cost and lower environmental impact.
- Additive and direct manufacturing processes that convert raw materials (such as metal, ceramic or plastic) more directly to finished products without many intermediate steps, using less materials and minimising waste.
- The use of advanced materials that provide high performance and multi-functionality allowing manufacturers to make products with less materials and lower overall weight without sacrificing performance.
- Materials can be designed or treated to impart desired properties such as being biodegradable, recyclable or re-engineered after the product’s end-of-life phase.
- Sophisticated packaging methods extend the shelf life of products; notably foodstuffs.

While manufacturers can innovate to achieve resource efficiency at factory or company level, most businesses operate within complex supply chains. The interdependency of manufacturers and their supply chains creates opportunities to take a more systems approach to achieving sustainable manufacturing.

Industrial ecology (IE) is an evolving field where industrial systems are viewed as part of the environmental system. There is potential to apply IE concepts more broadly to the manufacturing sector, including cradle-to-cradle, closed-loop production, zero waste manufacturing processes, design for environment/disassembly and industrial symbiosis. Specifically, IE includes the analysis of the social and industrial metabolism of industry, including tools such as life cycle assessment, material flow analysis, substance flow analysis and input-output analysis[32].

[32] Chris Davis, Igor Nikolic, and Gerard P.J. Dijkema. 2010. Industrial Ecology 2.0, The Journal of Industrial Ecology, Vol 14. No5

Industrial ecology precinct

One of the best-known examples of industrial ecology can be found in Kalundborg, a small industrial zone near Copenhagen in Denmark. Over time, this unplanned industrial park has evolved from a single power station into a cluster of companies that rely on each other for material inputs. In 1995, material and energy exchanges were about 3 million tonnes a year, providing estimated savings of US$10 million a year and an average pay-back time of six years[33].

In 2005, the UK Government launched the National Industrial Symbiosis Programme (NISP). NISP has delivered substantial benefits for the UK economy and businesses, and has boosted the UK economy by £1.5 billion – £2.4 billion.[34]

In Australia, the Kwinana Industrial Area, south of Perth is our best example of industrial symbiosis. As reported in the CSIRO's Ecos magazine in 2006 'There are 47 industrial synergies in place now – 32 by-product synergies, involving the reuse of solids, liquids or gasses, and 15 involving the shared use of utility infrastructure' [35]

By 2020, it is likely that manufacturers will have begun to make significant inroads to being more resource efficient – 'doing more with less' – through cleaner, leaner and 'greener' processing, smarter design using advanced and high performance materials as well as maximising efficiency within their supply chains.

Transitioning towards a low carbon economy

The Government has committed to a long-term carbon emissions reduction target of at least 80 per cent below 2000 levels by 2050. As a first step, Australia will reduce its emissions by between 5 and 15 per cent below 2000 levels by 2020.

In 2005, manufacturing accounted for over 25 per cent of Australia's energy use and over 28 per cent of greenhouse gas emissions. Australia's gradual transition towards a low carbon, cleaner energy future with the planned implementation of a carbon price and thereafter, an emissions trading scheme will challenge energy-intensive and trade exposed manufacturers in the near term, but conceivably provides a wide range of incentives and opportunities for manufacturers to adopt cleaner and less emissions-intensive technologies in the longer term.

To assist with the transition to a price on carbon, on 10 July 2011 Prime Minister Gillard launched the Australian Government's *Clean Energy Future*. The program provides a range of initiatives to assist industry to reduce its carbon footprint. Together with existing government programs, this provides an opportunity for the manufacturing sector to take the initiative and engage across sectors and with all levels of government to provide an advisory mechanism on green issues and ensure Australia remains competitive.

Improving energy efficiency will appear to be a fundamental first step for many manufacturers making the adjustment towards a lower carbon economy. Improved energy awareness, monitoring of energy efficiency through the entire production and supply chain

[33] http://www.iisd.org/business/viewcasestudy.aspx?id=77

[34] http://www.nisp.org.uk/Publications/Pathway.pdf

[35] ECOS, 2006 p22-26

and upgrading of production technologies to improve energy usage will likely become the norm by 2020 as many industries and companies strive to lower their carbon footprint. Accompanying such energy efficiency measures will be the increased use of a wider range of 'cleaner' energy from renewable sources or improved plant or building energy efficiency through the use of co-generation or tri-generation plants[36].

Manufacturers that are able to adapt their processes and products to the needs of a low carbon economy will have a competitive advantage over domestic and international competitors. Opportunities extend to include:

- Developing and/or manufacturing products and systems that support the growth of a low/no carbon energy future, such as components and energy management systems for solar and wind.
- Developing and/or manufacturing products that support the construction of a more sustainable built environment and infrastructure, including energy efficient building systems and materials with inherently lower embodied energy/carbon.
- Developing manufacturing techniques and technologies that are low carbon (and indeed, low net resource) and exporting those developments.[37]
- Target high value-add, high intellectual property manufactured products with relatively low carbon transport and hence, low shipping costs. Examples of these products generally come from the science and biotechnology areas such as medical devices and diagnostic equipment.

Global 'megatrends' – population demographics, people on the move and increasingly demanding, technological advances – opportunities abound!

Enormous market opportunities accompany a growing, ageing and increasingly urbanised global population. The need to house increasingly urbanised populations in a sustainable fashion will create demand for products and technologies that enable greener buildings and infrastructure. The rise in global urbanism is accompanied by an increased demand for greener mobility and transportation solutions, which again will be underpinned by innovative, cleaner, greener products, equipment and systems.

Population growth drives changes in, and usually increases, consumerism. Similarly a growing number of environmentally conscious consumers are reducing their environmental footprint, avoiding brands with poor environmental reputations and are often willing to pay a price premium for green products – all of which are opening up new markets for businesses.

Ageing populations will require improved healthcare products and services. Products of the future need to be designed so that older, less technically savvy people find them easy to use.

The increasing role that consumers play in setting expectations for sustainable and personalised products will require manufacturers to customise their products to meet

[36] The Australian. 23 March 2010. http://www.theaustralian.com.au/australian-it/tri-generation-plant-to-cut-banks-energy-bill/story-e6frgakx-1225844000091

[37] Prof. John Beynon, Dean of Engineering and Industrial Sciences, Swinburne University and Centre Leader, Australian Advanced Manufacturing Research Centre.

individual tastes and preferences. In addition to consumer sentiment on the environmental credentials of products discussed earlier, mass customisation is likely to be increasingly the norm. This is in contrast to the past, where mass production was the focus of manufacturers seeking to drive unit costs down through economies of scale and off-shoring of production to relatively lower labour cost economies.

The expected drive towards mass customisation is likely to create an increasing need for manufacturers to innovate in design, production and service delivery. From the design and production perspectives, manufacturers will need to respond very quickly to a much wider variety of product specifications.

Globalisation, the rise of emerging economies and global supply chains

Industries operate in an increasingly globalised world. To achieve success in this environment and achieve scale, Australian firms must seek to integrate into the global supply chain markets of multinational companies. Such markets for intermediate manufactured goods are estimated to comprise some two-thirds of world trade. A similar proportion is controlled by the top 500 multinational companies. The ability of firms to identify and exploit new and emerging markets, avoiding over-reliance on one or a few economic partners, will also be essential.

One grouping of emerging economies includes Brazil, Russia, India and China (colloquially called 'BRIC' countries). Whilst their collective relevance to Australia may be debatable, they nonetheless account for almost three billion people, or just under half of the world population. The middle classes in these countries are growing. With this, the disposable incomes of these middle class people are increasing. This represents a major opportunity for Australian manufacturers to export high value-added bespoke products and services into niche markets.

Australian manufacturers are practised in profitably manufacturing low volume, niche products due presumably to lessons learned from servicing the small domestic market. In contrast, firms in high volume economies like China and the USA tend to set up for high volume production rather than for the flexible and responsive demands from low volume/high mix customers. This competitive advantage for Australia can be exploited in these emerging markets, as well as the prosperous traditional markets in Europe and North America.

Recognising our competitive strengths

The size of Australia's domestic market is often seen as a disadvantage for local manufacturers but it can offer a competitive edge for those companies with the ability to design and manufacture products with small production volumes. Often this will be in niche markets where customisation is required. If a manufacturer is reliant on exports, then it will always have to struggle with labour cost and exchange rates. The alternative is to identify and commercialise manufacturing technologies that are cost competitive at a much smaller scale. Aside from maintaining local industrial bases and capabilities, there will be an increasing sustainability benefit and competitive advantage as transport costs, which are currently relatively low, increase due to energy and emissions constraints.[38]

As the BRIC economies play an increasingly important role in global trade, both in terms of the volume and increasing sophistication of their output, they will also play a significant role both as competitors and suppliers.

Chinese/Taiwanese mega manufacturers are emerging as dominant players in the global economy. For example, the Taiwan-based Hon Hai Group with its Chinese subsidiary Foxconn, is the world's largest contract maker of electronics. Foxconn is reputed to produce 50 per cent of the world's electronic products.

Integration into global supply chains and forming partnerships with firms in these countries, and in particular the large manufacturing base in China, will be vital to the success of Australian manufacturers. However, the scope for innovation is limited when product design and specifications are determined globally. This can restrict the ability of Australian manufacturers to differentiate their products, forcing them to compete on cost and absorb freight costs and exchange risks.

[38] Dr George Collins of the CAST CRC, comment on draft of the document

Opportunities created by innovation – industry examples

With these influencing factors and megatrends in mind, there are identifiable opportunities for Australian manufacturing. Rather than an exhaustive list, the following four opportunities should be seen as examples for high value manufacturing.

Medical devices

According to Access Economics[39], Australia contributes 1.1 per cent of the global expenditure on health R&D, yet 3.04 per cent of the benefits from global medical research can be attributed to Australian research. This defines our challenge and our opportunity – to successfully transform Australian research into commercial returns for local manufacturers.

Australia has developed a strong and vibrant medical device manufacturing industry encompassing the elements of specialist manufacturing, regulatory approvals and compliance, quality systems, design control, intellectual property protection and commercialisation. This industry is growing globally and expected to do so for the foreseeable future. It relies on access to new technology and valuing innovation.

IBISWorld recently published figures and analysis for Medical and Surgical Equipment Manufacturing in 2010[40]:

- Revenue of $3.2b
- Profit of $353.9m
- Exports valued at $1.7b (53 per cent of revenues)
- 3,785 businesses are involved
- Annual growth from 2006-11 was 4.8 per cent
- Anticipated growth from 2011-16 is 5.4 per cent

Future demand for new technologies and products is expected to grow strongly with low volatility due to increasing community expectations of healthcare (particularly from the 'baby boomers'), the pressures of an ageing population, income growth and price competition.

Access to global markets and strong demand is expected to drive employment growth in the sector at 3.5 per cent pa and wages growth by 4.3 per cent pa. Wages in this industry tend to be high due not only to the skills required, but also to the high costs of turnover incurred in training new staff in strict accordance with regulatory approvals (compliance) – therefore there is incentive for firms to retain trained staff.

[39] Access Economics. June 2008. *Exceptional Returns - The Value of Investing in Health R&D in Australia II* - http://www.asmr.org.au/ExceptII08.pdf

[40] IBISWorld Industry Report C2832. Nov 2010. *Medical and Surgical Equipment Manufacturing in Australia*

Australian automotive manufacturing industry

Changes in the global automotive industry are being driven by broader globalisation, environmental and resource factors. Both markets and production are experiencing major structural changes as evidenced by China emerging as both the largest automotive market and largest producer.

The rise in production in China, Korea and ASEAN economies, together with a demand for smaller vehicles have resulted in a downward trend in the volume of domestically produced vehicles sold in Australia. Vehicle builders, suppliers to the local vehicle builders and original equipment manufacturers have been forced to seek global markets for their products. The recent rise in the value of the Australian dollar in comparison to other major currencies has also accelerated this trend.

The choice for Australian automotive suppliers is to move to higher value added products and/or to focus on design and development of products which are then manufactured in lower cost economies. In this regard, both General Motors Holden and Ford Australia have produced designs for global platforms for their parent company.

Other opportunities for local manufacturers arise from the use of new materials for key components. The imperative to reduce fuel consumption and emissions from vehicles has created new opportunities for the use of lightweight materials for components and structures. Furthermore there are significant opportunities for software design for systems such as control strategies for electric vehicles, vehicle telematics, and smart vehicle-power grid interfaces for electric vehicles.

Transitioning textile manufacturing in Australia

Traditionally textile, clothing and footwear products are considered low-tech manufactures. However, technology and global challenges are opening up a vast array of new applications for textiles including smart protective textiles for the military and emergency services markets, textile composites for aerospace, automotive and marine applications, medical textiles including tissue engineering scaffolds, filtration textiles for water and energy applications, fibrous materials as components of mobile phones and batteries and large scale applications in mining, agriculture, aquaculture and horticulture. The future of textile manufacturing in Australia must increasingly be focussed on technical textiles and the development of products for demanding end-users and applications.

Although there is some scepticism about the future of textile manufacturing in a high wage economy such as Australia it should be noted that although commodity textile manufacturing has moved to low labour cost countries, technical textile manufacturing is still dominated by high wage economies such as Germany. The production of technical textiles in Germany has grown by 40 per cent in real terms since the mid-1990s; in part due to close collaboration with research institutes. As a result, German companies now have a 45 per cent share of the global market.

The Australian textile industry currently has a manufacturing base which can be transitioned to a successful knowledge-intensive technical textiles sector based on incorporating innovations in material science into fibrous structures. Australia has particular opportunities in fields such as:

- Healthcare - fibrous tissue engineering scaffolds, sensing wound dressings and bandages and sophisticated incontinence products.
- Defence – lightweight ballistic and blast protection, low multi-spectral materials and integration of power and sensing into textiles.
- Water, energy and environment – improved filtration media for the removal of toxic substances from air and water, selective recovery of valuable materials from waste streams and technical textile products for coastal protection.
- Mining – stronger and smarter geotextiles for the heavy roads, railways and tailings dams used in the mining industry.

Biomaterials

Biomaterials, which cover products as diverse as hip implants, cell therapy technologies and innovative drug delivery systems, was a global market of $25.6b in 2008. This is expected to reach US$65b in 2015 with a compound annual growth rate of 15 per cent from 2010-2015.[41] The orthopaedic and cardio-vascular areas are the dominant areas, and currently comprise 75 per cent of all revenues.

In the Australian manufacturing context the fledgling biomaterials industry has the potential to provide highly skilled Australian jobs and revenue as well as providing longer term benefit through improved quality of life and reduced healthcare costs.

The expansion of the biomaterials market is being driven by:

- An ageing population. Over 20 per cent of the world's population will be over 60 in 2050;
- An increasingly wealthy developing world (in particular China and India); and
- The expectation of improved quality of life.

Significant opportunities are available for new and improved products – although this is an area with significant regulatory hurdles, uncertain reimbursement pathways, increased pressure on government health spending and a relatively long path to market.

A range of small but innovative companies built on Australian generated R&D has appeared in recent years including AorTech Biomaterials[42] and Polynovo Biomaterials. AorTech Biomaterials has materials implanted in more than 3 million patients.

In addition, Australia has a number of companies developing biologically-based materials, such as collagens, for use in biomaterials applications. These companies are in part dependent on Australia's animal disease-free status and include, Holista Colltech, BioNova, Elastagen, Maverick, Devro and Allied Medical.

In contrast to the earlier more prominent role for synthetic biomaterials, the focus of regenerative medicine lies with human cells. However, regenerative medicine will still require a new generation of instructive, advanced materials able to coordinate local cellular processes or to act as materials for the in vitro production of stem cells for the 'cell therapies' treatment of human disease. The cell therapies market is estimated to be $2.3b by 2025[43].

Opportunities also exist for the production of blood cells and products and there is a requirement for facilities and materials that will allow this scale-up in a commercially viable way. Australian company Invetech is the world leader in the development and engineering of cell therapy scale-up equipment. Other opportunities exist for example in the development of materials for the delivery of small molecule drugs and biologics; bioactive coatings and surgical materials, for example, tissue sealants. All have the potential for manufacture in Australia.

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[41] Global Biomaterials Market (2010-2015) marketsandmarkets.com May 2011

[42] AorTech announced on 16 June 2011 that it had completed the relocation of its primary manufacturing operations from Melbourne to the Minneapolis/St. Paul area in the USA. Reasons given for the move included access to a larger pool of skilled staff in the US medical devices cluster, closeness to major markets, and currency stability.

[43] Market Research Report: *The Stem Cell Market Outlook. Pipelines, regulations, business models, and forecasts to 2025.* Business Insights Ltd., June 2011

Mining technology services

The mining technology services industry is an example of Australian manufacturing and related services firms leveraging Australia's mining and minerals industry, research strengths and global supply chain markets of multinational companies. This includes exploration, mine development and minerals processing.

In 2009, *HighGrade* surveyed 80 Australian owned and based mining technology and service sector. The revenue generated by these companies was $27.5 billion and they employed some 83,000 people.

The companies had grown by 19 per cent in the previous year despite the GFC.

The public/private ownership split was 45% / 35%. Western Australia was home to 34 of the 80 companies, 20 were from Queensland, 11 from New South Wales, 7 from Victoria and 4 from South Australia. Privately owned firms included Pybar Mining, UME Australia, Hofmann Engineering, Minepower, SBD Drilling, Metzke Engineering and Nepean Group.

A recent ABARE report identified the sector at $8 billion for technology companies' component only. Essentially, this sector is achieving:

- Excellent research infrastructure
- High levels of collaboration
- Cutting edge, world leading technologies
- Strong clusters and networks
- High exports
- Strong representation of large multinational enterprises and a large number of SMEs operating in domestic and international markets.

An excellent example of market development is the growth and specifically of Australian engineering firms designing and building gold plants in west and east Africa. This service has enabled the sale and export of locally produced goods into an international market.[44]

[44] Innovation Australia Board, communication of 26 September 2011

Summary

Australian manufacturers operate in an increasingly competitive global environment that is constantly changing, where many factors that affect the future of manufacturing are out of the direct control of firms. A good example of this is the impact of currency exchange rates that are putting pressure on Australian manufacturers now, in terms of export competitiveness. Furthermore, a range of mega-trends appears to be increasingly important and may remain in effect over the medium to long term.

Achieving a robust Australian manufacturing sector in the future will require ambitious vision, sound strategy and development of capabilities for manufacturing companies to stay competitive, profitable and sustainable over the long term.

A robust manufacturing sector of the future requires firms that are not only technologically savvy, but are also agile, flexible, adaptive, and efficient. This is only possible in firms that are knowledgeable, innovative and well managed, and which have access to information, technology and innovative practices as well as capital. More importantly, firms need to have the absorptive capacity to embrace new knowledge, technology and innovative practices.

Thus, the resilience or robustness of an industry sector will depend on the ability of its firms to adapt quickly to meet challenges and capture emerging opportunities. This requires that firms:

- Recognise that to succeed in the high value-add, low volume products in which Australian manufacturing is likely to have a competitive advantage, they must bundle products and services to sell solutions, rather than simply tangible products.
- Have the absorptive capacity to embrace the latest technological and business process innovations that provide competitive advantage.
- Have ready access to knowledge and world class capabilities that allow innovation and rapid adaption to changing market needs, tapping into innovative practices and building sustainable and profitable partnerships both domestically and globally.
- Have the capability to design, develop, make and sell products and services that are in demand.
- Operate with high efficiency and productivity, allowing them to optimise the use of their capital – human, intellectual and material.
- Have resilience in a low carbon and resource-constrained economy through resource efficiency.
- Have the ability to maximise leverage from strong and sustainable partnerships through local and global supply chains.
- Secure supply of resource inputs and skills, by direct acquisition, partnering or engaging in global supply chains.
- Harness technology and business process innovation that provides differentiation and competitive advantage. The continued evolution of ICTs, such as cloud computing, provides opportunities for enhancing firm productivity, marketing and product and service delivery.
- Possess the organisational flexibility to rapidly adapt to changing market needs – including changing their mix of skills and production technologies.

- Seek markets in the growing BRIC countries, both by partnering with them in global supply chains, and by meeting demands from their growing middle classes for niche and bespoke consumer products.

Global competitiveness requires world class capabilities that are effectively utilised. A key imperative is to ensure capabilities in supply chains for those sectors that are important to achieve a robust future for Australian manufacturing.

There is a broad consensus that Australia is not deriving the full benefits of our research investment; especially from publicly funded research. Hence it is imperative to improve the strategic alignment between the output from research organisations and industry/market demands. This will only come about through greater engagement and linkage between providers and users (and potential users) of research to ensure that there is an appropriate balance between 'push' from research organisations and 'pull' from firms that can benefit from research. Understanding trends and potential opportunities in the future will also be crucial in establishing a globally competitive manufacturing sector.

There is often a tendency to view the innovation needs of an industry through a sectoral lens. This needs to shift to a more system-wide approach to building an innovation system that supports a robust future for the entire Australian manufacturing sector. It would appear that policies and programs that support the development of knowledge, skills, competencies and capabilities that can be effectively translated *across* industry sectors are likely to contribute to the future robustness of manufacturing.

The future robustness of Australian manufacturing is also dependent on how well firms operate across complex global supply chains. This requires not only comprehensive knowledge of emerging market needs but also localised knowledge to facilitate adaptability to changing environmental and legislative landscapes in export markets. In particular, Australian firms need to be aware of environmental legislation that is increasingly becoming operational. This presents both a challenge as well as an opportunity to tap into an emerging greener global economy.

Having access to world class capabilities and knowledge is important for a firm’s future competitive advantage. However, it is equally important that a firm has the ability to absorb new knowledge and translate it into practice. Industry, the research community and government need to develop policies and initiatives that raise the capabilities and capacity of firms to absorb innovation in all its forms, to ensure that manufacturing firms of the future are adaptive, agile and innovative.

The strengths, weaknesses, opportunities and threats facing Australian manufacturing can be summarised as follows:

Strengths	***Weaknesses***
R&D Capacity Education system Capacity for low volume manufacturing Positive image of Australia Water technology Sustainable energy resources Sustainable energy technology development Financial and political stability Growing awareness of products-services nexus	Management skills Levels of trade and technical skills Commercialising R&D Image of Australian manufacturing vis a vis competitors Workforce retention and development
Price on carbon Ageing population Increasing health requirements Emerging technologies Urbanisation Computer Integrated Manufacturing Additive manufacturing Demand for customised products Expanding middle class in BRIC countries	Increasing energy prices* Price on carbon Water supply* Ageing workforce Increasing sophistication of BRIC countries Terms of trade and level and volatility of the Australian dollar 'Peak' resources*
Opportunities	***Threats***

*** Factors impacting on many/most economies**

Next steps - ensuring a robust Australian manufacturing sector in 2020

It has been suggested by some stakeholders that there would be value in further work to develop a likely scenario for 2020, and a further scenario to 2040.

Such scenarios would need to address both a description of the situation at those dates, and the initiatives needed to achieve these outcomes and avoid pitfalls.

Initiatives could involve coordinated implementation by government, industry (manufacturing, finance, professional and business services), researchers and commercialisation intermediaries to select and implement different strategies in the period to 2020. These could include:

- Initiatives by industry to advance the cause – especially in terms of collaboration and cooperation and skills building at all levels.
- Improving the strategic alignment between the priorities, work and output of research organisations and industry/market demands
- Means to raise the innovation absorptive capabilities of firms to grow businesses and generate highly skilled, attractive employment opportunities.
- Practical strategies for industry and government to improve skills in the key areas of management and technical and professional services, to grow Australian firms.
- Other initiatives from government could include technology roadmaps, technology and management advisory services, and influencing the education sector's course offerings.
- What other Australian Government agencies must do to achieve the desired outcomes.
- What other levels of government must do to achieve the desired outcomes.

Future Manufacturing Industry Innovation Council Strategic Roadmap 2010 - 11

Vision: A future manufacturing industry that provides innovative products and related service solutions to domestic and export markets in innovative ways, builds and retains its highly skilled workforce and is a vital enabler of highly productive and competitive Australian manufacturing.

2010 / 11 milestones		2014 outcomes
Supported the creation and growth of Australian multinational enterprises.		More companies with global leadership positions
Collaborated with stakeholders to identify and exploit domestic and export opportunities to provide innovative manufacturing solutions for the global mega-challenges of sustainable energy and water and health, including:		Robust and aligned investment environment
➢ Assisted, supported and leveraged the government's Supplier Advocates for Clean Technologies and Water.		Effective commercialisation of new products
Influenced taxation reform, including government response to 2009 Taxation Review, to enable national wealth creation.		
Influenced the formation and development of skills to support Australian future manufacturing and related services, including leadership and management training.		Adaptive and diverse pool of skilled people
		New positive image
Provided the Minister with strategic advice on priority issues affecting Australian future manufacturing and related services, including innovation policy, government coordination and policy certainty.		Conducive and continuous government support
		National, globally competitive regulatory environment

↑ ↓ ↑ ↓

Innovation is customer and productivity focused (revised pathway)	Globally-competitive investment environment (new pathway)	Reduce cost of doing business (existing pathway)	Taxation supports national wealth creation (existing pathway)	Train and educate workforce to equip it for current and future needs (revised pathway)	Create a positive image for Australian manufacturing, its products and services (revised pathway)	Provide policy certainty and consistency (revised pathway)

← **Pathways (actions)** →

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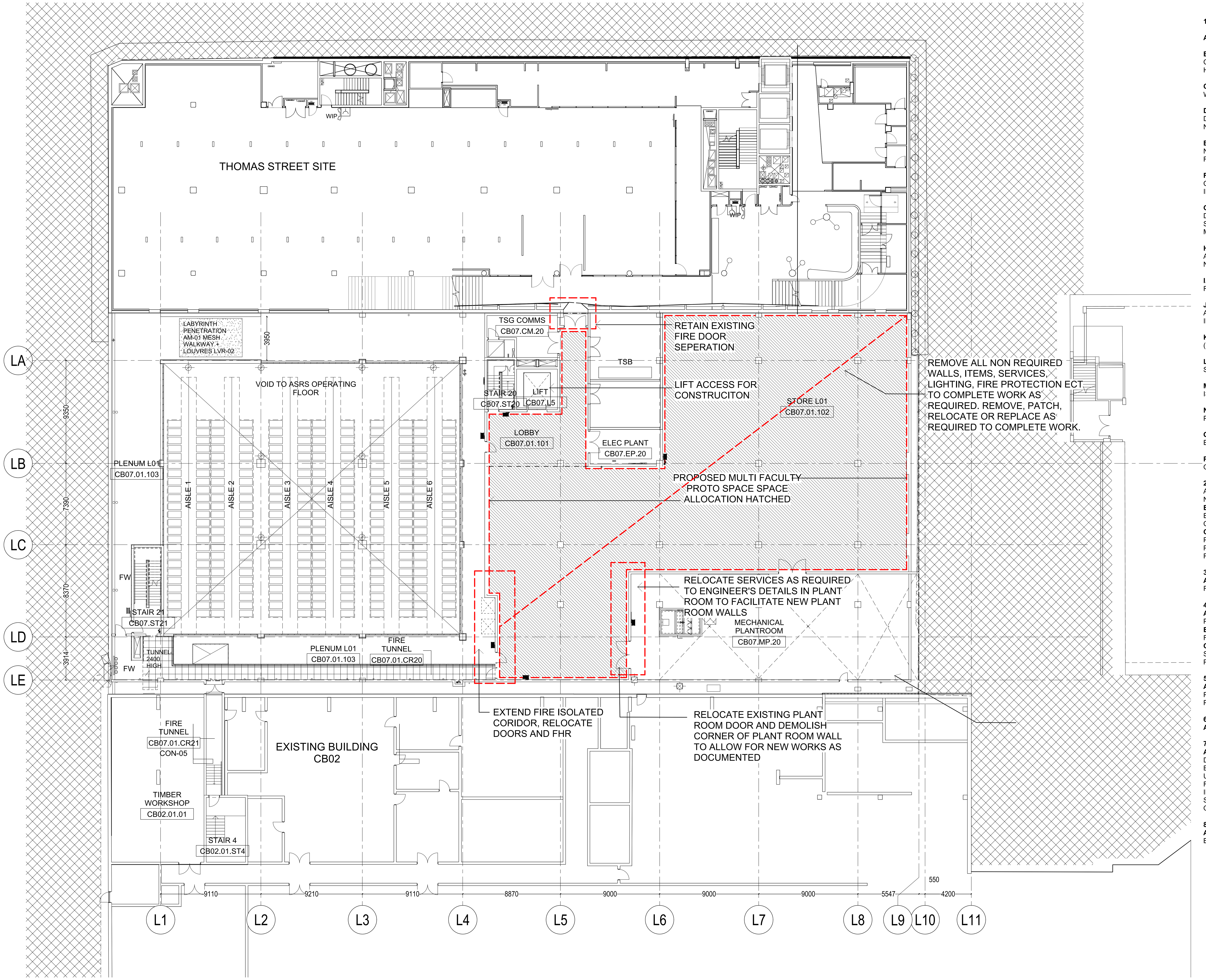
Information Technology Industry Innovation Council.



1 EXISTING AND CONTEXT PLAN
SCALE: 1:200@A1 ; 1:400@A3

1. DEMOLITION NOTES

A. CONTRACTOR TO DISPOSE OF / RECYCLE ALL ITEMS

B. CONTRACTOR TO REMOVE REDUNDANT SERVICES AND CONDUITS AND MAKE GOOD ANY DAMAGE IN THE PROCESS OR HIDDEN DAMAGE THAT IT SHOULD UNCOVER.

C. CONTRACTOR TO DEMOLISH EXISTING FLOOR FINISHES WHERE INDICATED.

D. ALL WALLS WHERE NOTED FOR DEMOLITION SHALL BE DEMOLISHED UP TO THE UNDERSIDE OF THE SOFFIT UNLESS NOTED OTHERWISE.

E. CARRY OUT ALL OTHER DEMOLITION WORK NOT NECESSARILY SHOWN ON THE DEMOLITION PLANS BUT IS REQUIRED TO EXECUTE NEW WORKS.

F. ALL SIGNS, DISUSED ELECTRICAL PLATES AND REDUNDANT CONDUITS AND DUCTS SHALL BE REMOVED FROM ALL INTERNAL WALL SURFACES

G. AFTER THE REMOVAL OF EXISTING CONDUITS, PLATES, DUCTS AND EQUIPMENT ETC FROM EXISTING RETAINED WALL SURFACES, FILL AND PATCH ALL REMAINING SCREW HOLES TO MATCH ADJACENT SURFACES

H.WHERE DEMOLITION WORK RESULTS IN DAMAGE TO ADJACENT WALL, FLOOR OR CEILING SURFACES, EVEN IF NOT NOTED, THESE SURFACES MUST BE MADE GOOD.

I. SAFETY FENCING AND OR HOARDING SHALL BE ERECTED TO RESTRICT UNAUTHORISED ENTRY

J. PROVIDE ALL CORE HOLES AND PENETRATIONS IN SLABS AND WALLS NECESSARY FOR SERVICES RETICULATION EVEN IF NOT SHOWN ON THIS DRAWING.

K. REMOVE ALL EXISTING SKIRTINGS, DUCTS AND CONDUITS (COMMS AND ELECTRICAL) WHERE INDICATED

L. DISCONNECT AND RETAIN EXISTING RUNNING MAN EXIT SIGNS.

M. DO NOT DEMOLISH ANY EXISTING SMOKE DETECTORS. ISOLATE AS NECESSARY PRIOR TO COMMENCING DEMOLITION.

N. STOP WASTE MATERIAL ACCUMULATING IN THE WORK PLACE.

O. TURN OFF ALL NON-ESSENTIAL POWER OUTLETS/ EQUIPMENT OVERNIGHT.

P. RETAIN EXISTING SERVICES RISERS, UNLESS NOTED OTHERWISE.

2. MAKE GOOD
A. MAKE GOOD ALL SURFACES AND MAKE READY TO RECEIVE NEW FINISH.
B. ALL FLOOR PREP TO BE ALLOWED FOR NEW FLOOR FINISH, ENSURE SUBSTRATE IS LEVELED WITH ARDIT OR EQUIVALENT COMPOUND TO ENSURE A LEVEL AND CONSISTENT FINISH.
C. ALL HOLES IN EXISTING WALLS AND COLUMNS TO BE PATCHED. ALLOW FOR NEW FINISH TO MATCH ADJACENT, PATCH ALL CHIPS TO COLUMNS AND PREPARE SURFACE TO RECEIVE NEW FINISH.

3. FLOOR FINISHES
A. CONTRACTOR TO PREPARE SURFACE TO RECEIVE NEW FLOOR FINISH

4. WALL FINISHES
A. PREPARE ALL WALLS THAT ARE TO RECEIVE PAINT FOR PRIMER COATS AS SPECIFIED AND TOP COATS AS SPECIFIED.
B. PATCH ALL HOLES TO ENSURE A LEVEL AND CONSISTENT FINISH PRIOR TO PRIMING AND PAINTING AS SPECIFIED.
C. ALLOW FOR SETTING BEADS TO CORNER PROFILES AND P50 SHADOWLINE BEADS TO THE TOP OF NEW PARTITIONS AND PLASTER LINING OR AS INDICATED

5. CEILING
A. CEILINGS TO BE CLEANED AND PAINTED WHERE NOTED. PREPARE ALL CEILINGS THAT ARE TO RECEIVE PAINT FOR PRIMER COATS AS SPECIFIED AND TOP COATS AS SPECIFIED.

6. SERVICES
A.REFER TO SERVICES ENGINEERS DOCUMENTATION

7. SECURITY
A. ALL SECURITY ENTRY DOORS ARE TO BE MAINTAINED DURING CONSTRUCTION, OR IF NECESSARY, EXISTING ELECTRONIC STRIKES TO BE RETAINED AND RE-INSTALLED UNDER THE BUILDER'S SCOPE OF WORKS. BUILDER TO ALLOW FOR CO-ORDINATION WITH SERVICES SUBCONTRACTOR TO INSTALL ANY NEW SECURITY ITEMS. NOTE THAT THE SECURITY SUPPLY AND INSTALLATION IS WITHIN THE BUILDER'S SCOPE OF WORK.

8. I.T. (DATA AND COMMS)
A. ALLOW FOR ALL I.T. WORKS TO BE CARRIED OUT WITHIN BUILDER'S SCOPE OF WORKS.

IMPORTANT NOTES:
1. DIMENSIONS SHALL NOT BE OBTAINED BY SCALING THE ARCHITECTURAL DRAWINGS.
2. ALL DIMENSIONS SHOWN ON THE DRAWINGS SHALL BE PHYSICALLY CHECKED AND VERIFIED ON SITE BY THE BUILDER BEFORE ANY CONSTRUCTION COMMENCES.
3. THE BUILDER SHALL CONFIRM IN WRITING THAT ALL DIMENSIONS HAVE BEEN CHECKED AND REPORT ANY DIMENSIONAL INCONSISTENCIES OR DISCREPANCIES TO THE ARCHITECTS AND OBTAIN THEIR INSTRUCTIONS AND/OR APPROVAL TO PROCEED.
4. ALL WORKS SHALL BE EXECUTED IN ACCORDANCE WITH THE CURRENT VERSION OF THE BCA AND ALL RELEVANT STANDARDS.
5. THESE DRAWINGS ARE PROTECTED BY COPYRIGHT.

SAFETY IN DESIGN:
THERE ARE INHERENT RISKS INVOLVED IN CONSTRUCTING, MAINTAINING, USING AND ULTIMATELY DISMANTLING AND DISPOSING OF ALL BUILDINGS. BURTENSHAW SCOUFIS ARCHITECTURE HAVE ELIMINATED OR MINIMISED THESE RISKS, AS FAR AS IS REASONABLY PRACTICABLE, THROUGH PRUDENT REVIEWS OF THE DESIGN DURING THE DESIGN PROCESSES. HAZARD CONTROLS MUST STILL BE IMPLEMENTED BY THE PRINCIPAL BUILDING CONTRACTOR DURING THE CONSTRUCTION STAGE AND SUBSEQUENTLY BY OWNERS OR OPERATORS TO ENSURE THE SAFETY OF ALL WORKERS AND OCCUPIERS FOR THE INTENDED LIFE OF THE BUILDING.

1m 2m 3.5m

Rev.	Description	Approved Date
	TENDER ISSUE - TN NOT FOR CONSTRUCTION	
01	TENDER ISSUE REVISION 1	29.08.16
02	TENDER ISSUE REVISION 2	20.10.16

Consultant

Project Name
BDG 07 - LVL B01
NEW MULTI FACULTY
PROTO SPACE FITOUT

UTS
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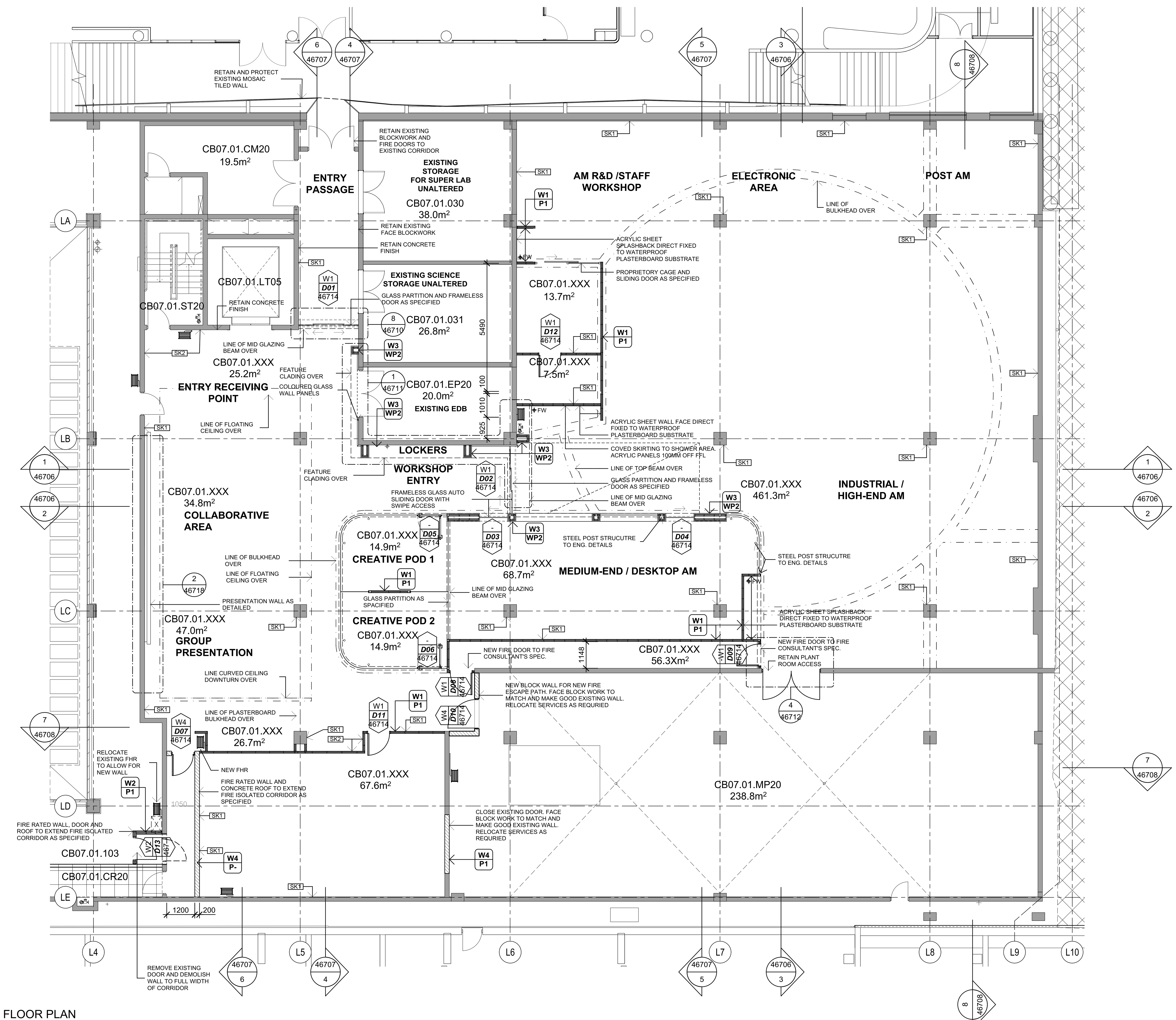
Drawing Title
CITY CAMPUS BROADWAY
BUILDING 07 BASEMENT LEVEL 01
NEW PROTO SPACE FITOUT WORK
EXISTING FLOOR PLAN

FMU Project Number 02809-N-15			
Drawn By HA	Checked GS	Approved By	Date App.
Drawing Scale AS SHOWN	Drawing Status TN		A1
UTS Drg File Name CB07B1AP	UTS Drg File No 46700		Rev No 02



1 GENERAL FLOOR PLAN
SCALE: 1:100@A1

IMPORTANT NOTES:
1. DIMENSIONS SHALL NOT BE OBTAINED BY SCALING THE ARCHITECTURAL DRAWINGS.
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1m 2m 3.5m

Rev.	Description	Approved Date
	TENDER ISSUE - TN NOT FOR CONSTRUCTION	
01	REVISED WORKSHOP EUIPMENT LAYOUT	10.10.16
02	TENDER ISSUE REVISION 2	20.10.16

Consultant

GENERAL KEY:

- W3 — WALL TYPE ABOVE/BELOW WINDOW OR DOOR
- WD3 — WINDOW/DOOR NUMBER
- 01 — SCHEDULE SHEET
- FL1 — GENERAL FLOOR TYPE KEY
- SK1 — GENERAL SKIRTING TYPE KEY
- W1 — GENERAL WALL KEY
- P1 — GENERAL PAINT COLOUR KEY
- SC1 — GENERAL CEILING FINISH KEY
- 2700 — CEILING HEIGHT FROM FFL KEY

WALL LEGEND

W1 1 LAYERS OF 13mm THICK GYPROCK EC08 IMPACTCHECK FIXED TO BOTH SIDES OF NEW 76mm STEEL STUDS EXTENDED TO UNDERSIDE OF CEILING OR TO TOP OF WALL . INSULATION AS SPECIFIED. FINISH LININGS AT ALL INTERNAL CORNERS AND AT CEILING JUNCTIONS WITH RONDO P50 SHADOWLINE SETTING BEADS.PAINT FINISH AS SPECIFIED AND APPLY NEW SKIRTING AS SPECIFIED

W2 2 LAYERS OF 13mm THICK GYPROCK EC08 FIRE CHECK FIXED TO BOTH SIDES OF NEW 76mm STEEL STUDS EXTENDED TO UNDERSIDE OF CEILING OR TO TOP OF WALL TO ACHIEVE A FIRE RATING OF 120/120/120. INSULATION AS SPECIFIED. FINISH LININGS AT ALL INTERNAL CORNERS AND AT CEILING JUNCTIONS WITH RONDO P50 SHADOWLINE SETTING BEADS.PAINT FINISH AS SPECIFIED AND APPLY NEW SKIRTING AS SPECIFIED

W3 76mm STEEL STUDS EXTENDED AS REQUIRED TO PROVIDE SUPPORT FOR CLADDING SPECIFIED. NEW CLADDING INSTALLED TO MANUFACTURES RECOMENDATIONS AND AS PER DETIALS.

W4 200MM CONCRETE BLOCK WALL TO TIE INTO AND MATCH ADJOIING EXISTING WALL. HEIGHT AS DETAILS TO UNDERSIDE OF NEW CONCRETE SLAB LID

GENERAL FINISHES KEY

F1 LAMINATE FINISH - LAMINEX - WHITE NATURAL FINISH 200
F2 LAMINATE FINISH - LAMINEX - ELEGANT OAK NATURAL FINISH 78
F3 SOLID SURFACE CORAIN - GLACIER WHITE
F4 HAFELE ABS PLYWOOD EDGE
F5 MAGNETIC WHITE BOARD LAMINATE
F6 FABRIC - INSTYLE ATLAS CITRUS
F7 LAMINATE FINISH - LAMINEX - BRUSHED ALUMINIUM
F8 STARFIRE COLOUR BACK GLASS - PROVIDE SAMPLE TO MATCH F1
F9 PERFORATED ALUMINIUM SHEET, ARROW METAL 3MM ALUMINIUM BLACK PWDERCOAT, PATTERN 240
F10 LAMINATE FINISH - LAMINEX - BLACK NATURAL FINISH 460
F11 ACRYLIC PANEL - INNOVATIVE SPLASHBACKS, COLOUR 'ANGEL' TBC

WP1 DELETED
WP2 DIBOND PANELS. COLOUR, BUTLERFINISH STEEL
WP3 DIBOND PANELS COLOUR, TRAFFIC YELLOW GLOSS

GENERAL FLOOR KEY

FL1 RUBBER FLOOR FINISH - REGUPOL EVEROLL, REFER TO ARCH. SPEC.
FL2 NEW PAINT EPOXY FLOOR FINISH - ROXSET RC, REFER TO ARCH. SPEC.
FL3 STEEL TROWEL CONCRETE SLAB
FL4 PAINTED LEVELING TOPPING TO MATCH EXISTING CORRIDOR

SK1 SELECTED SKIRTING 01 - 150mm DUCTED, BLACK ALUMINIUM SKIRTING
SK2 SELECTED SKIRTING 02 - 150MM FLAT, BLACK ALUMINIUM SKIRTING

FW FLOOR WASTE, REFER TO HYDRAULIC ENG. FOR DETAILS

GENERAL PAINT FINISHES KEY

P1 DULUX - ANTIQUE WHITE USA.
P2 DULUX - BLACK SATIN DURALLOY 19268
P3 REFER TO ARCH. SPECIFICATIONS

GENERAL CEILING AND LIGHTING KEY - REFER TO ENGINEERS DOCUMENTATION

PP SUSPENDED 2400 X 1200 PERFORATED ACOUSTIC SHEETS BACK FILLED SHADOW PERIMETER, SHEETS TO BE REMOVABLE FOR ACCESS TO SERVICES, REFER TO ARCH. SPEC.
SPB SET PLASTERBOARD CEILING WITH P50 SHADOWLINE TO PERIMETER
ACT SUSPENDED 600 XC 600 ACOUSTIC TILE CEILING WITH P50 SHADOWLINE TO PERIMETER
SLT SUSPENDED SLATS WITH ACOUSTIC BLANKET - REFER TO ARCH. SPECIFICATION
MC1 DIBOND PANELS. COLOUR, BUTLERFINISH STEEL
MC2 DIBOND PANELS. COLOUR, TRAFFIC YELLOW GLOSS
BB BUZZ BAR POWER GRID, REFER TO ENGINEER'S DETAILS
OFC OFF FORM CONCRETE TO ENGINEER'S DETAILS.
ACP VERTICAL ACOUSTIC PANEL. ARMSTRONG CS5143 WH 1800 X 400 X 40, COLOUR TBC
CA 600mm x 600mm SET PLASTERBOARD HINGED ACCESS PANEL WITH PERIMETER SETTING BEADS TO FINISH FLUSH WITH PLASTERBOARD

Project Name
BDG 07 - LVL B01
NEW PROTO SPACE FITOUT WORK

UTS
UNIVERSITY OF TECHNOLOGY, SYDNEY

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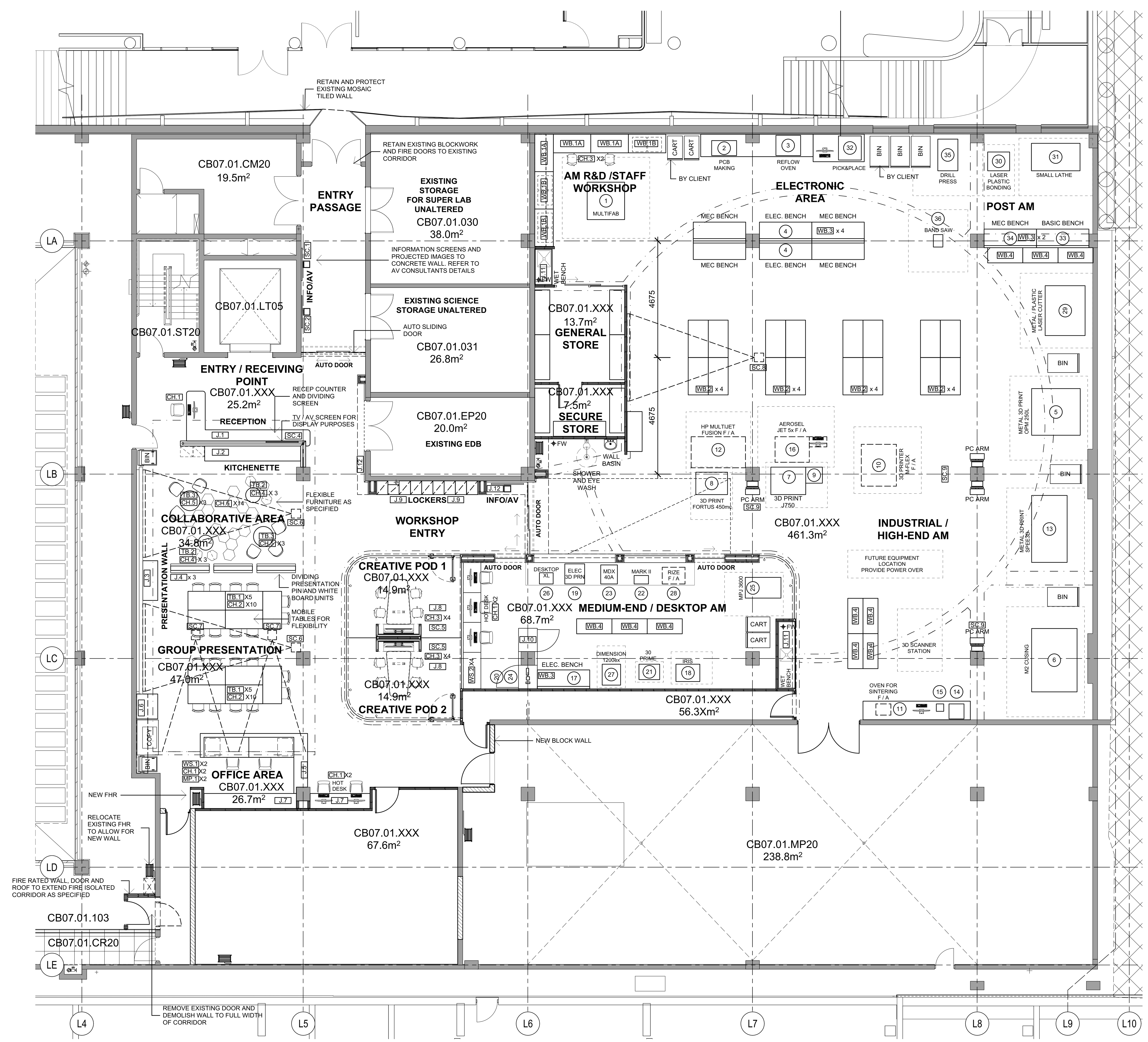
Drawing Title
CITY CAMPUS BROADWAY
BUILDING 07 BASEMENT LEVEL 01
NEW PROTO SPACE FITOUT WORK
PROPOSED GENERAL FLOOR PLAN

FMU Project Number
02809-N-15

Drawn By	Checked	Approved By	Date App.
HA	GS		

Drawing Scale	Drawing Status	
AS SHOWN	TN	A1

UTS Drg File Name	UTS Drg File No	Rev No
CB07B1AP	46701	02



1 JOINERY LAYOUT PLAN
SCALE: 1:100 @ A1

FURNITURE SCHEDULE

KEY	QUANTITY	DESCRIPTION
TB.1	10	UR CUSTOM FOLDING TABLE 1500mm x 750mm X 25mm THICK E0 VERTIBOARD TOPS FINISHED TO LAMINEX BAYE NATURAL FINISH WITH 2mm MATCHING ABS. UR BASE 1082 TO BLACK POWDERCOAT WITH POLISHED FEET ON CASTORS WITH LINKING DEVICES.
TB.2	2	BLADE CUSTOM TABLE Ø800mm x 25mm POLYTEC NATURAL OAK RAVINE MATCHING 1mm ABS EDGE. BLADE BASE FINISHED TO BLACK POWDER COAT. OVERALL FINISH HEIGHT 600-700mm
TB.3	2	BLADE CUSTOM TABLE Ø600mm x 25mm POLYTEC NATURAL OAK RAVINE MATCHING 1mm ABS EDGE. BLADE BASE FINISHED TO BLACK POWDER COAT. OVERALL FINISH HEIGHT 600-700mm
CH.1	8	M33 MEDIUM BACK TASK CHAIR, BLACK MESH BACK, SEAT UPHOLSTERED IN HOUSE BLACK FABRIC, GAS LIFT HEIGHT ADJUSTMENT, TENSION ADJUSTMENT AND SLIDING SEAT, ON 5 WAY POLYPROPYLENE BASE ON CASTORS.
CH.2	10	CATIFA 46(L) 560mm x 510mm x 800mm, SH 460mm. SINGLE COLOUR POLYPROPYLENE SHELL TO WHITE WITH FRONT UPPHOLSTERY IN COM FABRIC ON A SLED BASE TO POWDERCOAT BLACK V39.
CH.3	10	HIGH TASK CHAIR....................................
CH.4	6	DUET BARSTOOL 410mm x 416mm x 450mm, FEATURING A SOLID FSC ASH TIMBER SEAT WITH STAINED TO COLOUR ON A MILD STEEL SLED BASE FINISHED TO STANDARD BLACK POWDERCOAT.
CH.5	6	MONK CHAIR 550mm x 590mm x 800mm SEAT HEIGHT 440mm, FEATURING A BENT PLYWOOD SHELL TO THE SEAT AND BACK UPPHOLSTERED IN GROUP X+ HOUSE FABRIC ON A SOLID OAK 4 LEGS FRAME TO FINISH.
CH.6	14	HEXAGONAL MODULAR STOOL 450mm HEIGHT (QTY 20) UPHOLSTERED IN FABRIC COM.
WS.1	2	AWM ALTO SIT TO STAND WINDER SYSTEM WORKSTATION, 2100mm x 800mm x 25mm THICK TOP FINISHED TO LAMINEX BAYE NATURAL FINISH WITH 2mm MATCHING ABS. WINDER WORKSTATION BASE FINISHED TO WHITE POWDER COAT. OVERALL FINISH HEIGHT 750mm.
WS.2	4	AWM ALTO SIT TO STAND WINDER SYSTEM WORKSTATION, 1200mm x 600mm x 25mm (PLUS ONE CUSTOM TO SUIT WALL) THICK TOP FINISHED TO LAMINEX BAYE NATURAL FINISH WITH 2mm MATCHING ABS. WINDER WORKSTATION BASE FINISHED TO WHITE POWDER COAT. OVERALL FINISH HEIGHT 750mm.
MP.1	2	AWM MOBILE PEDESTAL METAL IN WHITE COLOUR, 395mm x 530mm x 600mm (WITH CASTORS). PEDESTAL COME WITH PENCIL TRAY, 5 HEAVY DUTY LOCKABLE CASTORS, A4 FILING AND DRAWER DIVIDERS.

WORKBENCH SCHEDULE, REFER TO ATTACHED DRAWING SET FROM WILSON GILKES

KEY	QUANTITY	DESCRIPTION
WB.1A	3	STAFF WORKSHOP STANDING CUSTOM BENCH WITH SHELF UNDER
WB.1B	3	STAFF WORKSHOP STANDING CUSTOM BENCH WITH OPEN SPACE UNDER FOR MOBILE STORE UNITS AS DETAILED
WB.2	16	WORKSHOP, STANDING GENERAL WORK BENCH WITH SHELF UNDER
WB.3	9	WORKSHOP, STANDING MECHANICAL / ELECTRICAL WORK BENCH, REFER TO DETAILS
WB.4	10	WORKSHOP, MOBILE STORAGE UNITS

AV SCREEN SCHEDULE

KEY	QUANTITY	DESCRIPTION	KEY	QUANTITY	DESCRIPTION
SC.1/2/3	3	WALL MOUNTED LCD SCREEN AND TOUCH INTERFACE TO AV CONSULTANT SPEC.	SC.7	2	CEILING MOUNTED PROJECTOR SCREEN PROJECTED TO PREFINISHED WALL TO AV CONSULTANT SPEC.
SC.4	1	WALL MOUNTED LCD SCREEN TO AV CONSULTANT SPEC.	SC.8	2	CEILING MOUNTED PROJECTOR SCREEN PROJECTED TO AUTO RETRACTABLE ROLL SCREEN TO AV CONSULTANT SPEC.
SC.5	3	UTS SPEC POD MOUNTED SCREEN TO AV CONSULTANT SPEC.	SC.9	3	WALL MOUNTED PC STAND. SUPPLIER ATDEC GCX M SERIES FLUSH MOUNT MONITER, KEYBOARD AND CPU HOLDER. REFER TO SPEC FOR DETAILS
SC.6	2	CEILING MOUNTED PROJECTOR SCREEN PROJECTED TO PREFINISHED WALL TO AV CONSULTANT SPEC.			

JOINERY SCHEDULE

KEY	QUANTITY	DESCRIPTION	KEY	QUANTITY	DESCRIPTION
J.1	1	RECEPTION DESK REFER TO DWG 467--	J.8	3	CREATIVE POD DESK REFER TO DWG 467--
J.2	1	KITCHENETTE / RECEP STORE UNIT REFER TO DWG 467--	J.9	1	LOCKERS REFER TO DWG 467--
J.3	1	PRESENTATION WALL AND AV JOINERY REFER TO DWG 467--	J.10	1	MEDIUM END STORE UNIT REFER TO DWG 467--
J.4	3	MOBILE PRESENTATION DIVIDERS AND STORE REFER TO DWG 467--	J.11	2	STAINLESS STEEL WET BENCH X 2 (A & B) REFER TO DWG 467--
J.5	1	OFFICE AREA COUNTER STORE UNIT REFER TO DWG 467--	J.12	1	COLOUR BACK GLASS TO ENTRY AREA REFER TO DWG 467--
J.6	1	SORTING BENCH AND OVERHEAD STORE UNIT REFER TO DWG 467--			
J.7	1	OFFICE STORE UNIT AND HOT DESK REFER TO DWG 467--			

EQUIPMENT SCHEDULE - TBC BY CLIENT, ITEMS LISTED AS F / A AND SHOWN DOTTED ARE FUTURE ACQUISITIONS

KEY	DESCRIPTION / MODEL / SIZE	KEY	DESCRIPTION / MODEL / SIZE
01.	MULTIFAB R&D PRINTER: MULTIFAB (WxDxH TBC)	16.	ELECTRONIC PRINTER: OPTOMEC AEROSOL JET 5X (1375Wx1020Dx2240H)
02.	MULTILAYER PCB MAKING: DRAGONFLY 2020 (600Wx1000Dx600H)	17.	STANDARD ELECTRONIC BENCHTOP - BOSCOTEK
03.	BENCHTOP REFLOW OVEN: GF-12HT (990Wx813D x483H)	18.	3D PRINTER: MCOR IRIS (1160Wx720Dx1740H)
04.	ADV. ELECTRONIC BENCHTOP: BOSCOTEK (WxDxH TBC) x 2	19.	ELECTRONIC 3D PRINTER: VOXEL8 PROFESSIONAL (WxDxH TBC)
05.	METAL 3D PRINTER: OPM250L (1870Wx2230Dx2288H)	20.	HEADSET
06.	3D PRINTER: CONCEPT LASER M2 CUSING (2542Wx1818Dx1987H)	21.	3D PRINTER: OBJECT 3D PRIME (825Wx620Dx590H)
07.	3D PRINTER: STRATASYS J750 (1400Wx1100Dx1260H)	22.	3D PRINTER: MARKFORGED MARK II (575Wx332Dx360H)
08.	3D PRINTER: STRATASYS FORTUS 450mc (1295Wx902Dx1984H)	23.	SMALL CNC MILL: ROLAND MDX-40A (760Wx669Dx554H)
09.	3D PRINTER MATERIAL CABINET: STRATASYS J750 (670Wx640Dx1170H)	24.	3D SCANNER: ARTEC SPIDER (130Wx140Dx190H) ARTEC EVA (64Wx158Dx262H)
10.	3D PRINTER: EXONE M-FLEX (1400Wx1675Dx1855H)	25.	3D PRINTER: 3D SYSTEM MJP3600 (749Wx1194Dx1511H)
11.	OVEN FOR SINTERING TBA	26.	3D PRINTER: ENVISIONTEC DESKTOPXL (450Wx550Dx890H)
12.	3D PRINTER: HP MULTIJET FUSION (2178Wx1238Dx1448H)	27.	3D PRINTER: STRATASYS DIMENSION 1200es (737Wx838Dx1143H)
13.	METAL 3D PRINTER: SPEE3D (2680Wx1420Dx2270H)	28.	3D PRINTER: RIZE (WxDxH TBC)
14.	3D SCANNING - COLOUR / LARGE SCALE (WxDxH TBC)	29.	SMALL METAL/PLASTIC LASER CUTTER: COHERENT META 10 (2000Wx1600Dx1200H)
15.	3D SCANNER - CREAFORM METRASCAN (300Wx300Dx300H)	30.	LASER PLASTIC BONDING: LPKF PRECISION WELD 3000 (875Wx750Dx1430H)
		31.	SMALL LATHE: SCHAUBLIN 225 TMi-CNC (1950Wx1100Dx1610H)
		32.	PICK&PLACE: DDM NOVASTAR L-SF40 (914Wx965Dx635H)
		33.	BASIC BENCHTOP: BOSCOTEK (WxDxH)
		34.	MECHANICAL BENCHTOP: BOSCOTEK (WxDxH)
		35.	DRILL PRESS: HAFCO STANDARD SIZE/MODEL (WxDxH TBC)
		36.	BAND SAW: JET JWBS14Q (WxDxH TBC)

GENERAL KEY:

- W3 — WALL TYPE ABOVE/BELOW WINDOW OR DOOR
- WD3 — WINDOW/DOOR NUMBER
- 01 — SCHEDULE SHEET
- FL1 — GENERAL FLOOR TYPE KEY
- SK1 — GENERAL SKIRTING TYPE KEY
- W1 — GENERAL WALL KEY
- P1 — GENERAL PAINT COLOUR KEY
- SC1 — GENERAL CEILING FINISH KEY
- 2700 — CEILING HEIGHT FROM FFL KEY

WALL LEGEND

W1 1 LAYERS OF 13mm THICK GYPROCK EC08 IMPACTCHECK FIXED TO BOTH SIDES OF NEW 76mm STEEL STUDS EXTENDED TO UNDERSIDE OF CEILING OR TO TOP OF WALL . INSULATION AS SPECIFIED. FINISH LININGS AT ALL INTERNAL CORNERS AND AT CEILING JUNCTIONS WITH RONDO P50 SHADOWLINE SETTING BEADS.PAINT FINISH AS SPECIFIED AND APPLY NEW SKIRTING AS SPECIFIED

W2 2 LAYERS OF 13mm THICK GYPROCK EC08 FIRE CHECK FIXED TO BOTH SIDES OF NEW 76mm STEEL STUDS EXTENDED TO UNDERSIDE OF CEILING OR TO TOP OF WALL TO ACHIEVE A FIRE RATING OF 120/120/120. INSULATION AS SPECIFIED. FINISH LININGS AT ALL INTERNAL CORNERS AND AT CEILING JUNCTIONS WITH RONDO P50 SHADOWLINE SETTING BEADS.PAINT FINISH AS SPECIFIED AND APPLY NEW SKIRTING AS SPECIFIED

W3 76mm STEEL STUDS EXTENDED AS REQUIRED TO PROVIDE SUPPORT FOR CLADDING SPECIFIED. NEW CLADDING INSTALLED TO MANUFACTURES RECOMENDATIONS AND AS PER DETIALS.

W4 200MM CONCRETE BLOCK WALL TO TIE INTO AND MATCH ADJOIING EXISTING WALL. HEIGHT AS DETAILS TO UNDERSIDE OF NEW CONCRETE SLAB LID

GENERAL FINISHES KEY

F1 LAMINATE FINISH - LAMINEX - WHITE NATURAL FINISH 200
F2 LAMINATE FINISH - LAMINEX - ELEGANT OAK NATURAL FINISH 78
F3 SOLID SURFACE CORAIN - GLACIER WHITE
F4 HAFELE ABS PLYWOOD EDGE
F5 MAGNETIC WHITE BOARD LAMINATE
F6 FABRIC - INSTYLE ATLAS CITRUS
F7 LAMINATE FINISH - LAMINEX - BRUSHED ALUMINIUM
F8 STARFIRE COLOUR BACK GLASS - PROVIDE SAMPLE TO MATCH F1
F9 PERFORATED ALUMINIUM SHEET, ARROW METAL 3MM ALUMINIUM BLACK PWDERCOAT, PATTERN 240
F10 LAMINATE FINISH - LAMINEX - BLACK NATURAL FINISH 460
F11 ACRYLIC PANEL - INNOVATIVE SPLASHBACKS, COLOUR 'ANGEL' TBC

WP1 DELETED
WP2 DIBOND PANELS. COLOUR, BUTLERFINISH STEEL
WP3 DIBOND PANELS COLOUR, TRAFFIC YELLOW GLOSS

GENERAL FLOOR KEY

FL1 RUBBER FLOOR FINISH - REGUPOL EVEROLL, REFER TO ARCH. SPEC.
FL2 NEW PAINT EPOXY FLOOR FINISH - ROXSET RC, REFER TO ARCH. SPEC.
FL3 STEEL TROWEL CONCRETE SLAB
FL4 PAINTED LEVELING TOPPING TO MATCH EXISTING CORRIDOR

SK1 SELECTED SKIRTING 01 - 150mm DUCTED, BLACK ALUMINIUM SKIRTING
SK2 SELECTED SKIRTING 02 - 150MM FLAT, BLACK ALUMINIUM SKIRTING

FW FLOOR WASTE, REFER TO HYDRAULIC ENG. FOR DETAILS

GENERAL PAINT FINISHES KEY

P1 DULUX - ANTIQUE WHITE USA.
P2 DULUX - BLACK SATIN DURALLOY 19268
P3 REFER TO ARCH. SPECIFICATIONS

GENERAL CEILING AND LIGHTING KEY - REFER TO ENGINEERS DOCUMENTATION

PP SUSPENDED 2400 X 1200 PERFORATED ACOUSTIC SHEETS BACK FILLED SHADOW PERIMETER, SHEETS TO BE REMOVABLE FOR ACCESS TO SERVICES, REFER TO ARCH. SPEC.
SPB SET PLASTERBOARD CEILING WITH P50 SHADOWLINE TO PERIMETER
ACT SUSPENDED 600 XC 600 ACOUSTIC TILE CEILING WITH P50 SHADOWLINE TO PERIMETER
SLT SUSPENDED SLATS WITH ACOUSTIC BLANKET - REFER TO ARCH. SPECIFICATION
MC1 DIBOND PANELS. COLOUR, BUTLERFINISH STEEL
MC2 DIBOND PANELS. COLOUR, TRAFFIC YELLOW GLOSS
BB BUZZ BAR POWER GRID, REFER TO ENGINEER'S DETAILS
OFC OFF FORM CONCRETE TO ENGINEER'S DETAILS.
ACP VERTICAL ACOUSTIC PANEL. ARMSTRONG CS5143 WH 1800 X 400 X 40, COLOUR TBC
CA 600mm x 600mm SET PLASTERBOARD HINGED ACCESS PANEL WITH PERIMETER SETTING BEADS TO FINISH FLUSH WITH PLASTERBOARD

IMPORTANT NOTES:
1. DIMENSIONS SHALL NOT BE OBTAINED BY SCALING THE ARCHITECTURAL DRAWINGS.
2. ALL DIMENSIONS SHOWN ON THE DRAWINGS SHALL BE PHYSICALLY CHECKED AND VERIFIED ON SITE BY THE BUILDER BEFORE ANY CONSTRUCTION COMMENCES.
3. THE BUILDER SHALL CONFIRM IN WRITING THAT ALL DIMENSIONS HAVE BEEN CHECKED AND REPORT ANY DIMENSIONAL INCONSISTENCIES OR DISCREPANCIES TO THE ARCHITECTS AND OBTAIN THEIR INSTRUCTIONS AND/OR APPROVAL TO PROCEED.
4. ALL WORKS SHALL BE EXECUTED IN ACCORDANCE WITH THE CURRENT VERSION OF THE BCA AND ALL RELEVANT STANDARDS.
5. THESE DRAWINGS ARE PROTECTED BY COPYRIGHT.

SAFETY IN DESIGN:
THERE ARE INHERENT RISKS INVOLVED IN CONSTRUCTING, MAINTAINING, USING AND ULTIMATELY DISMANTLING AND DISPOSING OF ALL BUILDINGS. BURTENSHAW SCOUFIS ARCHITECTURE HAVE ELIMINATED OR MINIMISED THESE RISKS, AS FAR AS IS REASONABLY PRACTICABLE, THROUGH PRUDENT REVIEWS OF THE DESIGN DURING THE DESIGN PROCESSES. HAZARD CONTROLS MUST STILL BE IMPLEMENTED BY THE PRINCIPAL BUILDING CONTRACTOR DURING THE CONSTRUCTION STAGE AND SUBSEQUENTLY BY OWNERS OR OPERATORS TO ENSURE THE SAFETY OF ALL WORKERS AND OCCUPIERS FOR THE INTENDED LIFE OF THE BUILDING.

1m 2m 3.5m

Rev.	Description	Approved Date
	TENDER ISSUE - TN NOT FOR CONSTRUCTION	
01	REVISED WORKSHOP EUIPMENT LAYOUT	10.10.16
02	TENDER ISSUE REVISION 2	20.10.16

Consultant

Project Name
BDG 07 - LVL B01
NEW PROTO SPACE FITOUT WORK

UTS
UNIVERSITY OF TECHNOLOGY, SYDNEY

FACILITIES MANAGEMENT OPERATIONS
Tower,Building 1,Level 19,15 Broadway
Broadway NSW 2007
Ph: 9514-2000 Fax: 9514-4690

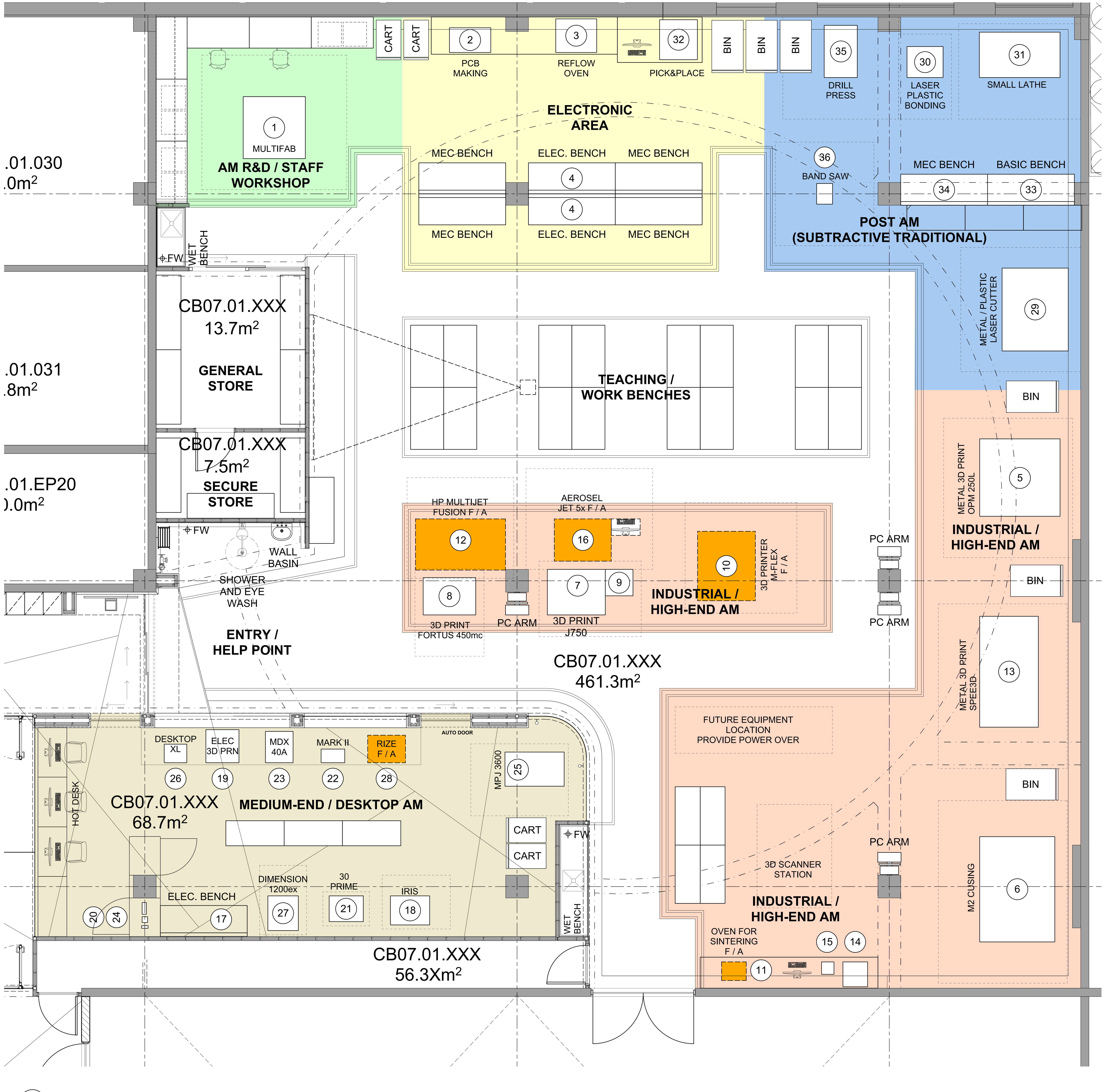
Drawing Title
CITY CAMPUS BROADWAY
BUILDING 07 BASEMENT LEVEL 01
NEW PROTO SPACE FITOUT WORK
JOINERY LAYOUT PLAN

FMU Project Number
02809-N-15

Drawn By	Checked	Approved By	Date App.
FK	GS		

Drawing Scale	Drawing Status	
AS SHOWN	TN	A1

UTS Drg File Name	UTS Drg File No	Rev No
CB07B1AP	46702 A	02



1 WORKSHOP LAYOUT PLAN
SCALE: 1:50 @ A1

EQUIPMENT SCHEDULE - TBC BY CLIENT

KEY	DESCRIPTION / MODEL / SIZE
AM R&D	
01.	MULTIFAB R&D PRINTER: MULTIFAB (WxDxH)
ELECTRONIC AREA	
02.	MULTILAYER PCB MAKING: DRAGONFLY 2020 (600Wx1000Dx600H)
03.	BENCHTOP REFLOW OVEN: GF-12HT (990Wx813D x483H)
04.	ADV. ELECTRONIC BENCHTOP: BOSCOTEK (WxDxH) x 2
17.	STANDARD ELECTRONIC BENCHTOP - BOSCOTEK (WxDxH)
33.	BASIC BENCHTOP: BOSCOTEK (WxDxH)
34.	MECHANICAL BENCHTOP: BOSCOTEK (WxDxH)
INDUSTRIAL HIGH END AM	
05.	METAL 3D PRINTER: OPM250L (1870Wx2230Dx2288H)
06.	3D PRINTER: CONCEPT LASER M2 CUSING (2542Wx1818Dx1987H)
07.	3D PRINTER: STRATASYS J750 (1400Wx1100Dx1260H)
09.	3D PRINTER MATERIAL CABINET: STRATASYS J750 (670Wx640Dx1170H)
08.	3D PRINTER: STRATASYS FORTUS 450mc (1295Wx902Dx1984H)
10.	3D PRINTER: EXONE M-FLEX (1400Wx1675Dx1855H)
11.	OVEN FOR SINTERING
12.	3D PRINTER: HP MULTIJET FUSION (2178Wx1238Dx1448H)
13.	METAL 3D PRINTER: SPEE3D (2680Wx1420Dx2270H)
14.	3D SCANNING - COLOUR / LARGE SCALE (WxDxH)
15.	3D SCANNER - CREAFORM METRASCAN (300Wx300Dx300H)
16.	ELECTRONIC PRINTER: OPTOMEC AEROSOL JET 5X (1375Wx1020Dx2240H)
MEDIUM / DESKTOP AM	
18.	3D PRINTER: MCOR IRIS (1160Wx720Dx940H)
19.	ELECTRONIC 3D PRINTER: VOXEL8 PROFESSIONAL (WxDxH)
20.	VR HEADSET
21.	3D PRINTER: OBJECT 3D PRIME (825Wx620Dx590H)
22.	3D PRINTER: MARKFORGED MARK II (575Wx332Dx360H)
23.	SMALL CNC MILL: ROLAND MDX-40A (760Wx669Dx554H)
24.	3D SCANNER: ARTEC SPIDER (130Wx140Dx190H) ARTEC EVA (64Wx158Dx262H)
25.	3D PRINTER: 3D SYSTEM MJP3600 (749Wx1194Dx1511H)
26.	3D PRINTER: ENVISIONTEC DESKTOPXL (450Wx550Dx890H)
27.	3D PRINTER: STRATASYS DIMENSION 1200es (737Wx838Dx1143H)
28.	3D PRINTER: RIZE (915Wx644Dx543H)
POST AM (SUBTRACTIVE/TRADITIONAL)	
29.	SMALL METAL/PLASTIC LASER CUTTER: COHERENT META 10 (2000Wx1600Dx1200H)
30.	LASER PLASTIC BONDING: LPKF PRECISION WELD 3000 (875Wx750Dx1430H)
31.	SMALL LATHE: SCHAUBLIN 225 TMi-CNC (1950Wx1100Dx1610H)
32.	PICK&PLACE: DDM NOVASTAR L-SF40 (914Wx965Dx635H)
35.	DRILL PRESS: HAFCO STANDARD SIZE/MODEL (WxDxH)
36.	BAND SAW: JET JWBS14Q (WxDxH)

EQUIPMENT DELIVERY

DAY 1 ACQUISITION

FUTURE ACQUISITION

IMPORTANT NOTES:
1. DIMENSIONS SHALL NOT BE OBTAINED BY SCALING THE ARCHITECTURAL DRAWINGS.
2. ALL DIMENSIONS SHOWN ON THE DRAWINGS SHALL BE PHYSICALLY CHECKED AND VERIFIED ON SITE BY THE BUILDER BEFORE ANY CONSTRUCTION COMMENCES.
3. THE BUILDER SHALL CONFIRM IN WRITING THAT ALL DIMENSIONS HAVE BEEN CHECKED AND REPORT ANY DIMENSIONAL INCONSISTENCIES OR DISCREPANCIES TO THE ARCHITECTS AND OBTAIN THEIR INSTRUCTIONS AND/OR APPROVAL TO PROCEED.
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5. THESE DRAWINGS ARE PROTECTED BY COPYRIGHT.

SAFETY IN DESIGN:
THERE ARE INHERENT RISKS INVOLVED IN CONSTRUCTING, MAINTAINING, USING AND ULTIMATELY DISMANTLING AND DISPOSING OF ALL BUILDINGS. BURTENSHAW SCOUFIS ARCHITECTURE HAVE ELIMINATED OR MINIMISED THESE RISKS, AS FAR AS IS REASONABLY PRACTICABLE, THROUGH PRUDENT REVIEWS OF THE DESIGN DURING THE DESIGN PROCESSES. HAZARD CONTROLS MUST STILL BE IMPLEMENTED BY THE PRINCIPAL BUILDING CONTRACTOR DURING THE CONSTRUCTION STAGE AND SUBSEQUENTLY BY OWNERS OR OPERATORS TO ENSURE THE SAFETY OF ALL WORKERS AND OCCUPIERS FOR THE INTENDED LIFE OF THE BUILDING.

1m 2m 3.5m

TENDER ISSUE - TN
NOT FOR CONSTRUCTION

Rev.	Description	Approved Date
01	REVISED WORKSHOP EUIPMENT LAYOUT	10.10.16
02	TENDER ISSUE REVISION 2	20.10.16

Consultant

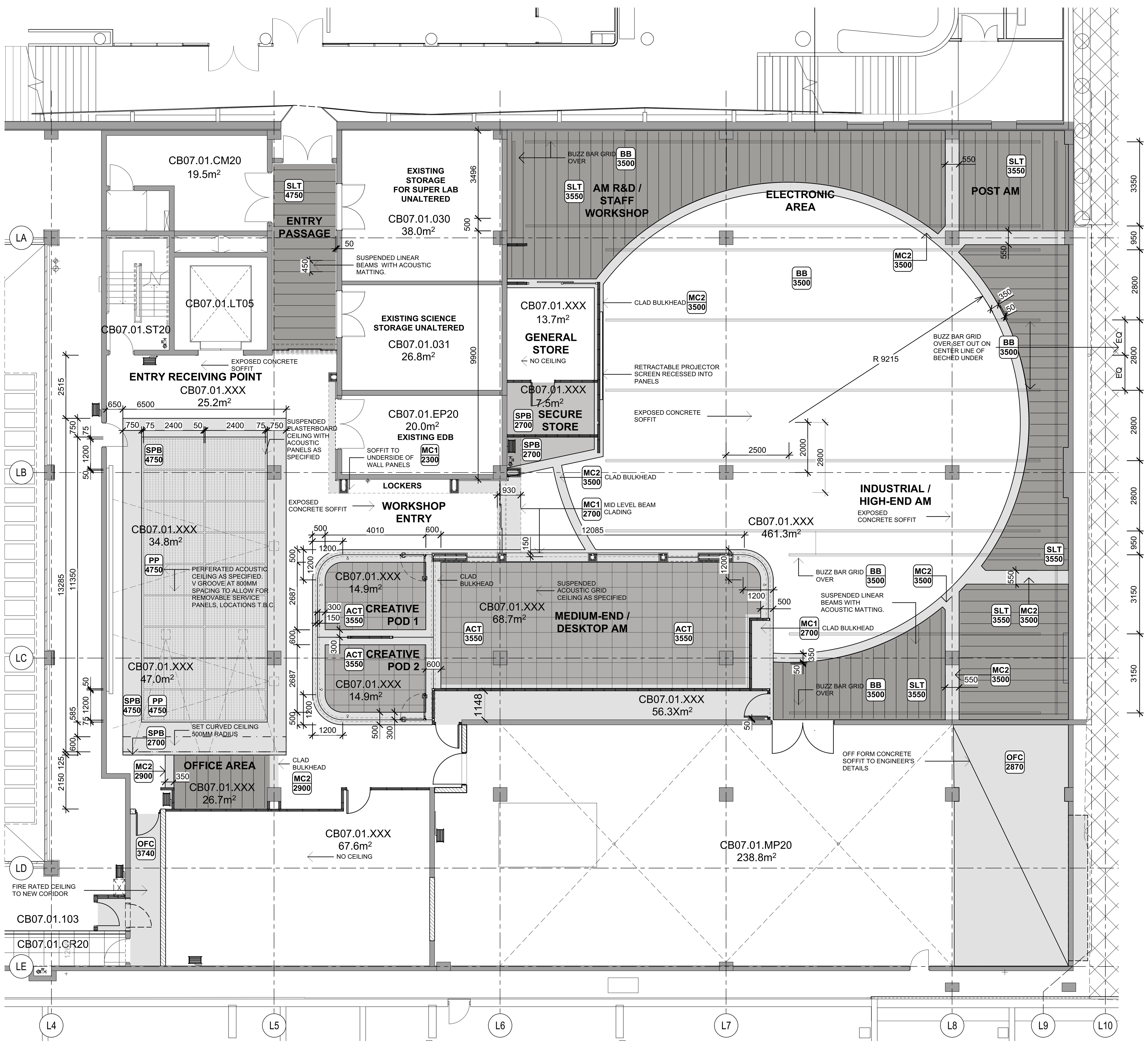
Project Name
BDG 07 - LVL B01
NEW PROTO SPACE FITOUT WORK

UTS
UNIVERSITY OF TECHNOLOGY, SYDNEY

FACILITIES MANAGEMENT OPERATIONS
Tower,Building 1,Level 19,15 Broadway
Broadway NSW 2007
Ph: 9514-2000 Fax: 9514-4690

Drawing Title
CITY CAMPUS BROADWAY
BUILDING 07 BASEMENT LEVEL 01
NEW PROTO SPACE FITOUT WORK
JOINERY LAYOUT PLAN

FMU Project Number: 02809-N-15			
Drawn By: JK	Checked: GS	Approved By	Date App.
Drawing Scale: AS SHOWN	Drawing Status: TN	A1	
UTS Drg File Name: CB07B1AP	UTS Drg File No: 46702 B	Rev No: 02	



1 PROPOSED REFLECTED CEILING PLAN
SCALE: 1:100 @ A1

IMPORTANT NOTES:
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SAFETY IN DESIGN:
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1m 2m 3.5m

Rev.	Description	Approved Date
	TENDER ISSUE - TN NOT FOR CONSTRUCTION	
01	TENDER ISSUE	29.08.16
02	TENDER ISSUE REVISION 2	20.10.16

Consultant

Project Name
BDG 07 - LVL B01
NEW PROTO SPACE FITOUT WORK

UTS
UNIVERSITY OF TECHNOLOGY, SYDNEY

FACILITIES MANAGEMENT OPERATIONS
Tower,Building 1,Level 19,15 Broadway
Broadway NSW 2007
Ph: 9514-2000 Fax: 9514-4690

GENERAL KEY:

- W3 — WALL TYPE ABOVE/BELOW WINDOW OR DOOR
- WD3 — WINDOW/DOOR NUMBER
- 01 — SCHEDULE SHEET
- FL1 — GENERAL FLOOR TYPE KEY
- SK1 — GENERAL SKIRTING TYPE KEY
- W1 — GENERAL WALL KEY
- P1 — GENERAL PAINT COLOUR KEY
- SC1 — GENERAL CEILING FINISH KEY
- 2700 — CEILING HEIGHT FROM FFL KEY

WALL LEGEND

W1 1 LAYERS OF 13mm THICK GYPROCK EC08 IMPACTCHECK FIXED TO BOTH SIDES OF NEW 76mm STEEL STUDS EXTENDED TO UNDERSIDE OF CEILING OR TO TOP OF WALL . INSULATION AS SPECIFIED. FINISH LININGS AT ALL INTERNAL CORNERS AND AT CEILING JUNCTIONS WITH RONDO P50 SHADOWLINE SETTING BEADS.PAINT FINISH AS SPECIFIED AND APPLY NEW SKIRTING AS SPECIFIED

W2 2 LAYERS OF 13mm THICK GYPROCK EC08 FIRE CHECK FIXED TO BOTH SIDES OF NEW 76mm STEEL STUDS EXTENDED TO UNDERSIDE OF CEILING OR TO TOP OF WALL TO ACHIEVE A FIRE RATING OF 120/120/120. INSULATION AS SPECIFIED. FINISH LININGS AT ALL INTERNAL CORNERS AND AT CEILING JUNCTIONS WITH RONDO P50 SHADOWLINE SETTING BEADS.PAINT FINISH AS SPECIFIED AND APPLY NEW SKIRTING AS SPECIFIED

W3 76mm STEEL STUDS EXTENDED AS REQUIRED TO PROVIDE SUPPORT FOR CLADDING SPECIFIED. NEW CLADDING INSTALLED TO MANUFACTURES RECOMENDATIONS AND AS PER DETIALS.

W4 200MM CONCRETE BLOCK WALL TO TIE INTO AND MATCH ADJOIING EXISTING WALL. HEIGHT AS DETAILS TO UNDERSIDE OF NEW CONCRETE SLAB LID

GENERAL FINISHES KEY

F1 LAMINATE FINISH - LAMINEX - WHITE NATURAL FINISH 200
F2 LAMINATE FINISH - LAMINEX - ELEGANT OAK NATURAL FINISH 78
F3 SOLID SURFACE CORAIN - GLACIER WHITE
F4 HAFELE ABS PLYWOOD EDGE
F5 MAGNETIC WHITE BOARD LAMINATE
F6 FABRIC - INSTYLE ATLAS CITRUS
F7 LAMINATE FINISH - LAMINEX - BRUSHED ALUMINIUM
F8 STARFIRE COLOUR BACK GLASS - PROVIDE SAMPLE TO MATCH F1
F9 PERFORATED ALUMINIUM SHEET, ARROW METAL 3MM ALUMINIUM BLACK PWDERCOAT, PATTERN 240
F10 LAMINATE FINISH - LAMINEX - BLACK NATURAL FINISH 460
F11 ACRYLIC PANEL - INNOVATIVE SPLASHBACKS, COLOUR 'ANGEL' TBC

WP1 DELETED
WP2 DIBOND PANELS. COLOUR, BUTLERFINISH STEEL
WP3 DIBOND PANELS COLOUR, TRAFFIC YELLOW GLOSS

GENERAL FLOOR KEY

FL1 RUBBER FLOOR FINISH - REGUPOL EVEROLL, REFER TO ARCH. SPEC.
FL2 NEW PAINT EPOXY FLOOR FINISH - ROXSET RC, REFER TO ARCH. SPEC.
FL3 STEEL TROWEL CONCRETE SLAB
FL4 PAINTED LEVELING TOPPING TO MATCH EXISTING CORRIDOR

SK1 SELECTED SKIRTING 01 - 150mm DUCTED, BLACK ALUMINIUM SKIRTING
SK2 SELECTED SKIRTING 02 - 150MM FLAT, BLACK ALUMINIUM SKIRTING

FW FLOOR WASTE, REFER TO HYDRAULIC ENG. FOR DETAILS

GENERAL PAINT FINISHES KEY

P1 DULUX - ANTIQUE WHITE USA.
P2 DULUX - BLACK SATIN DURALLOY 19268
P3 REFER TO ARCH. SPECIFICATIONS

GENERAL CEILING AND LIGHTING KEY - REFER TO ENGINEERS DOCUMENTATION

PP SUSPENDED 2400 X 1200 PERFORATED ACOUSTIC SHEETS BACK FILLED SHADOW PERIMETER, SHEETS TO BE REMOVABLE FOR ACCESS TO SERVICES, REFER TO ARCH. SPEC.
SPB SET PLASTERBOARD CEILING WITH P50 SHADOWLINE TO PERIMETER
ACT SUSPENDED 600 XC 600 ACOUSTIC TILE CEILING WITH P50 SHADOWLINE TO PERIMETER
SLT SUSPENDED SLATS WITH ACOUSTIC BLANKET - REFER TO ARCH. SPECIFICATION
MC1 DIBOND PANELS. COLOUR, BUTLERFINISH STEEL
MC2 DIBOND PANELS. COLOUR, TRAFFIC YELLOW GLOSS
BB BUZZ BAR POWER GRID, REFER TO ENGINEER'S DETAILS
OFC OFF FORM CONCRETE TO ENGINEER'S DETAILS.
ACP VERTICAL ACOUSTIC PANEL. ARMSTRONG CS5143 WH 1800 X 400 X 40, COLOUR TBC
CA 600mm x 600mm SET PLASTERBOARD HINGED ACCESS PANEL WITH PERIMETER SETTING BEADS TO FINISH FLUSH WITH PLASTERBOARD

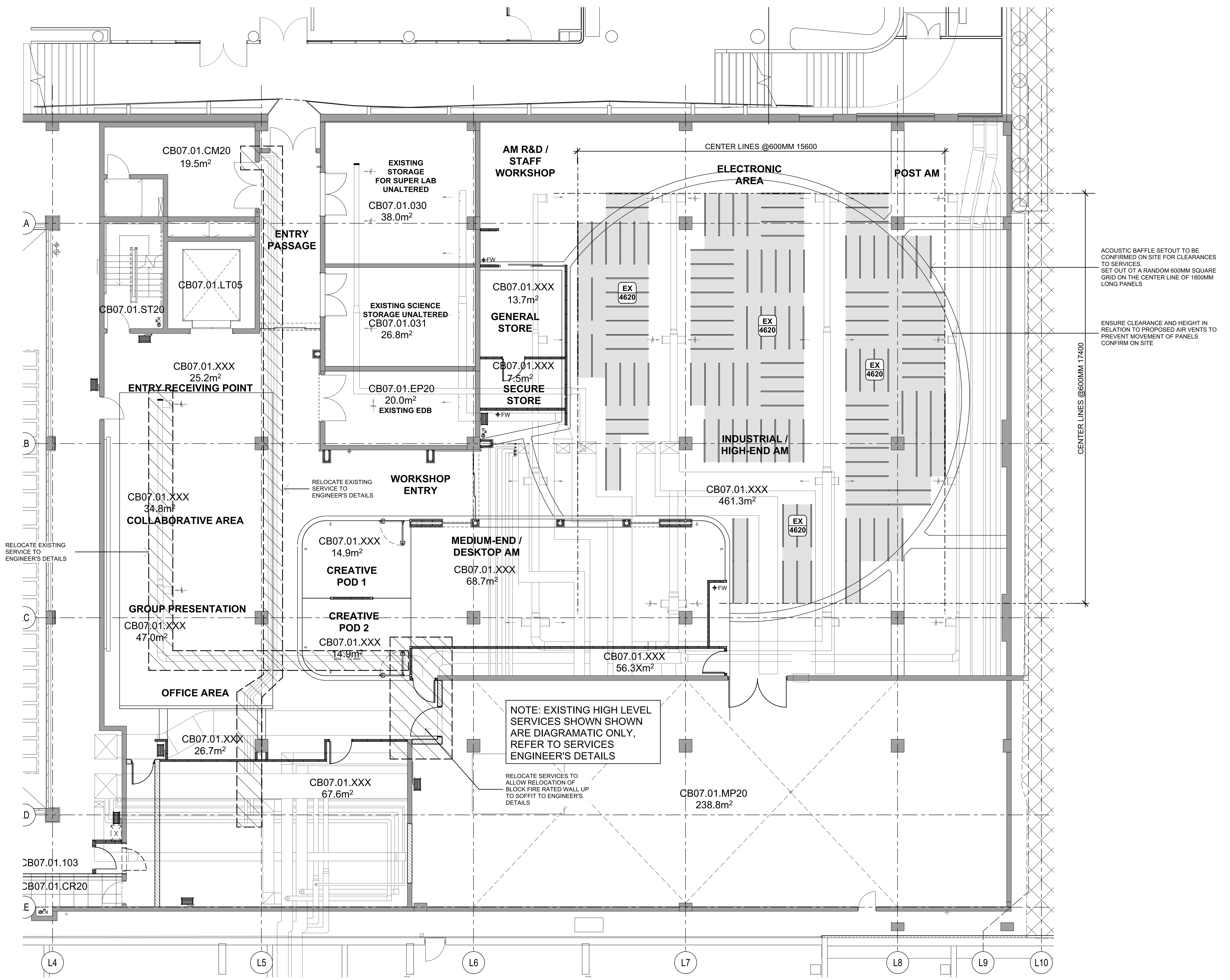
Drawing Title
CITY CAMPUS BROADWAY
BUILDING 07 BASEMENT LEVEL 01
NEW PROTO SPACE FITOUT WORK
PROPOSED REFLECTED CEILING PLAN

FMU Project Number
02809-N-15

Drawn By	Checked	Approved By	Date App.
HA	GS		

Drawing Scale	Drawing Status	
AS SHOWN	TN	A1

UTS Drg File Name	UTS Drg File No	Rev No
CB07B1AP	46703	02



1 PROPOSED HIGH LEVEL REFLECTED CEILING PLAN
SCALE: 1:100 @ A1

IMPORTANT NOTES:
1. DIMENSIONS SHALL NOT BE OBTAINED BY SCALING THE ARCHITECTURAL DRAWINGS.
2. ALL DIMENSIONS SHOWN ON THE DRAWINGS SHALL BE PHYSICALLY CHECKED AND VERIFIED ON SITE BY THE BUILDER BEFORE ANY CONSTRUCTION COMMENCES.
3. THE BUILDER SHALL CONFIRM IN WRITING THAT ALL DIMENSIONS HAVE BEEN CHECKED AND REPORT ANY DIMENSIONAL INCONSISTENCIES OR DISCREPANCIES TO THE ARCHITECTS AND OBTAIN THEIR INSTRUCTIONS AND/OR APPROVAL TO PROCEED.
4. ALL WORKS SHALL BE EXECUTED IN ACCORDANCE WITH THE CURRENT VERSION OF THE BCA AND ALL RELEVANT STANDARDS.
5. THESE DRAWINGS ARE PROTECTED BY COPYRIGHT.

SAFETY IN DESIGN:
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1m 2m 3.5m

Rev.	Description	Approved Date
	TENDER ISSUE - TN NOT FOR CONSTRUCTION	
01	TENDER ISSUE	29.08.16
02	TENDER ISSUE REVISION 2	20.10.16

Consultant

Project Name
BDG 07 - LVL B01
NEW PROTO SPACE FITOUT WORK

UTS
UNIVERSITY OF TECHNOLOGY, SYDNEY

FACILITIES MANAGEMENT OPERATIONS
Tower,Building 1,Level 19,15 Broadway
Broadway NSW 2007
Ph: 9514-2000 Fax: 9514-4690

Drawing Title
CITY CAMPUS BROADWAY
BUILDING 07 BASEMENT LEVEL 01
NEW PROTO SPACE FITOUT WORK
PROPOSED HIGH LEVEL
REFLECTED CEILING PLAN

FMU Project Number
02809-N-15

Drawn By	Checked	Approved By	Date App.
HA	GS		

Drawing Scale	Drawing Status	
AS SHOWN	TN	A1

UTS Drg File Name	UTS Drg File No	Rev No
CB07B1AP	46704	02

GENERAL KEY:

- W3 ← WALL TYPE ABOVE/BELOW WINDOW OR DOOR
- WD3 ← WINDOW/DOOR NUMBER
- 01 ← SCHEDULE SHEET
- FL1 ← GENERAL FLOOR TYPE KEY
- SK1 ← GENERAL SKIRTING TYPE KEY
- W1 ← GENERAL WALL KEY
- P1 ← GENERAL PAINT COLOUR KEY
- SC1 ← GENERAL CEILING FINISH KEY
- 2700 ← CEILING HEIGHT FROM FFL KEY

WALL LEGEND

W1 1 LAYERS OF 13mm THICK GYPROCK EC08 IMPACTCHECK FIXED TO BOTH SIDES OF NEW 76mm STEEL STUDS EXTENDED TO UNDERSIDE OF CEILING OR TO TOP OF WALL . INSULATION AS SPECIFIED. FINISH LININGS AT ALL INTERNAL CORNERS AND AT CEILING JUNCTIONS WITH RONDO P50 SHADOWLINE SETTING BEADS.PAINT FINISH AS SPECIFIED AND APPLY NEW SKIRTING AS SPECIFIED

W2 2 LAYERS OF 13mm THICK GYPROCK EC08 FIRE CHECK FIXED TO BOTH SIDES OF NEW 76mm STEEL STUDS EXTENDED TO UNDERSIDE OF CEILING OR TO TOP OF WALL TO ACHIEVE A FIRE RATING OF 120/120/120. INSULATION AS SPECIFIED. FINISH LININGS AT ALL INTERNAL CORNERS AND AT CEILING JUNCTIONS WITH RONDO P50 SHADOWLINE SETTING BEADS.PAINT FINISH AS SPECIFIED AND APPLY NEW SKIRTING AS SPECIFIED

W3 76mm STEEL STUDS EXTENDED AS REQUIRED TO PROVIDE SUPPORT FOR CLADDING SPECIFIED. NEW CLADDING INSTALLED TO MANUFACTURES RECOMENDATIONS AND AS PER DETIALS.

W4 200MM CONCRETE BLOCK WALL TO TIE INTO AND MATCH ADJOIING EXISTING WALL. HEIGHT AS DETAILS TO UNDERSIDE OF NEW CONCRETE SLAB LID

GENERAL FINISHES KEY

F1 LAMINATE FINISH - LAMINEX - WHITE NATURAL FINISH 200
F2 LAMINATE FINISH - LAMINEX - ELEGANT OAK NATURAL FINISH 78
F3 SOLID SURFACE CORAIN - GLACIER WHITE
F4 HAFELE ABS PLYWOOD EDGE
F5 MAGNETIC WHITE BOARD LAMINATE
F6 FABRIC - INSTYLE ATLAS CITRUS
F7 LAMINATE FINISH - LAMINEX - BRUSHED ALUMINIUM
F8 STARFIRE COLOUR BACK GLASS - PROVIDE SAMPLE TO MATCH F1
F9 PERFORATED ALUMINIUM SHEET, ARROW METAL 3MM ALUMINIUM BLACK PWDERCOAT, PATTERN 240
F10 LAMINATE FINISH - LAMINEX - BLACK NATURAL FINISH 460
F11 ACRYLIC PANEL - INNOVATIVE SPLASHBACKS, COLOUR 'ANGEL' TBC

WP1 DELETED
WP2 DIBOND PANELS. COLOUR, BUTLERFINISH STEEL
WP3 DIBOND PANELS COLOUR, TRAFFIC YELLOW GLOSS

GENERAL FLOOR KEY

FL1 RUBBER FLOOR FINISH - REGUPOL EVEROLL, REFER TO ARCH. SPEC.
FL2 NEW PAINT EPOXY FLOOR FINISH - ROXSET RC, REFER TO ARCH. SPEC.
FL3 STEEL TROWEL CONCRETE SLAB
FL4 PAINTED LEVELING TOPPING TO MATCH EXISTING CORRIDOR

SK1 SELECTED SKIRTING 01 - 150mm DUCTED, BLACK ALUMINIUM SKIRTING
SK2 SELECTED SKIRTING 02 - 150MM FLAT, BLACK ALUMINIUM SKIRTING

FW FLOOR WASTE, REFER TO HYDRAULIC ENG. FOR DETAILS

GENERAL PAINT FINISHES KEY

P1 DULUX - ANTIQUE WHITE USA.
P2 DULUX - BLACK SATIN DURALLOY 19268
P3 REFER TO ARCH. SPECIFICATIONS

GENERAL CEILING AND LIGHTING KEY - REFER TO ENGINEERS DOCUMENTATION

PP SUSPENDED 2400 X 1200 PERFORATED ACOUSTIC SHEETS BACK FILLED SHADOW PERIMETER, SHEETS TO BE REMOVABLE FOR ACCESS TO SERVICES, REFER TO ARCH. SPEC.
SPB SET PLASTERBOARD CEILING WITH P50 SHADOWLINE TO PERIMETER
ACT SUSPENDED 600 XC 600 ACOUSTIC TILE CEILING WITH P50 SHADOWLINE TO PERIMETER
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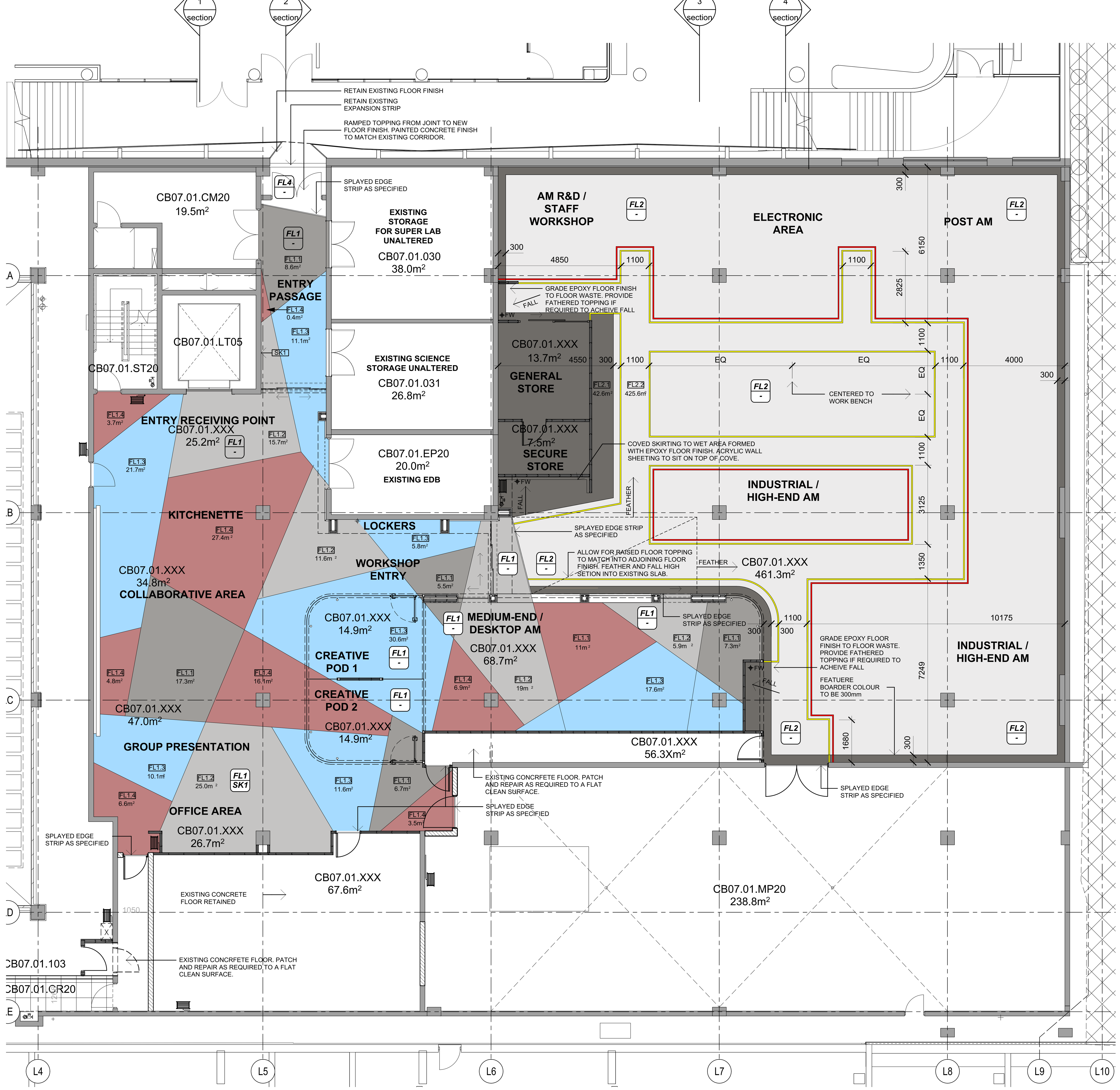

1 FLOOR FINISHES LAYOUT PLAN
SCALE: 1:100 @ A1

RUBBER FLOORING SCHEDULE

KEY	TAG	QUANTITY	DESCRIPTION
	FL1.1	45.3m2	EVERROLL INTENSITY MONS
	FL1.2	77.2m2	EVERROLL INTENSITY ISLAND
	FL1.3	108.4m2	EVERROLL SHAPE NOME
	FL1.4	80.6m2	EVERROLL SHAPE GOA

EPOXY FLOORING SCHEDULE

KEY	TAG	QUANTITY	DESCRIPTION
	FL2.1	59.4m2	ROXSET DARK GREY ROX-003
	FL2.2	394m2	ROXSET LIGHT GREY 142 ROX-004

EQUIPMENT AND WALKWAY LINE MARKING TAPE

KEY	DESCRIPTION
	EQUIPMENT EXCLUSION / ZONE 50MM RED TAPE AS SPECIFIED
	PEDESTRIAN WALKWAY 50MM YELLOW TAPE AS SPECIFIED

NOTE : LAYOUT OF LINE MARKING TBC

IMPORTANT NOTES:
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Consultant

Project Name
BDG 07 - LVL B01
NEW PROTO SPACE FITOUT WORK

UNIVERSITY OF TECHNOLOGY, SYDNEY

FACILITIES MANAGEMENT OPERATIONS
Tower,Building 1,Level 19,15 Broadway
Broadway NSW 2007
Ph: 9514-2000 Fax: 9514-4690

Drawing Title
CITY CAMPUS BROADWAY
BUILDING 07 BASEMENT LEVEL 01
NEW PROTO SPACE FITOUT WORK
FLOOR FINISHES LAYOUT PLAN

FMU Project Number
02809-N-15

Drawn By	Checked	Approved By	Date App.
HA	GS		

Drawing Scale	Drawing Status	
.AS SHOWN	TN	A1

UTS Drg File Name	UTS Drg File No	Rev No
CB07B1AP	46705	02

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LIST OF INDUSTRY PARTNERSHIPS
_THE UNIVERSITY OF QUEENSLAND

(http://www.abb.com/)

(https://www.accenture.com/au-en)

(http://www.aecom.com/)

(http://www.angloamerican.com/)

(http://www.baosteel.com/group_en/)

(http://www.bechtel.com/)

bhpbilliton (http://www.bhpbilliton.com/)

BOEING (http://www.boeing.com/company/key-orgs/boeing-international/)

CISCO (http://www.cisco.com/)

CREDIT SUISSE (https://www.credit-suisse.com/global/en.html)

Deloitte. (http://www2.deloitte.com/au/en.html)

DOW (http://www.dow.com/)

EY (http://www.ey.com/AU/en/home)

GLENCORE (http://www.glencore.com/)

Google (https://www.google.com/intl/en/about/)

HATCH™ (https://www.hatch.com/)

Hilton HOTELS & RESORTS (http://www3.hilton.com/en/index.html)

Honeywell (http://www.honeywell.com/)

(https://www.ibm.com/au-en/)

(http://www.janssen.com/)

(https://www.jnj.com.au/)

(https://home.kpmg.com/au/en/home.html)

(http://www.leo-pharma.com.au/)

(https://www.morganstanley.com.au/)

NIHON SUPERIOR (http://nihonsuperior.co.jp/english/)

NORTON ROSE (http://www.nortonrosefulbright.com/au/)

pwc (http://www.pwc.com.au/)

RioTinto (http://www.riotinto.com/)

SAP (http://go.sap.com/australia/index.html)

SIEMENS (https://www.siemens.com/au/en/home.html)

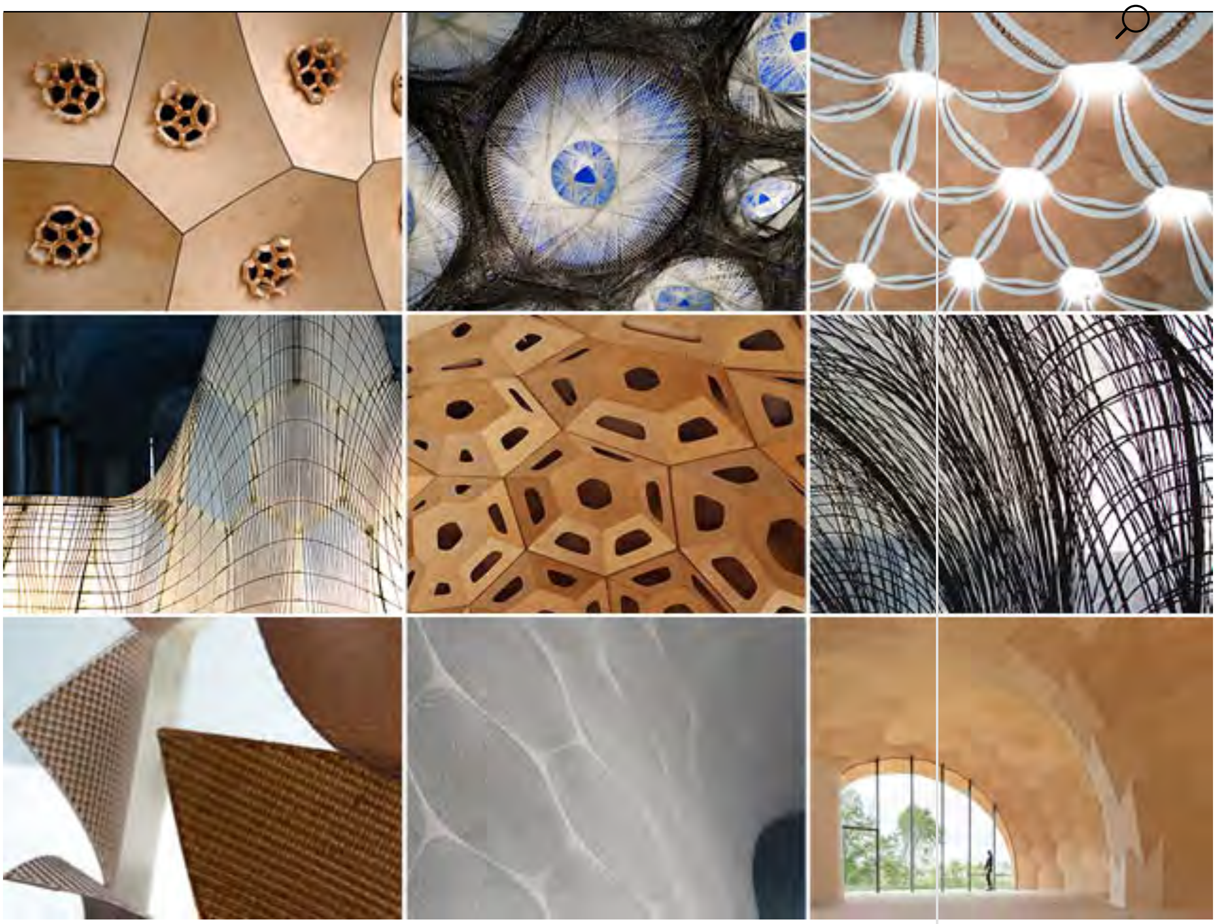
(https://www.thiess.com/)

(http://www.vale.com/australia/EN/Pages/default.aspx)

LIST OF FUNDED PROJECTS_INSTITUTE FOR COMPUTATIONAL DESIGN AND CONSTRUCTION, STUTTGART

News Team Education Research

Projects Publications Institute



List of Funded ProjectsInstitute for Computational Design and Construction

FUNDED RESEARCH PROJECTS

Collaborative Research Centre SFB 1244 – Adaptive Building Skins and Structures for the Built Environment of Tomorrow
Teilprojekt A02: Development of integrative architectural design approach and computational design tools for adaptive lightweight construction and digital fabrication

Funding Body	German Research Foundation (DFG)
Funding ID	DFG SFB 1244 TP A02
Role	Principal Investigator (PI)
Period	2017 – 2021

Additive Manufacturing of Large Fibre Composite Elements for Building Construction (AddFiberFab)

Funding Body	Landesstiftung Baden-Württemberg
Funding ID	IAF-9 AddFiberFab
Role	Principal Investigator (PI)
Period	2017 – 2020

Human-Robot Collaboration in Timber Construction: Potentials for Prefabrication

Funding Body	Forschungsinitiative Zukunft Bau, Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR)
Funding ID	SWD-10.08.18.7-16.56
Role	Principal Investigator (PI)
Period	2017 – 2019

Personalised 3D- and 4D-Printing of programmable, self-adjusting and multifunctional Material Systems for Sports and Medical Applications (4DmultiMATS)

Funding Body	Landesstiftung Baden-Württemberg
Funding ID	IAF-2 4DmultiMATS
Role	Co – Principal Investigator (PI)
Period	2017 – 2020

Smart, Innovative Manufacturing of Curved Wooden Components for Architecture with Complex Geometry

Funding Body	Eidgenössische Kommission für Technologie und Innovation KTI
Funding ID	KTI 25114.1
Role	Research Partner
Period	2017 – 2019

Performative Design Methodology based on Robotic Fabrication for Sustainable Architecture

Funding Body	Sino-German Center for Research Promotion: DFG and NSFC
Funding ID	GZ 1162
Role	Co-Principal Investigator (PI)
Period	2016 – 2019

Highly Insulated and Recyclable Solid Timber Construction

Funding Body	Forschungsinitiative Zukunft Bau, Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR)
Funding ID	SWD-10.08.18.7-15.59
Role	Principal Investigator (PI)
Period	2016 – 2017

Collaborative Research Centre Transregio 141 – Biological Design and Integrative Structures

Teilprojekt A07: The skeleton of the sand dollar as a biological model for segmented shells in building construction

Funding Body	German Research Foundation (DFG)
Funding ID	DFG SFB/TRR 141 TP A07
Role	Associated Scientist
Period	2014 – 2018

Collaborative Research Centre Transregio 141 – Biological Design and Integrative Structures
Teilprojekt A08: Continuous fused deposition modelling of architectural envelopes based on the shell formation of molluscs

Funding Body	German Research Foundation (DFG)
Funding ID	DFG SFB/TRR 141 TP A08
Role	Co-Principal Investigator (PI)
Period	2014 – 2018

Collaborative Research Centre Transregio 141 – Biological Design and Integrative Structures
Teilprojekt B02: Evolutionary processes driving biological variation and diversity as models for ex-ploratory digital design tools in architecture

Funding Body	German Research Foundation (DFG)
Funding ID	DFG SFB/TRR 141 TP B02
Role	Co-Principal Investigator (PI)
Period	2014 – 2018

Holz R3 – Regional, Robotisch Gefertigt, Ressourcenschonend: Holzleichtbau und digitale Planung für das Bauen im Bestand

Funding Body	Landesstiftung Baden-Württemberg
Funding ID	NaBau-5
Role	Principal Investigator (PI)
Period	2014 – 2017

Combination of local robotic precision and autonomous flying drones for resource efficient production of continuous architectural scale fiber composite structures

Funding Body	VW Stiftung
Funding ID	VW Experiment 89210
Role	Principal Investigator (PI)
Period	2015 – 2016

LUX _ Licht, natürliche Ressource für Stadt und Gebäude

Funding Body	Forschungsinitiative Zukunft Bau, Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR)
Funding ID	SWD-10.08.18.7-15.30
Role	Associated Scientist
Period	2015 – 2017

Robotic Fabrication in Timber Construction

Funding Body	EU EFRE und Land Baden-Württemberg
Funding ID	EU EFRE / BW 501210
Role	Principal Investigator (PI)
Period	2013 – 2015

Design Computation for Automotive Design

Funding Body	Mercedes Benz AG
Funding ID	MB 1059225194
Role	Principal Investigator R&D
Period	2013 – 2016

Evolutionary Computational Design for Automotive Design

Funding Body	Mercedes Benz AG
Funding ID	MB 1059183886
Role	Principal Investigator R&D
Period	2011 – 2012

FUNDED DOCTORAL RESEARCH

Erosion-Based Morphological Formation Processes in Architecture

Funding Body	Landesgraduiertenförderung Baden-Württemberg
Total Costs	Doctoral Research Stipend
Recipient	Katja Rinderspacker
Period	2014 – 2017

Architectural Potentials of Robotic Fabrication in Wood Construction

Funding Body	Studienstiftung des Deutschen Volkes
Total Costs	Doctoral Research Stipend
Recipient	Oliver David Krieg
Period	2014 – 2017

Behavioural Design Computation and Adaptive Robotic Fabrication in Architecture

Funding Body	Landesgraduiertenförderung Baden-Württemberg
Total Costs	Doctoral Research Stipend
Recipient	Lauren Vasey
Period	2014 – 2017

3D printed Hygroscopic Programmable Material Systems

Funding Body	Natural Sciences and Engineering Research Council of Canada (NSERC)
Total Costs	Doctoral Research Stipend
Recipient	David Correa Zuluaga
Period	2014 – 2017

Generating and Constraining Variants in Parametric Design

Funding Body	Landesgraduiertenstipendium des Freistaates Bayern
Total Costs	Doctoral Research Stipend
Recipient	Manuela Irlwek
Period	2010 – 2013

FUNDED RESEARCH DEMONSTRATORS AND BUILDING PROJECTS

ICD/ITKE Research Pavilion 2016-17

Location	University of Stuttgart, Germany
Main Funding	VW Stiftung, GETTYLAB and industry partners
Role	Principal Investigator (PI)
Period	2016 – 2017

Elytra Filament Pavilion

Location	Vitra Design Museum, Weil am Rhein, Germany
Main Funding	Vitra Design Museum, GETTYLAB
Role	Principal Investigator (PI)
Period	2016 – 2017

Elytra Filament Pavilion

Location	Victoria and Albert Museum, London, UK
Main Funding	V&A Museum, University of Stuttgart, GETTYLAB, and industry partners
Role	Principal Investigator (PI)
Period	2014 – 2016

ICD/ITKE Research Pavilion 2015-16

Location	University of Stuttgart, Germany
Main Funding	German Research Foundation (DFG), GETTYLAB and industry partners
Role	Principal Investigator (PI)
Period	2015 – 2016

University of Stuttgart Fair Stand

Location	Hannover Fair, Germany
Main Funding	University of Stuttgart and industry partners
Role	Principal Investigator (PI)
Period	2015

ICD Aggregate Pavilion 2015

Location	University of Stuttgart, Germany
Main Funding	Holcim Awards for Sustainable Construction and industry partners

Role	Principal Investigator (PI)
Period	2015

ICD/ITKE Research Pavilion 2014-15

Location	University of Stuttgart, Germany
Main Funding	Industry partners
Role	Principal Investigator (PI)
Period	2014 – 2015

Hive: A Human and Robot Collaborative Building Process

Location	Las Vegas, Nevada, USA
Main Funding	Autodesk and industry partners
Role	Research Partner
Period	2015

ICD/ITKE Research Pavilion 2013-14

Location	University of Stuttgart, Germany
Main Funding	Competence Network Biomimetics and industry partners
Role	Principal Investigator (PI)
Period	2013 – 2014

Leichtbau BW Installation

Location	Hannover Fair, Germany
Main Funding	Landesagentur für Leichtbau Baden-Württemberg
Role	Principal Investigator (PI)
Period	2014

Landesgartenschau Exhibition Hall

Location	Landesgartenschau Schwäbisch Gmünd, Germany
Main Funding	EU EFRE and Land Baden-Württemberg
Role	Principal Investigator (PI)
Period	2014

HygroSkin: Meteorosensitive Pavilion

Location	FRAC Centre Orléans, France
Main Funding	FRAC Centre Orléans, Robert Bosch Stiftung, and industry partners
Role	Principal Investigator (PI)
Period	2013

ICD/ITKE Research Pavilion 2012

Location	University of Stuttgart, Germany
Main Funding	Industry partners
Role	Principal Investigator (PI)
Period	2012

HygroScope: Meteorosensitive Morphology

Location	Centre Pompidou Paris, France
Main Funding	Centre Pompidou Paris and industry partners
Role	Principal Investigator (PI)
Period	2012

Material Equilibria Installation

Location	ggggallery Copenhagen, Denmark
Main Funding	ggggallery Copenhagen
Role	Principal Investigator (PI)
Period	2012

Textile Hybrid M1: La Tour de l'Architecte

Location	University of Stuttgart, Germany
Main Funding	Robert Bosch Stiftung and industry partners
Role	Principal Investigator (PI)
Period	2011

ICD/ITKE Research Pavilion 2011

Location	University of Stuttgart, Germany
Main Funding	Industry partners
Role	Principal Investigator (PI)
Period	2011

ICD/ITKE Research Pavilion 2010

Location	University of Stuttgart, Germany
Main Funding	Industry partners
Role	Principal Investigator (PI)
Period	2010

» Prof. Achim Menges

Innovative Manufacturing CRC
A collaborative venture between industry, government and researchers

Australian Government
Department of Industry, Innovation and Science

Business
Cooperative Research Centres Programme

Innovative Manufacturing CRC (IMCRC)

The IMCRC has a vision for a globally connected and smarter Australian manufacturing industry. We are industry-led and develop important new technologies, products and services in Australia's manufacturing sector. We operate in the context of the Australian Government's Cooperative Research Centre (CRC) program to improve the competitiveness, productivity and sustainability of Australian manufacturing firms, and to drive digital and business model transformation. We will deliver manufacturing outcomes in line with government priorities in key growth sectors and in science, research and innovation, encourage and enable small and medium enterprise (SME) participation in collaborative research, and fund projects to tackle industry specific problems through research partnerships between industry entities and research organisations. The IMCRC is a not-for-profit organisation.

The IMCRC currently has two primary focus areas, which will continue to evolve over time to align with new innovations and industry demand.

- **Key enabling and innovative manufacturing technologies** including for example additive manufacturing (3D printing), nanotechnology, micro and nano electronics, photonics, advanced materials, advanced manufacturing systems, simulation, augmented reality as well as range of product development and lifecycle management (PLM) technologies.
- **Industry Transformation** integrating new technology platforms with business model innovation to deliver targeted business improvement through the value chain, focusing on digital and data driven manufacturing, innovation, leadership and the uptake of Industry 4.0, particularly with SME manufacturers.

More information about the IMCRC, is available on our website at **www.imcrc.org** or by contacting

David Chuter
IMCRC Chief Executive Officer
david.chuter@imcrc.org
+61 413 884267

IMCRC Manufacturing Innovation Projects

- The IMCRC runs from 2016 to 2022.
- We have up to $40 million in Commonwealth funding available during this term for industry projects to match dollar for dollar industry cash contributions. This includes funding for Industry Transformation initiatives.
- In kind contributions are also sought, however not matched by IMCRC, and nor is capital expenditure.
- Essential Participants in the IMCRC contribute at least $500K in cash over the term of IMCRC.
- Applications are to be created and submitted by a lead industry participant using the templates available at http://www.imcrc.org/new-research-projects.html
- Key project assessment criteria require that a Project
  - is industry led, delivers clear manufacturing outcomes, and involves innovative and advanced manufacturing (ideally within a key growth sector);
  - demonstrates genuine collaboration, including with SMEs, and also with Growth Centres and other CRCs;
  - creates opportunities to access global supply chains;
  - delivers wider / multiplier benefits to Australian manufacturing industry – contributes to the sector transformation and sustainability;
  - requires high quality research with Universities, CSIRO and/or other research organisations in Australia, and facilitates PhD student scholarships;
  - has a clear IP utilisation / commercialisation plan (note that IMCRC does not own Project IP – ownership is determined between the industry and research participants where it can most effectively be commercialised);
  - has a clear business innovation and transformation plan and/or Industry 4.0 adoption plan (IMCRC is developing diagnostics, education and training materials and methodology to facilitate this), and
  - has a defined return on research investment, with both manufacturing and commercial outcomes.
- Projects are reviewed initially by the IMCRC Innovation Investment Committee (IIC) which can approve projects up to $1m in cash value, or recommend approval to the IMCRC Board.
- IMCRC invites new project applications from industry for projects up to $6 million total cash investment ($3 million from industry plus $3 million from IMCRC).

V4 18th February 2017

VICTORIA’S FUTURE INDUSTRIES

Construction Technologies

Discussion Paper
August 2015

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This document is also available in PDF and accessible Word format at
http://www.business.vic.gov.au/futureindustries

Contents

Construction Technologies

Executive Summary

The Victorian Government has identified the construction materials and technologies industries as one of a number of sectors strategically important for the State. Firms in these industries provide inputs into the construction sector, which is both an important enabler in the Victorian economy and a significant sector in its own right.

The construction sector is important to Victoria's economy. It employs almost 240,000 people and contributes 6.7% or $21.6 billion to the State's gross value-added. The sector includes residential, non-residential and engineering construction. Construction projects draw on many suppliers, trades and professions. The outlook for the sector is positive, driven by a continuing increase in Victoria's population and the need to provide housing and related infrastructure.

Productivity in the construction sector is often cited as problematic. While noting that most advanced economies were concerned about the performance of their construction sectors, the Productivity Commission's 2014 Inquiry into Public Infrastructure found a complex picture. It found some evidence that comparator countries had better productivity, but identified numerous causes for this. The Commission suggested the main opportunities for productivity gains would be found from improvements in project planning, firm level operating and managerial processes; prefabrication and design; use of technology and choice of technique; labour utilisation and workplace relations; and overarching regulatory and competition policy structures. It noted that innovative approaches to design and planning and the expanded use of prefabricated or pre cast elements were often identified as having particular potential to improve productivity growth.

There is a long-run trend away from artisan-based work undertaken in situ to projects involving the assembly of components fabricated elsewhere known as 'off-site construction'. New IT systems such as Building Information Modelling (BIM) are being deployed to improve design and management of the construction process, as well as the operational efficiency of the building once completed. Expectations of higher levels of environmental performance has focused more attention on design quality and the impacts of products specified, creating demand for smart and green projects. Flagship projects demonstrate the capability of Victoria's construction sector in this regard.

This paper outlines how the performance of the construction technologies sector might be improved and identifies a number of areas for stakeholders to further consider:

- Capitalising on Melbourne's status as the world's most liveable city.
- Capturing the demonstration benefit from green, smart projects.
- Accelerating the uptake of new materials and technologies.
- The role of government in the take up of Building Information Modelling.
- Establishing Victoria as Australia's centre of excellence for off-site construction technologies and businesses.
- Utilising the strength of Victoria's research base for the benefit of the building materials and building technology industries.
- Getting better at exporting and managing the import challenge.

Purpose

This discussion paper has been prepared by the Department of Economic Development, Jobs, Transport and Resources (DEDJTR) in order to develop a Victorian construction industry technologies strategy. The Department is seeking input from all industry stakeholders on how government can best collaborate with industry, unions, academics and others to support future growth and development of this priority sector.

The opportunities and challenges set out in this discussion paper are based on research and input from interactions with many Victorian construction related businesses and industry organisations over recent years.

Your feedback will help us to identify critical issues impacting on potential growth and job creation and where future effort should be best directed. A number of questions are proposed throughout the paper.

Submissions can be made by email to: fi.construction@ecodev.vic.gov.au.

Scope

The construction sector includes residential building, non-residential building and engineering construction such as infrastructure. Victoria's construction sector can be considered as the market for Victorian construction materials and construction technologies.

In general terms, construction materials are outputs of the manufactured goods sector (for example bricks, windows, metal sheeting etc.) or of the mining sector – outputs such as sand or aggregate.

Major construction projects often involve a set of professional services such as project management, construction management, engineering, architecture, planning, surveying and cost planning etc. These professionals hold the expertise and know-how that represents much of the sector's 'technology' on the definition above. There is a separate discussion paper on professional services and so these are not considered within the scope of the present paper.

Finally, construction technologies can also be realised through production equipment, which is classified as a manufactured good. Construction technologies may also be realised through IT systems that might be classified as an IT product or as the output of IT services.

Questions for your consideration

QUESTION 1. How might technology uptake be increased in the Victorian construction sector?

QUESTION 2. What role can Government play in supporting technology demonstration on projects?

QUESTION 3. How can the uptake of Building Information Modelling (BIM) be encouraged on Victorian construction projects?

QUESTION 4. What would be the costs and benefits of requiring the use of BIM on all significant public sector projects?

QUESTION 5. Is modular construction a viable option for Victoria's social and low cost housing requirements?

QUESTION 6. What opportunities are there to establish Victoria as a centre of excellence for off-site construction?

QUESTION 7. How can Melbourne's strong international reputation as a liveable city be capitalised on to expand market opportunities for the construction materials and technology sector?

QUESTION 8. How can construction materials and construction technology firms build on the export success and relationships of Victorian architecture, planning and engineering firms?

QUESTION 9. How can more be gained by using Victoria's design and construction capabilities in green smart building to demonstrate new possibilities?

QUESTION 10. How can Victoria's construction materials and technology firms better capitalise on its strong research base in materials science?

QUESTION 11. How can better industry and research collaboration be facilitated?

QUESTION 12. How can firms be encouraged and supported to develop and experiment with new processes to improve the efficiency of the building process?

QUESTION 13. Is the IT research base in Victorian being fully utilised to develop new smart products for the construction industry?

QUESTION 14. Are there regulatory or attitudinal barriers that inhibit the uptake of new materials or processes on Victorian construction projects?

QUESTION 15. Are there opportunities to increase materials innovation by providing information and advice on how to achieve a regulatory approval?

Part One
Victoria's Economic Development Strategy

Victoria has a number of competitive advantages that create a diverse, flexible and resilient economy. These include: world-class industries; highly-skilled workforce; multicultural population; close proximity and links to the fast growing Asian region; world recognised liveability and tourist destination; good transport networks with well-connected cities and regions; and access to productive agricultural land and energy resources.

Despite these advantages, the Victorian economy has underperformed in recent years, with high unemployment (particularly youth and the disadvantaged), weak productivity growth and flat business investment. Victoria also faces a number of medium-long term challenges from global competition, strong population growth, climate change and the need to transition to a low carbon economy, and the impacts of structural change on Victoria's industries and regions (e.g. automotive and agricultural changes).

The Victorian Government recognises that it has a vital role to play – with other levels of government and the private sector – to respond to these challenges and support sustained economic growth and job creation in Victoria.

The government's overarching economic development strategy focuses on five priority areas:

- Building more productive and liveable cities and regions through transport, infrastructure and land use planning.
- Gaining and maintaining competitive advantage through active industry and innovation policy.
- Improving conditions for business through taxation, efficient regulation and public sector reforms.
- Better connecting Victoria to national and global markets by increasing targeted trade and investment attraction.
- Developing Victorians' capabilities and fostering inclusion through skills and employment.

The government's Future Industries Fund (including the New Energy Jobs Fund) ($200m) will focus on six sectors that have potential for strong growth and jobs:

- medical technology and pharmaceuticals
- new energy technology
- food and fibre
- transport, defence and construction technology
- international education
- professional services.

The government will collaborate with the business and wider community to develop and implement strategies for these sectors.

The government's Future Industries Fund (including the New Energy Jobs Fund) ($200m) will focus on six sectors that have potential for strong growth and jobs.

Part Two
Sector Overview

The construction sector includes three segments:

- residential building (new houses, units and apartments and alterations and additions)
- non residential building (offices, industrial, accommodation, education, entertainment, health and aged care and wholesale and retail trade) and
- engineering construction (roads, railways, bridges, harbours, water, sewerage, electricity, pipelines, telecommunications, and mining).

Construction is undertaken within a complex system that coordinates the activities of many actors in order to design, build and complete projects within regulatory and institutional frameworks. Figure 1 provides a model of the actors and information flows in the construction sector[1].

A key contributor to the Victorian economy

The construction industry is a major sector in the Victorian economy, contributing $21.6 billion or around 6.7% of the State's gross value added in 2014[2].

The Victorian Building Authority reports the value of building permits issued in 2014 was at a record $26.9 billion, up 11% from the previous high of 2011. Building permit activity in 2014 was also 14% higher than the $23.5 billion reported in 2013[3].

Despite this recent optimism many commentators, such as the Housing Industry Australia (HIA) expect moderate growth in Victorian construction from 2015 onwards[4]. Figure 2 shows the value of work undertaken in Victoria over the period 1995 to 2013.

The outlook for the sector is positive

Demand for construction materials and construction technologies is largely determined by the level of activity in Victoria's construction sector. Some demand originates interstate and overseas.

The sector's outlook is positive. Victoria's population growth over the next 20 years is expected to average around 1.6% per annum. Melbourne's population is predicted to grow 1.8% per annum, reaching six million by 2031, making it Australia's most populous city. It is estimated 774,000 new homes will be needed between 2011 and 2031 to accommodate the population increase, underpinned by immigration[5].

New infrastructure projects include urban renewal at Fishermans Bend, the Ballarat West Employment Zone, E-Gate and the Queen Victoria Market Precinct. There are also large investments across health services, such as the Latrobe Regional Hospital upgrade and the ongoing $250 million Monash Children's Hospital Redevelopment.

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1 From Gann and Salter Innovation in project-based, service-enhanced firms: the construction of complex products and systems. Research Policy Vol 29 2000:955-972

2 ABS – 5220.0 Australian National Accounts: State Accounts

3 Victorian Building Authority – Media Release, 15 March 2015

4 HIA, Media Release, New Home Building set to ease in Victoria, 24 November 2014

5 Victoria in Future 2015, Population and Household Projections to 2051, Department of Environment, Land, Water & Planning, 2015.

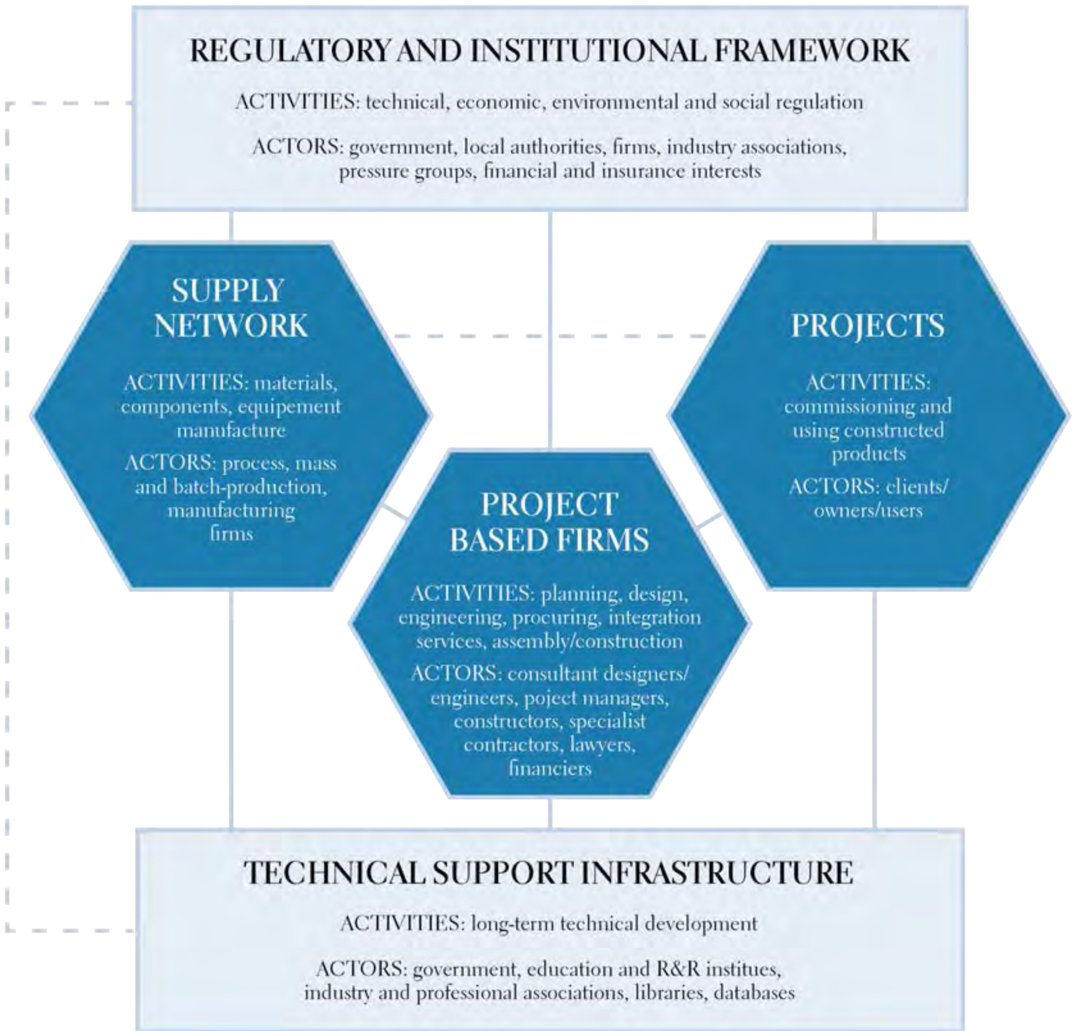
Major transport projects include the Tullamarine Freeway Widening project and the Metro Rail Tunnel development. The latter project, with an estimated cost approaching $11 billion is designed to significantly increase capacity and transform Melbourne's rail network from a suburban rail system to a metro-style rapid transport system.

Victoria's fifth largest employer

The construction sector accounts for 238,000 jobs (Dec 2014) or 8.2% of the workforce, placing it as Victoria's fifth largest industry sector[6].

As can be seen in Figure 3, the construction workforce is dominated by the technician and trade group, followed by labourers, managers and clerical and administrative workers. Trades within the technician and trade group include bricklayers, carpenters and joiners, painting trades workers, glaziers, plasterers, tilers, plumbers, air conditioning and mechanical services plumbers, drainers, gas fitters, electricians, and lift mechanics.

Figure 1: Actors and knowledge flows in the construction sector



6 Commonwealth Government's Department of Employment website – 12 month average to February 2015

Construction is dominated by small businesses

Victoria's construction sector comprises around 89,000 businesses. Around 53,000 are non-employing, while 35,000 have 19 or fewer employees. Only 1,000 businesses have between 20 and 199 employees while 49 report more than 200 employees. The largest number of businesses are in the house constructors' category, followed by carpentry services, electrical services and plumbing services.

The stability of the industry's workforce is subject to external pressures. Historically, there has been considerable turnover and movement of staff, particularly within smaller businesses.

There are around 5,500 firms in Victoria's construction materials sector. More than half (around 2,900) employ 1-19 people while nearly 350 employ 20-199 staff.

As can be seen in Figure 5, firms manufacturing wooden structural fittings and components (largely trusses and frames) and other fabricated metal products (not all of which are necessarily construction-related) are the largest groups within the construction materials sector. Of interest in relation to later sections of this paper, Victoria has 38 firms producing prefabricated timber buildings and 115 firms producing prefabricated metal buildings. Note that some categories, for example adhesive manufacturing and paint manufacturing supply to sectors other than the construction sector.

The patterns of growth and internationalisation of construction materials firms are likely to be different to those in other sectors. Many construction materials such as quarry materials and bricks are bulky, of relatively low value, and expensive to transport. Production of materials of this type is usually through a plant with economies of scale within proximity to major markets to economise on transport costs. Expansion and internationalisation of businesses producing these products will likely be through investment in plant in proximity to new markets, rather than expanding production from existing plant in Victoria. The internationalisation model of Australian construction coined 'multi-domestic' – essentially is the consolidation of regional plants within one operating company. Economies of scale are generated through management, marketing and innovation rather than in production. Meanwhile, production of construction equipment and other construction technologies are more likely to be concentrated in a single facility.

The patterns of growth and internationalisation of construction materials firms are likely to be different to those in other sectors.

Figure 2: Value of construction work done, Victoria, 1995 – 2013, billions of dollars (Source ABS 8755.0)

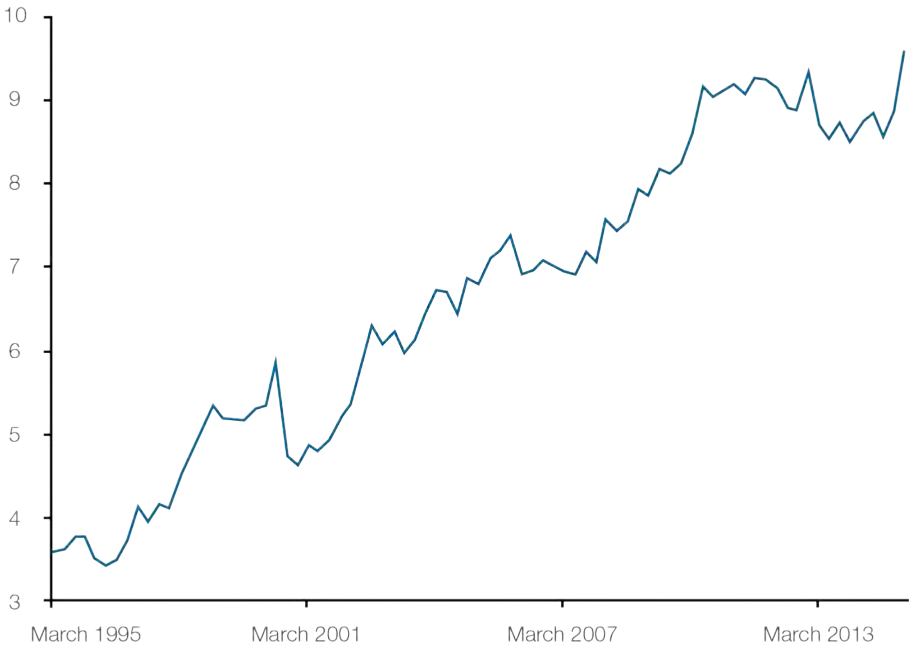


Figure 3: Distribution of occupation types in Victoria's construction sector, 2011 (Source 2011 ABS Census Data)

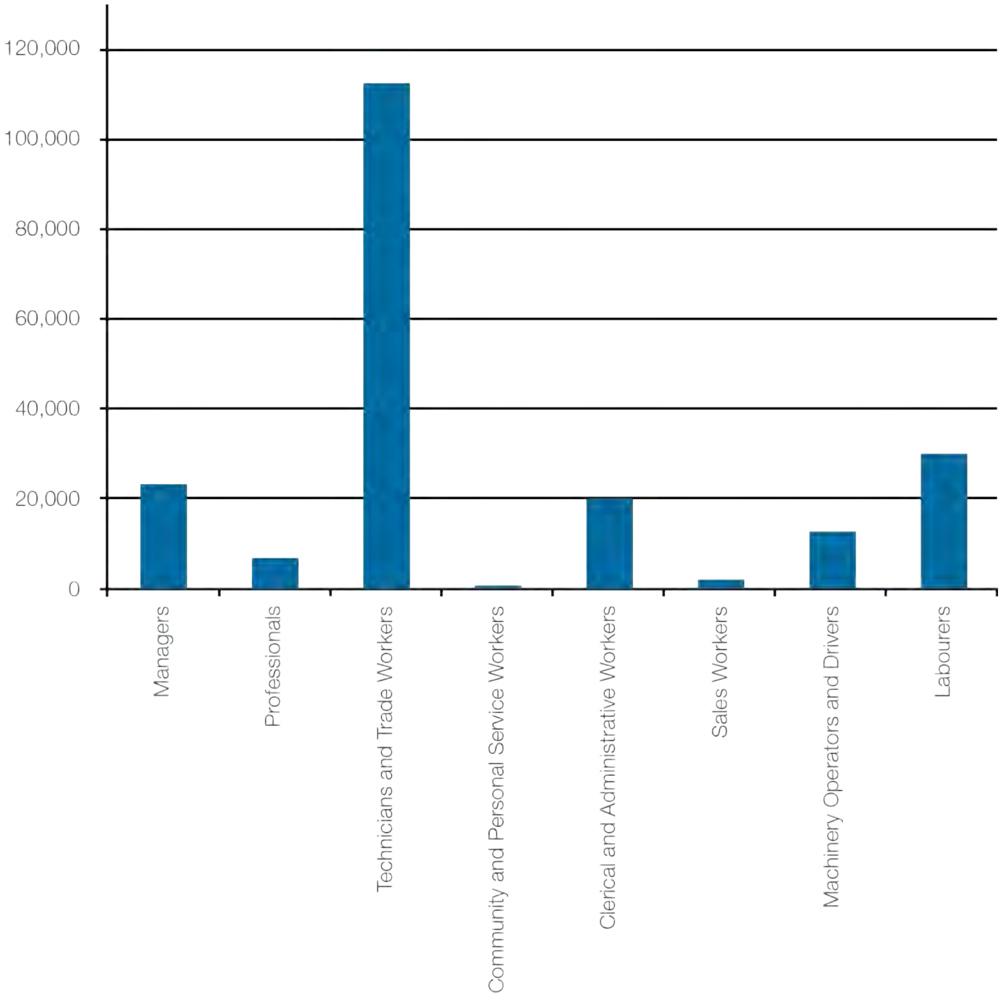
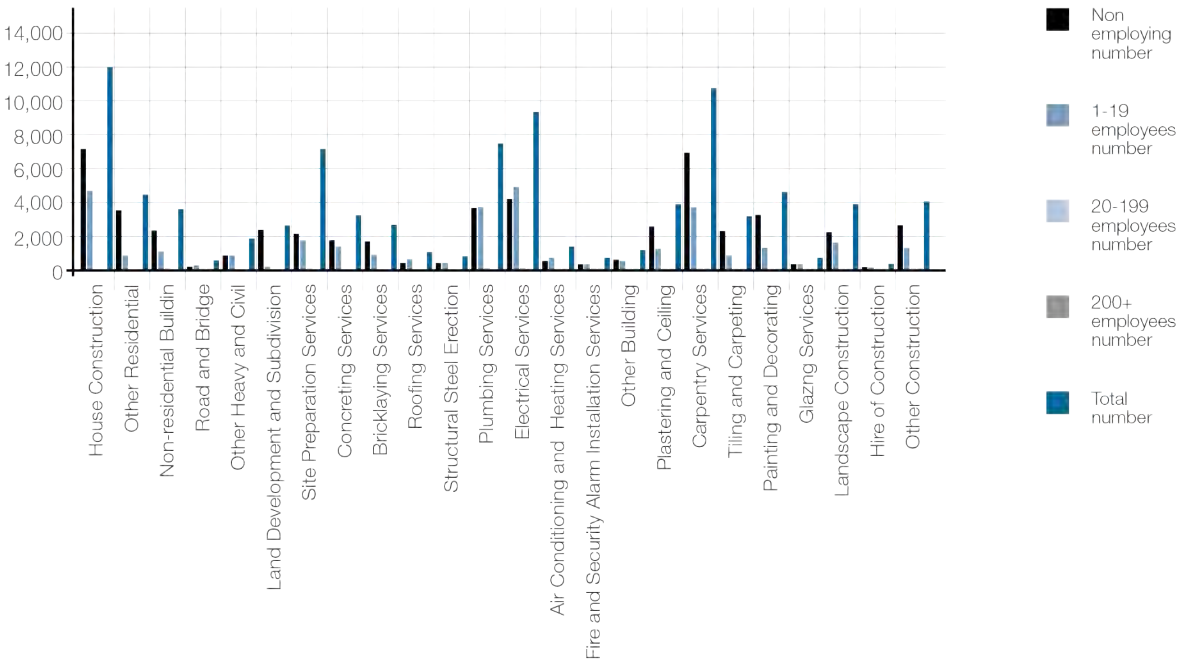
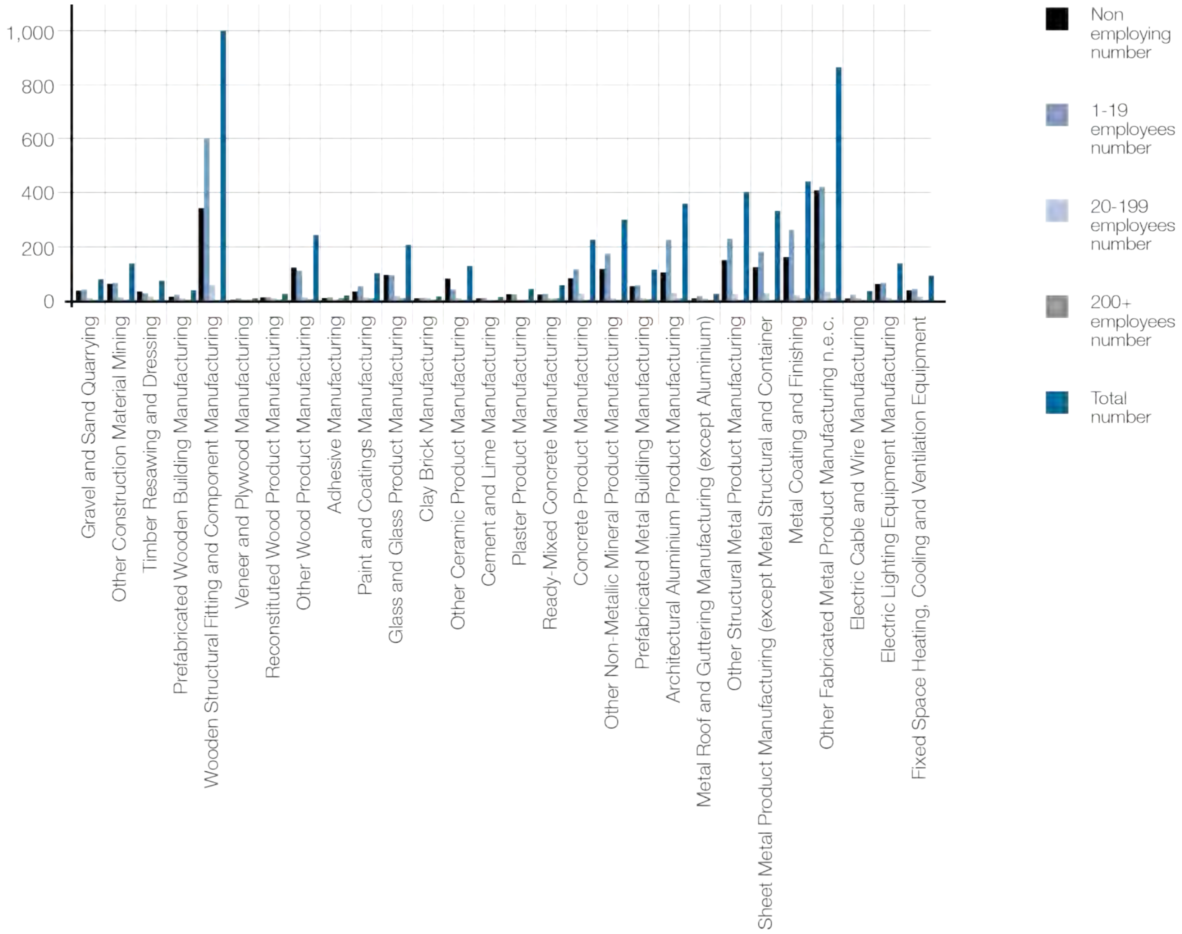


*Figure 4: Victorian construction business by number of employees, June 2014**



**Source ABS Cat 8165.0 Counts of Australian Businesses*

*Figure 5: Victorian materials construction business by number of employees, June 2014**



**Source ABS Cat 8165.0 Counts of Australian Businesses*

Part Three
Opportunities and Challenges

Greater uptake of technologies will improve productivity

The recent Productivity Commission Inquiry into Public Infrastructure noted that concerns about productivity in national construction industries are common in many advanced economies[7]. The Commission found some evidence that Australian productivity and efficiency lagged behind some comparator countries. It also found that productivity was driven by numerous factors including workplace relations and capital intensity.

The Commission suggested productivity improvement in the construction sector would most likely be found in areas such as improving project planning and procurement processes; better firm level operating and managerial processes; greater use of prefabrication and design; improved labour utilisation and workplace relations; and improved regulatory and competition policy structures. It noted that innovative approaches to design and planning and expanding the use of prefabricated or pre cast elements offered the greatest opportunities for productivity growth.

Confirmation of the potential of the areas mentioned above can be found in work by the US National Research Council, which identifies five areas having the potential for 'breakthrough' productivity improvements. Similar to the Commission's findings, these include widespread take up of BIM; improved coordination of people, processes, materials, equipment and information on site (i.e. project management); greater use of off-site fabrication; widespread use of demonstration installations to disseminate good practices and effective performance measurement to drive efficiency and support innovation.

Other prospective technologies suggested to the Commission included those around ICT, which would allow people to work more flexibly; on site mechanisation; materials management systems; automated tracking and GPS systems; cameras and bar coding technologies; mobile technologies and BIM.

A potential incentive for smaller firms to invest in technology is the Commonwealth's new Small Business Stimulus Package, which allows an immediate tax deduction for any individual assets they buy costing less than $20,000.

QUESTION 1.	How might technology uptake be increased in the Victorian construction sector?
QUESTION 2.	What role can Government play in supporting technology demonstration on projects?

The Commission found some evidence that Australian productivity and efficiency lagged behind some comparator countries.

7 Productivity Commission Public Infrastructure – Inquiry Report 2014

Building Information Modelling will increase overall efficiencies

Building Information Modelling (BIM) provides a common platform and data across all those involved in construction projects, and for facilities management. Creating a common project platform for architects, designers and engineers, and the supply chain increases efficiency by reducing errors arising from incorrect or out of date information, and reducing reworking. Once the project is complete, facility managers can utilise the BIM database to better service and maintain a structure throughout its life cycle.

In 2014, McGraw Hill Construction (MHC) found that 51% of Australian and New Zealand firms surveyed reported that they were using BIM on more than 30% of their projects[8]. MHC also reported that 75% of Australian and New Zealand users reported a positive Return on Investment (ROI) with 30% citing ROI of 25% or more. The report shows that while awareness of BIM in Australian and New Zealand industry is high, the commitment to use BIM is still lower compared to other regions such as North America and Europe. Allen Consulting Group estimates more widespread uptake of BIM could deliver an immediate boost to Australia's economic output (GDP) by at least 0.2 basis points, and as much as 0.5 basis points by 2025[9].

Obstacles to the introduction of BIM include the lack of interoperability among various systems, some legal uncertainties about IP ownership and liabilities where information is shared and relied upon across a project, high but falling capital and training costs, and only partial use of the capabilities that BIM offers. Government may be able to play a role both as a champion of BIM, and working to establish standards and guidelines. There could be an opportunity for Victoria to lead on this issue as some major companies in this domain are based here. For example Victorian based Aconex has a range of online platform project tools with BIM capabilities.

Another issue is that many firms only use its 3D design capabilities and do not collaborate externally on their modelling or share information on a project. Greater benefits are available by using BIM's collaborative potential. Another challenge for BIM uptake relates to its cost relative to other project management and design tools, with many small to medium sized enterprises hesitant to pay the licence fees involved. However, as BIM's use becomes more widespread, technology companies are beginning to develop tools which provide BIM at lower costs.

A number of overseas governments including Hong Kong, Singapore and the UK are currently mandating the use of BIM on government building projects with the aim of driving uptake. While mandating the use of BIM will provide governments with the capability to more effectively manage assets, it will also require new skills, processes and capabilities of its facility management to realise the full benefits. The Victorian Government has recently announced that it is also actively exploring the use of BIM to improve project efficiency and outcomes. Currently it is working with relevant agencies to identify suitable projects to participate in a pilot study[10].

QUESTION 3.	How can the uptake of BIM be encouraged on Victorian construction projects?
QUESTION 4.	What would be the costs and benefits of requiring the use of BIM on all significant public sector projects?

Off-site construction will deliver productivity gains

The term 'off-site' construction refers to prefabricated and/or modular building components and units manufactured off-site for assembly on-site. This is the continuation of a long-run trend away from artisan and craft-based work in-situ to the production of components elsewhere. For example, timber building frames were once made on site – from the 1960s roof trusses displaced roofs cut in situ and now most

8 The Business Value of BIM in Australia and New Zealand: How Building Information Modelling is Transforming the Construction Industry – 2014

9 Allen Consulting Group – Productivity in the Buildings Network: Assessing The Impacts Of Building Information Models – 2010

10 Victorian Budget 15/16, For Families, State Capital Program, Budget Paper No. 4, May 2015.

house frames are produced by computer-controlled machines in factory environments and simply placed and fastened on site. Building elements such as lifts, heating, ventilation and air-conditioning equipment also have a long history of pre-fabrication.

Now off-site construction is producing complete buildings, or parts of buildings such as toilets or bathrooms. Off-site construction brings manufacturing techniques and disciplines to the construction sector including production line efficiencies, automation and advanced manufacturing techniques, mass customisation and complex systems thinking. This form of construction can offer reduced construction times, costs, project payback times and waste while improving workplace safety. It can also contribute productivity improvement by reducing time lost due to adverse weather, reducing traffic congestion and general disruption around work sites.

An example of what can be achieved is the assembly in just six days of the four storey, 128 room Bendigo Hospital Hotel. Components were manufactured by the Hickory Group in its automated Melbourne facility and transported to the site where the building was completed by a small assembly team using a single 200 tonne crane. Hickory's next major project is a 43 storey residential tower slated for Melbourne's CBD. This project contains substantial prefabricated structural elements and is expected to be completed 50% faster than if traditional methods were employed.

Off-site construction is more widely used in Europe and North America and is becoming more common in some Asian markets. In Australia the uptake has grown steadily now accounting for an estimated 3% of all new starts. Strong growth is expected with some commentators predicting that over the next ten years up to 15-25% of new building in Australia will be prefabricated or modular construction[11].

In Australia modular construction is increasingly being used by Governments to deliver low cost affordable housing for low income earners. For example, to address its growing population and lack of housing affordability, the Western Australia Government has pledged to produce 20,000 new affordable housing options by 2020. Under this project the WA Government is supporting the use of modular construction techniques in the building of low cost modular apartment buildings[12]. Similar large scale initiatives for public housing have been proposed in other States, including Victoria[13].

QUESTION 5. Is modular construction a viable option for Victoria's social and low cost housing needs?

Victoria can be a centre of excellence for off-site construction

There is an opportunity for Victoria to establish itself as the nation's centre of excellence in off-site construction both commercially and as a prefabrication skills centre.

The industry's peak body PrefabAus observes a large portion of Australia's off-site construction activity is either in Victoria or being carried out by Victorian-based companies. Australia's largest and most advanced modular construction firm is the Hickory Group, which is based in Victoria and has significant projects in Western Australia and New South Wales. It distributes thousands of its modular bathrooms interstate each year. Victoria is home to numerous other innovative off-site construction manufacturers such as Arkit, Prebuilt, Mosdscape and K.L. Modular Systems. These firms also operate in the commercial and residential markets and distribute interstate.

The growth of new technologies in construction, such as off site construction and BIM will impact on the composition of the industry's workforce. Wider skills in areas such as engineering and design will need to be

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11 David Chandler's – A case for an Australian Construction Strategy – 2014 and PwC's Reconstructing productivity – Productivity in the Construction Sector 2013

12 Business News Weekly 16 July 2014 www.businessnews.com.au/article/Modular-affordable-apartments-go-up-in-Perth-s-south

13 Carolyn Whitzman, Clare Newton and Alexander Sheko, Transforming Housing: Affordable Housing for All, Partnership options for policy, investment and demonstration projects – April 2014

acquired, whilst the demand for some lower skilled roles may eventually reduce. The need to plan and establish new training centres and programs is essential to facilitate the development of the right skills for the future construction industry.

The Australian Research Council's (ARC's) Training Centre for Advanced Manufacturing of Prefabricated Housing is to be established at the University of Melbourne with industry partners, Amoveo, Prebuilt, Prefabaus, Meko, Tektum and CIMC Modular. With funding of $4m, this centre can be a strategic asset to leverage the state's status as the Australian leader in the field.

According to internal DEDJTR intelligence, a lack of understanding around off-site construction, particularly by regulators, educators and financiers is limiting the sector's development. In particular, industry cites a lack of recognition and support by government of new building technologies in its regulations and the procurement process as a key challenge for the industry and as a disincentive in technology uptake.

Other key challenges flagged by industry include.

- Limited access to finance due to the sector attracting a higher risk profile from banks.
- Negative cashflow impacts due to the bulk of costs being borne upfront in off-site construction, but payments scheduled around assembly milestones on site.
- Lack of training from educational institutions in modular and prefabrication techniques.
- Lack of scale compared to its Northern hemisphere competitors including China.
- High transport costs and distance to markets.
- High upfront investment required to innovate with building materials.
- Protecting IP, particularly in global markets.

However, off-site technologies present a two-edged sword for construction materials firms. On the one hand, the technology offers the prospect of new export markets, and innovative firms have taken up that opportunity. On the other hand, off-site construction opens up the possibility of import competition.

One industry commentator warns that prefabricated imports into Australia could value $30 billion by 2025 and cost around 75,000 jobs nationally[14]. The challenge for Victoria is to ensure the local industry continues to innovate and develop towards manufacturing high quality customised products, which are valued and demanded both locally and overseas. The reality of this warning can be seen in the precedent of modular construction in the LNG sector. Traditionally builds were undertaken on site. However the construction of the trains and other components has been modularised and much of this work in the recent investment boom was lost to offshore competitors.

QUESTION 6. What opportunities are there to establish Victoria as a centre of excellence for off-site construction?

[14] David Chandler's – A case for an Australian Construction Strategy – 2014

Capitalising on Melbourne's status as the world's most liveable city

Melbourne ranks very favourably in comparison with other major cities. The Economic Intelligence Unit's World's Most Liveable Cities Survey has ranked Melbourne as the world's most liveable city for five years consecutively. Melbourne also scores well in similar rankings conducted by other organisations. Issues such as the quality of architecture and the build environment, public transportation, environmental issues, access to nature, urban design and urban policies are the basis for the rankings.

The credibility provided by such rankings provides an opportunity to promote Victorian construction-related products and services, particularly in Asian markets with less liveable cities.

Melbourne's high liveability ranking underscores its sound infrastructure, with a portion of Victoria's investment in this area being completed through Public Private Partnerships (PPP). These projects are administered by the Victorian Government agency *Partnerships Victoria*, whose aim is to use the innovative skills and abilities of the private sector in a way that is most likely to deliver value for money and improved services to the community. Since 2002-03, *Partnerships Victoria* projects have accounted for approximately 10 per cent of annual public asset investment commitments through 24 PPP projects with capital investment of around $12.4 billion[15].

QUESTION 7.	How can Melbourne's strong international reputation as a liveable city be capitalised on to expand market opportunities for the construction materials and technology sector?

Melbourne's liveability profile can build export opportunities

Victorian firms have been successful exporters of design, engineering and architectural services, accounting for 40% of the nation's exports in this area and 4% of Victoria's total services exports[16]. Victorian architects, urban planners and engineers have been prominent in the design of new cities and infrastructure in China and elsewhere. Annual growth of construction output in emerging markets is expected to remain at around 5.3% per cent annum to 2020[17].

The Victorian Government has a history of supporting the industry's professional services through trade missions to strategic markets, facilitating international relationships particularly through sister state and sister city arrangements, and supporting the establishment of industry clusters such as the Australian Urban System (AUS). Many Victorian professional services companies have had success in Asian and other international markets and have built relationships over time with clients there. Victorian universities through their international relationships have been active in promoting the local industry and facilitating export opportunities. For example academics from Melbourne University have attended various trade missions with AUS to China highlighting Victoria's building and design capabilities to increase R&D activities such as presenting at several Shanghai Construction Group Forums on tall structures.

QUESTION 8.	How can construction materials and construction technology firms build on the export success and relationships of Victorian architecture, planning and engineering firms?

Victoria is a showcase for smart construction

Buildings create a range of impacts on the environment. The urban environment changes land use; buildings are major users of energy for lighting, heating and cooling thereby contributing to greenhouse gas emissions; buildings create micro-climates that collectively raise the temperature of their surroundings; their inhabitants use water for washing and ablutions and the buildings footprint increases storm water runoff and

15 Victorian Government's Department of Treasury and Finance website

16 Department of Economic Development, Jobs, Training and Resources internal data (2015)

17 PRNewswire Global Construction Market Worth $10.3 Trillion in 2020, 17 February 2015

affects subterranean water patterns; and buildings consume non-renewable resources and create waste during construction.

Victoria has flagship examples of high performing green, smart buildings including Pixel, a commercial building which in 2012 received the highest green rating given by a leading US based sustainability index. The building was designed by Victorian architects Studio 505 and built by Grocon Constructions, both exporters and strong proponents of green building technologies.

Pixel was designed and built to achieve carbon neutrality by using renewable energy sources on site with surplus energy fed back into the grid. The building features miniature wind turbines developed and produced locally, a 'living roof' designed at Melbourne University and photovoltaic roof panels. The building collects rainwater and mines water from the sewerage system, achieving independence from the public water supply – except for drinking water.

Pixel along with other green commercial buildings in Melbourne, such as Council House 2 and the 60L Green Building, showcase Victoria's green building capabilities and liveability.

QUESTION 9. How can more be gained by using Victoria's design and construction capabilities in green smart building to demonstrate new possibilities?

Further adoption of new materials will improve the sector's performance

A variety of advanced materials offering benefits over traditional materials could be produced or utilised in Victoria:

- New concrete and concrete replacement products such as Waffle Pods, Bubble Deck and pre-stressed and pre-cast concrete floors are manufactured off site and provide builders with lighter and more flexible products. The production of cement generates 8% of global CO_2 emissions – so an alternative that generates less concrete offers the industry a substantially more environmentally friendly product. The construction of Pixel outlined above led to the development of Pixelcrete – a product with the strength of concrete, but containing 60 per cent less cement and manufactured from recycled and reclaimed aggregate. At the time Pixelcrete was the only 'green' concrete in the world suitable for use in-situ for post tensioned suspended slabs.
- The uptake of smarter glazing products such as double or triple glazed windows which provide better heat insulation, save energy and provide significant acoustic insulation. New technologies offer the possibility of windows incorporating photovoltaic collectors.
- A variety of plastics with significant green credentials are now being widely used in the construction industry, ranging from super tough flooring tiles to energy efficient insulation products. An example is the increasing popularity of Expanded Polystyrene in building insulation.
- Cross Laminated Timber (CLT) is a new building material offering rapid construction opportunities. CLT is fabricated by bonding timber boards with structural adhesives to produce a solid and fire resistant timber panel. This ultra-strong flexible material is increasingly being used in high-rise apartments. Melbourne currently has the world's largest free standing CLT building in the Forte project at Docklands.

Carbon Fiber Reinforced Plastic (CFRP) is a lightweight material that is three times stronger and stiffer than steel, aluminium or titanium and not subject to corrosion or fatigue. CFRP is being used by structural engineers on bridges, including in repairs to the West Gate Bridge in 2011.

Industry and research partnerships will increase technology uptake

Victoria has outstanding materials science capabilities at its universities and at CSIRO's Clayton facility. Collaboration through R & D can encourage technology uptake and generate opportunities for the construction industry, some successful examples include:

- Dulux and CSIRO partnered to develop a powder coating system for heat-sensitive substrates that is both emissions free and environmentally sustainable. The system, which replaced conventional liquid coatings used in the coating of plastics and Medium Density Fibreboard (MDF) composite board, was successfully commercialised in Victoria. The product avoids the use of toxic solvent emissions from liquid coatings and reduces solid waste going to landfill.
- The Victorian and Commonwealth Government have made significant investments in the Carbon Nexus facility, a state-of-the-art research and analysis laboratory and pilot scale plant located at Deakin University and developing carbon fibre applications, including for construction.

QUESTION 10.	How can Victoria's construction materials and technology firms better capitalise on its strong research base in materials science?
QUESTION 11.	How can better industry and research collaboration be facilitated?

Victoria has the proven ability to commercialise construction technologies

Victorian firms have demonstrated their ability to generate and commercialise innovative construction technologies.

For example, Grocon Construction developed the *Lubeca* jump form system in 2002, while constructing the 92-storey, 300m Eureka Tower. The system involves an automatic climbing mechanism, which jump forms two building floors at a time. This system is reported to halve the number of concrete pours and reduce the amount of steel required on projects[18]. In comparison with traditional jump form methods, the *Lubeca* system saves time and cost while providing a significantly safer working environment. Grocon has exported the *Lubeca* IP worldwide.

IT will drive many of the productivity improvements in the construction sector. An example of a Victorian IT firm specialising in the construction sector is Aconex. Founded in 2000, the firm provides a suite of software tailored for the sector's needs, including low cost BIM software. By 2014, Aconex had been used on construction and engineering projects globally with an aggregate value of more than $800 billion. The company was successfully floated on the ASX in 2014.

As with materials, Victoria has excellent research facilities able to support the development of innovative IT technologies. These could include smart systems incorporating sophisticated sensors, able to monitor a building's structural and environmental performance.

QUESTION 12.	How can firms be encouraged and supported to develop and experiment with new processes to improve the efficiency of the building process.
QUESTION 13.	Is the IT research base in Victoria being fully utilised to develop new smart products for the construction industry?

[18] Tom Glasby, Cement Concrete & Aggregates Australia (CCAA) 16 November, 2009

A technology friendly regulatory environment could improve competitiveness

Regulatory requirements are often cited as the cause of additional costs and lost productivity in the construction sector.

The Building Code of Australia (BCA) sets out the requirements for construction work in Victoria. It contains a set of performance requirements, with 'deemed to satisfy' provisions. These reflect the requirements of Australian Standards and other documents that outline sound construction practices. In an effort to encourage familiarity and use, the Code is available online where it can be accessed free of charge.

The BCA has been drafted to encourage innovation in design, construction methods and materials use. It makes provision for alternatives to 'deemed to satisfy' methods. However for approval by a building authority or certifier, alternative solutions may require documentation and evidence that they meet the Code's relevant performance standards.

While the BCA framework allows alternative solutions, critics claim there are a very limited number of 'deemed to satisfy' options. The cost of providing evidence for alternative solutions is very high and is reported to inhibit innovation in all but the largest projects where the cost per unit can be less of a disincentive. A particular area of dissatisfaction has been around the lack of application of 'deemed to satisfy' provisions to multi-storey timber buildings. While nine storey timber buildings can be constructed under 'deemed to satisfy' provisions in the UK, lower buildings in Australia currently must use the expensive alternative solutions path. It is understood that the inclusion of 'deemed to satisfy' provisions in the BCA for multi storey timber buildings are being considered.

It has also been claimed that products that do not conform to Australian Standards are in use in Australia's building and construction sector, raising questions about safety and posing commercial challenges for producers of conforming products. Industry has suggested that awareness of the role of regulatory bodies could be improved, that building certification arrangements could be reviewed and that stakeholders could examine how best to address any gaps and weaknesses in the building and construction sector conformance framework[19].

Examples which highlight these concerns include a product recall of electrical cable that was sold through major Australian retailers[20] and a building fire involving an external wall cladding system that was manufactured from a combustible and non-compliant material (Aluminium Composite Panels)[21]. The latter example highlights that the industry needs to balance innovation with its capability to understand innovative products in the context of compliance with building law.

The Victorian Government remains proactive on addressing issues around non-compliant building materials, continuing to push for a national approach to the certification and mandatory labelling of high risk building products. Victoria's Planning Minister recently attended a National Building Minister's Forum where he won support from the other States and Territories to put building product safety reforms on the agenda.[22] The Premier of Victoria has also pledged to make a submission to the upcoming Commonwealth's Senate Economic References Committee Inquiry into non-conforming building products.

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19 AiGroup – The quest for a level playing field. The non-conforming building product dilemma- November 2013

20 INFINITY & OLSENT branded Infinity TPS & Orange Round Electrical Cables, Australian Competition and Consumer Commission, 2014

21 Lacrosse Building Fire, Municipal Building Surveyor, City of Melbourne, April 2015. https://www.melbourne.vic.gov.au/AboutCouncil/MediaReleases/Documents/150428%20MBS%20report%20on%20Lacrosse%20Apartment%20Fire%20Docklands.pdf

22 Victorian Government, Media Release, Push for safer material in high-rises to keep the community safe, Minister for Planning – 31 July 2015

QUESTION 14.	Are there regulatory or attitudinal barriers that inhibit the uptake of new materials or processes on Victorian construction projects?
QUESTION 15.	Are there opportunities to increase materials innovation by providing information and advice on how to achieve regulatory approval?

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> The Advanced Manufacturing Growth Centre's Sector Competitiveness Plan is an insightful report that will help boost capability, while developing global opportunities for Australia's manufacturing industry. As Australia's Chief Scientist, I will support the work of the Advanced Manufacturing Growth Centre.

Dr Alan Finkel, Australia's Chief Scientist

ACKNOWLEDGEMENTS

The AMGC wishes to acknowledge representatives and alumni from the following manufacturing companies, industry associations, government bodies, research institutions and universities for their valuable input into the Sector Competitiveness Plan. These organisations have not endorsed the contents of this plan.

COMPANIES
(including through alumni)

A&I Coatings
ACS Australia
Aerosonde
Air Radiators
Airbus Australia
Alchin Long Group
AlphaBeta Advisors
Amcor
Aquacell
Atcor
Austal
Beurteaux Seating Solutions
Boeing International
Bosch
Cablex
Capral Ltd
Cap-XX
Carbon Revolution
Cell Therapies
Ceramisphere
Chute Technology
Cochlear
CSC
CSL
CSR Building Products
Dow Chemical Australia
Flextronics
Godfrey Hirst
Hedweld
HI Fraser
Hitco
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Qenos
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Quickstep Technologies
ResMed
Rinstrum
Rocla
Romar Engineering
Siemens
Silanna
Thales
Weir Minerals

GOVERNMENT BODIES

Austrade
Australian Government Department of Industry, Innovation and Science
Entrepreneurs' Programme Committee
Innovation Australia
New South Wales Government
Office of the Chief Scientist
Queensland Government
Standards Australia
Victorian Government

INDUSTRY ASSOCIATIONS

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Ai Group
AMTIL
Australian Design Alliance
Australian Paint Manufacturers' Federation
Australian 3D Manufacturing Association
Aviation Aerospace Australia
Business Council of Australia
Council of Textile and Fashion
Geelong Manufacturing Council
Furniture Cabinet Joinery Alliance
HunterNet
Manufacturing on the Move
Medical Technology Association of Australia
Midlands Aerospace Alliance
NSW Business Chamber
PACIA
Regional Development Australia
Regional Development Victoria
South East Melbourne Manufacturers Alliance

RESEARCH INSTITUTIONS

Advanced Composite Structures Australia
Ausbiotech (CSIRO Clayton)
Australian National University
CSIRO
Innovative Manufacturing CRC
Manufacturing Skills Australia
University of New South Wales
University of Technology Sydney
Western Sydney University

FOREWORD

The Advanced Manufacturing Growth Centre (AMGC) was established by the Australian Government in 2015 as a key plank of its Industry Innovation and Competitiveness Agenda, and we passionately believe that a strong and vibrant manufacturing sector is critical to Australia's future.

Members of the AMGC team met with small and large manufacturers from around the country to understand not only their unique sources of competitiveness and their aspirations for growth, but also their challenges. We have consulted with other members of Australia's manufacturing ecosystem, including international customers, entrepreneurs, academics, researchers and representatives at all levels of government.

What has become clear from these discussions is that there is significant potential for Australia to grow its manufacturing sector and become more globally competitive. However, we have also come across a number of common misconceptions about the sector that need to be addressed.

The biggest of these misconceptions is that Australian manufacturing entails production alone. The reality is that the term 'manufacturing' now covers a much broader range of activities than those performed in traditional factories where people made thousands of identical units on long production lines. Today, manufacturing centres on complex research and design work in the pre-production phase. There are also many value-adding post-production opportunities in the form of ongoing services. This means that a significant amount of relevant activity might not be sufficiently captured and counted in analysis of the manufacturing sector. Recognising the importance of these activities will greatly expand the potential areas where Australian manufacturing can compete.

Many Australian manufacturers have already found ways to compete internationally, and successfully sell final products or intermediate components into the supply chains of other local or global manufacturers. For these manufacturers, cost is often a less important source of competitive advantage than delivering value to customers through technical leadership and service offerings.

Another view is that Australian manufacturing possesses enough managerial talent to create globally competitive manufacturing businesses. Unfortunately, our research indicates that while we have a large and talented cohort of managers, many of them lag behind their international counterparts in some areas. This gap needs to be highlighted so that it can be closed.

A further misconception is that government can and needs to single-handedly 'fix' manufacturing. While government can play an important role, we believe that industry must take the lead in driving the sector's future growth. This report aims to provide practical advice to help companies achieve this goal and to allow government to assist.

Australian manufacturing has a bright future if it focuses its efforts and takes advantage of its strengths. We are home to many of the creative and service-oriented skills that are now in demand. Our traditional disadvantage of distance from major markets is becoming less relevant in the digital age. Most importantly, we have a community of entrepreneurs, governments, research institutions, investors and others that are focused on driving growth and customer satisfaction by building great businesses and exporting our ingenuity to the world.

Finally, let us emphasise that this Sector Competitiveness Plan is aimed at encouraging all Australian manufacturers to continuously advance and become or remain globally competitive.

Dr Jens Goennemann
Managing Director
Advanced Manufacturing Growth Centre Ltd

CONTENTS

> It is essential that any analysis of competitiveness looks beyond product cost.

1 EXECUTIVE SUMMARY

1 EXECUTIVE SUMMARY

1.1 CONTEXT

Manufacturing has an important role to play as Australia looks to create a diverse, innovative and globally oriented economy. The nature of global manufacturing is changing in ways that provide positive opportunities for Australia, if we are bold enough to seize them.

The Advanced Manufacturing Growth Centre Ltd (AMGC) is a not-for-profit organisation, distinct from but supported by the Australian Government. It was created to champion an industry-led approach to transforming Australian manufacturing.

The AMGC has created a 10-year Sector Competitiveness Plan (SCP) with input from companies and industry associations, research organisations and governments to enhance the competitiveness of Australia's manufacturing sector. The purpose of this Plan is to take a strategic look at manufacturing over the next decade to:

- Identify and analyse opportunities to lift the competitiveness of Australian manufacturing
- Set out actions for companies, governments and research organisations to realise these opportunities and transform the manufacturing sector
- Articulate the role of the AMGC in facilitating this transformation and begin the process of aligning diverse stakeholders around this national challenge.

"Where Australia has achieved success in global markets, it has often related to an innovation in product performance.

1.2 SECTOR COMPETITIVENESS DIAGNOSIS

Studies of the manufacturing sector tend to focus primarily on cost as the key driver of competitiveness. While cost is undoubtedly important, it is far from the only dimension of competitiveness, especially for Australian manufacturers in global markets. In fact, when international customers choose to purchase from an Australian company rather than a cheaper or geographically closer competitor from another country, they are usually doing so because the Australian product offers something different. This difference could stem from innovative design features, an exceptional reputation for reliability and collaboration, or an outstanding service offer.

In recognising this feature of Australian manufacturing success, it is essential that any analysis of competitiveness looks beyond product cost competitiveness – that is, costs that drive final price. The analysis should also consider value differentiation, or sources of value beyond unit cost; and market focus, such as 'where we play' in the value chain, in global markets and in skill-intense products.

Our analysis of manufacturing competitiveness, which is summarised in this Plan, is based on in-depth analysis of two sub-industries: medical technology and aerospace. It reveals that Australian manufacturing has existing competitive advantages and opportunities for improvement in each of three dimensions of competitiveness:

- **Lifting competitiveness by reducing Australian manufacturing's production costs:** Australian manufacturing has a production cost disadvantage relative to benchmark industrial countries. The size of the disadvantage varies by product group, but is estimated at between 7.3 and 15.1 percentage points in the two sub-industries analysed. The disadvantage in other sub-industries may well be higher. The factors contributing to this disadvantage include labour costs, material input costs, capital efficiency and overheads. Overall, while Australia is unlikely to become the lowest-cost location for manufacturing production, there are a number of opportunities to increase cost competitiveness. First, high-skill labour is significantly cheaper in Australia than the international benchmark. For example, in the medical devices industry, management and professional wages are 38% lower in Australia than in the United States (US). However, this often doesn't flow through to lower overall labour costs because Australia's high-skill workers have a more limited mix of skills (e.g. only 17% of Australian aerospace workers have bachelor's degrees compared with 44% in the US). Second, Australia has an opportunity to lift its competitiveness in capital efficiency and overheads. It can do this by improving management quality in areas where Australia lags significantly behind other nations, and by collaborating more to overcome the challenges of scale. Australia's manufacturing firms are small relative to major competitors, even allowing for differences in market size. Third, Australian manufacturing can reduce costs through increased productivity by adopting advanced production processes, involving higher capital intensity, automation and 'Industry 4.0' techniques.

- **Lifting competitiveness by increasing the value differentiation of Australia's manufactured products and associated services:** While Australian manufacturers may not often be the lowest-cost producers, they can and do compete on sources of value other than cost. A panel of international purchasing managers and customers interviewed for this report identified a number of reasons why they choose to buy manufactured goods from Australia. These included product quality (design and technology leadership), reliability and reputation (on-time and in-full delivery, flexibility, safety and transparency) and service support (pre- and post-production). This finding is confirmed by the tendency in recent years for more value to stem from non-production parts of the value chain, including research and development (R&D) and services (see Exhibit 2). Australia's export performance confirms the importance of these factors. Where Australia has achieved success in global markets, it has often related to an innovation in product performance. Examples include ResMed's capturing of 40% of the global market for sleep disorder devices, or Cablex carving out a niche in tailoring cable harness solutions for small runs of aircraft.

However, Australian businesses currently spend relatively little on R&D, and government support for business-led R&D is not optimally designed. In fact, the current funding mix is not likely to maximise investment by firms in R&D across different risk profiles, spillover benefits and time horizons. Australia is an outlier in the mix of assistance that it provides for business-led R&D, with heavy reliance on 'indirect' forms of assistance such as the federal government's R&D Tax Incentive. Further, the current design of the R&D Tax Incentive does not ensure that public expenditure goes towards R&D activity that would have otherwise not happened. Australian manufacturing can also increase its competitiveness by providing value-adding services associated with manufactured goods, building on our skills and strengths in service sectors.

- **Lifting competitiveness by shifting Australian manufacturing towards higher-potential markets:** Australian manufacturers can reduce the cost and improve the value of the products they sell on global markets, and they can also improve their competitiveness by shifting their focus towards the highest-potential markets and playing to our national strengths. Some manufacturing sub-industries under-serve a number of key export markets, including markets for intermediate goods. Additionally, Australian manufacturers are poorly connected into global value chains, with among the lowest level of backward linkages among OECD (Organisation for Economic Co-operation and Development) countries.

Industry 4.0

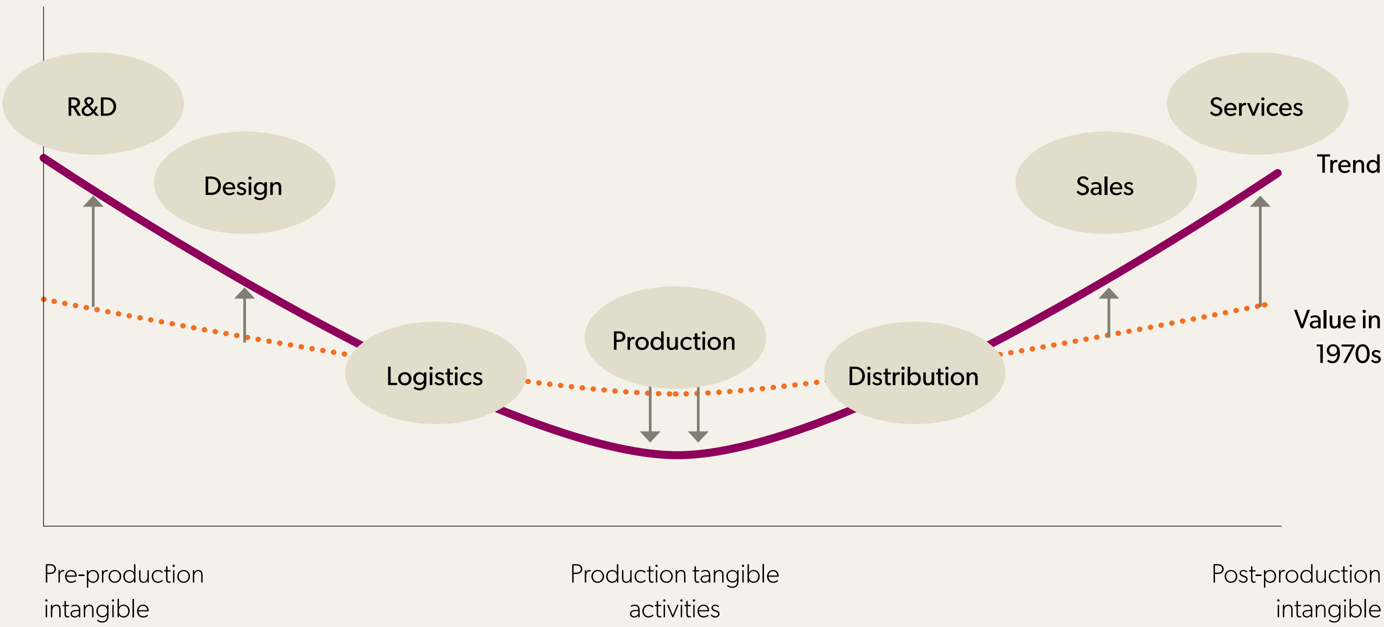
'Industry 4.0' refers to the suite of digital technologies augmenting industrial processes, including '1) the rise of data volumes, computational power and connectivity; 2) emergence of business-intelligence capabilities; 3) new forms of human-machine interactions; 4) improvements in transferring digital instructions to the physical world, e.g. 3D printing'.

Exhibit 1 – Competitiveness in manufacturing is driven by three factors

Three sources of competitiveness	Examples of ways to drive competitiveness, as explored in this plan
1 Reduce cost	Manufacturers can increase their competitiveness by reducing their costs. For example: – Manufacturers can reduce their costs by reducing the **cost of their inputs**, such as transport, energy and materials, etc. – More **advanced production techniques** that enable greater output with existing resources can improve efficiency and reduce costs per unit – Manufacturers can reduce their costs per unit by **increasing their scale** and fractionalising overheads and other fixed costs
2 Improve value	Manufacturers can increase their competitiveness by improving their value proposition to customers. For example: – Manufacturers can focus on **innovation and technological improvements** that give their products a distinctive performance value proposition – Manufacturers can increase the value of their products by providing **value-adding services** that improve their function, utility and longevity
3 Shift market focus	Manufacturers can increase their competitiveness by moving into higher-potential products and markets in which their proposition is more distinctive. For example: – Manufacturers can identify and enter **high-growth or high-value product segments** – Manufacturers can identify and enter **under-served geographies** and participate in **global value chains**

Exhibit 2 – Value in manufacturing is shifting from production to pre- and post-production intangibles such as R&D and Services

Value added, illustrative



Source: Curve adapted from: 'Interconnected economies benefiting from global value chains', OECD 2013

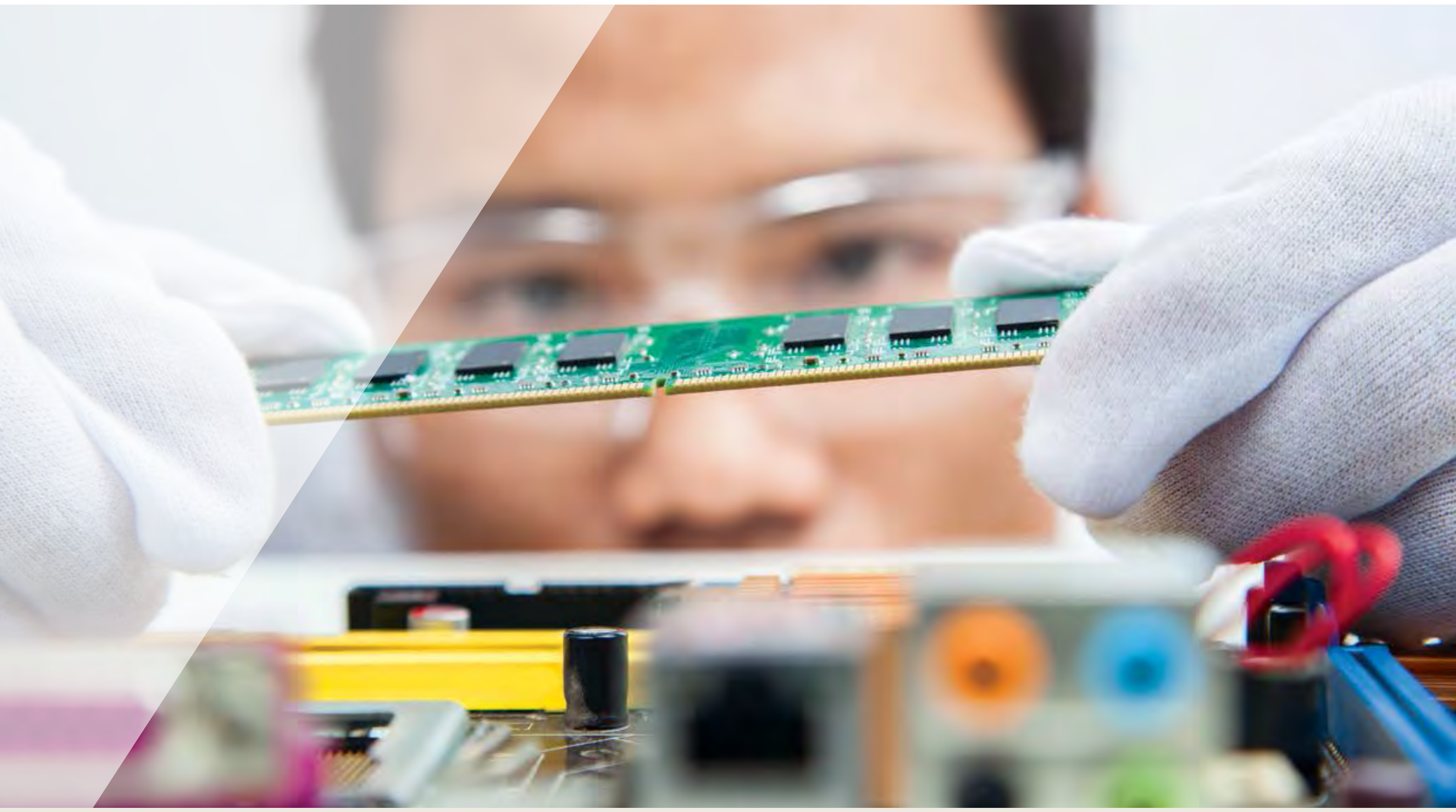
1.3 AUSTRALIA'S MANUFACTURING OPPORTUNITY

Global data confirms that the world's most competitive companies succeed by increasing value differentiation, improving market focus and optimising product cost and processes. For example, global companies ranked in the top 25% for productivity, compared with the bottom 25%, exhibit 3.17 times the R&D intensity, 1.75 times the patent portfolio, 1.08 times the share of services in revenue, 1.61 times the capital efficiency, 1.50 times newer equipment and 1.30 times the plant automation.

> Every Australian manufacturer, big or small, high-tech or lower-tech, can improve its operations by employing advanced knowledge, processes and business models.

However, there is no single formula for success. In fact, we observed that Australian manufacturers follow a range of practices to differentiate themselves, including:

- **Focusing on increasing value differentiation.** These manufacturers are:
  - '*Innovation leaders*': those that use high-skill workforces and R&D investments to develop distinctive value in their products, such as Cochlear, ResMed and Quickstep, or
  - '*Servitised firms*': those that have evolved their model beyond a pure product, with an often high-skilled workforce and a high share of services in revenue, such as Invetech and Ford Australia.
- **Focusing on identifying untapped or niche markets.** These companies are '*market finders*', seeking out under-served markets in which they have strategic advantages, and using high value-density products or mass customisation to meet consumer needs. Examples include Codan, Cablex and Textron Systems Australia.



- **Focusing on reducing cost.** These companies are '*process winners*'. They differentiate through process excellence and cost competitiveness, using capital efficiency, automation and process improvement. An example is Amcor.

Every Australian manufacturer, big or small, high-tech or lower-tech, can improve its operations by employing advanced knowledge, processes and business models. This concept of 'advanced manufacturing' deliberately departs from the current Australian Bureau of Statistics (ABS) definition, which places manufacturing firms in either 'advanced manufacturing' or 'basic manufacturing' categories according to industry codes associated with the products they produce. Our definition recognises that manufacturing firms can adopt advanced techniques irrespective of what they produce and that there is no hard line separating 'advanced' firms from other manufacturers. All firms can aspire to continuously improve their production processes and evolve their business models.

While there are many examples of successful Australian companies, not all of Australian manufacturing exhibits the 'advanced' characteristics identified above. In fact, the majority of Australian companies do not report characteristics such as R&D collaboration; the introduction of new goods, services or processes; the use of science, technology, engineering and maths – or STEM – skills; supply of overseas markets; or increasing IT expenditure.

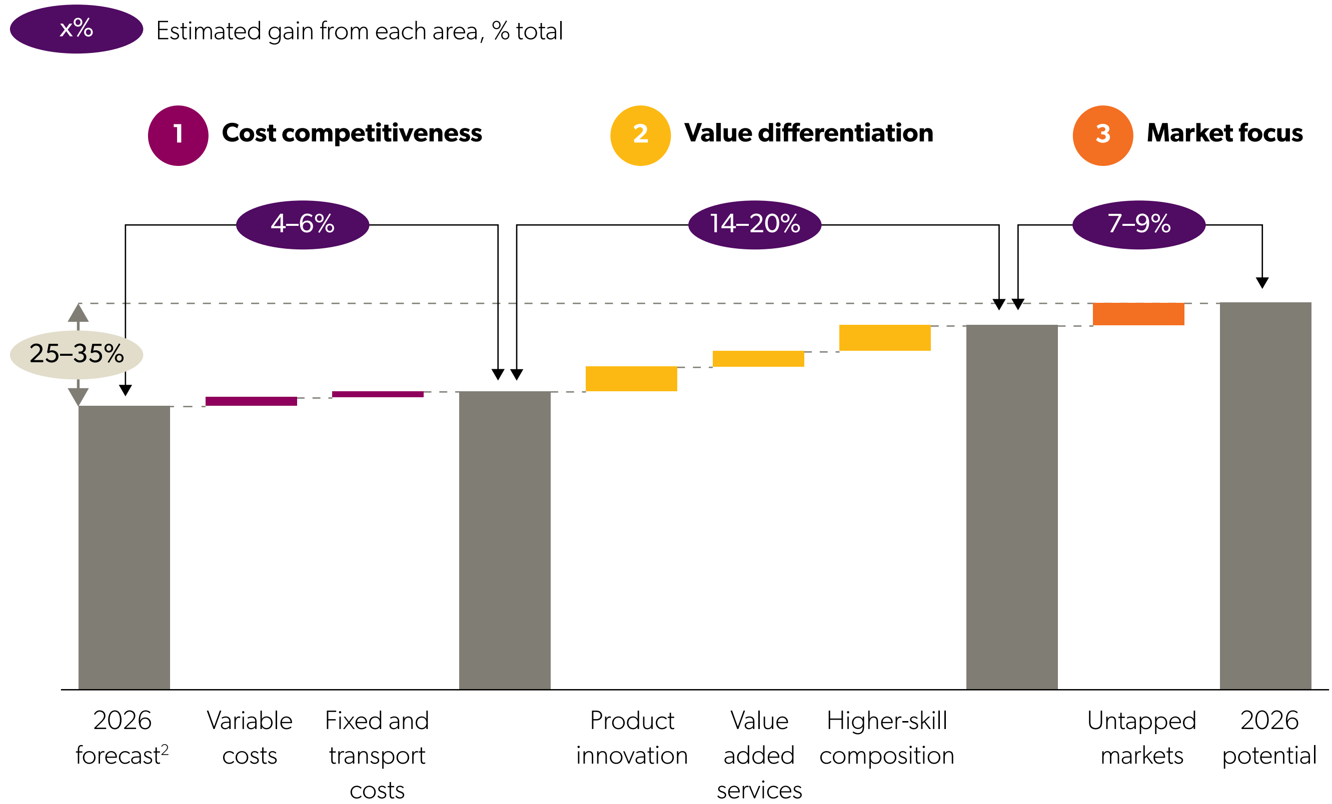
The rewards for success in advancing manufacturing are substantial. The current size of Australian manufacturing (in the year to June 2016) is $97.7 billion, with 886,800 employed persons and an estimated 331,000 people employed in other sectors as a direct result of manufacturing activity. Analysis of the potential 'size of the prize' in improving manufacturing competitiveness suggests that Australia can capture a 25–35% increase in value added by 2026 (see Exhibit 3).[1] This figure is driven primarily by improvements in value differentiation, which would account for a 14–20% improvement; and shifts in market focus, which would account for a 7–9% improvement. Improvements in cost competitiveness would account for the smallest component of the potential uplift, at 4–6%.

1 The base case size of manufacturing in 2026 uses the 2006–14 compound annual growth rate as the average annual growth rate through to 2026. For detailed methodology of this estimate, see Section 3.2 and Annex B.

Exhibit 3 – Growth in manufacturing can be achieved by focusing on greater value differentiation and improved market focus, not cost alone

Estimated potential value gain across advanced manufacturing

Percentage of value added in 2026 relative to straight-line trend projection[1]



Notes

- Benchmarking 'landed' product cost against other high-cost countries revealed a 9–14% cost gap
- Improvement estimates based on different scenarios of closing the cost gap and either banking savings as profit or passing through lower prices
- Value estimate triangulated through assessing sub-category export improvement potential in each vertical, and through comparing firm-level profit margins for highly innovative vs average firms
- Product focus from matching US proportion in high skill industries
- GVC integration based on uplifting exports in key markets to Australian average category share.

1 Increase based on extrapolation from aerospace and med tech analysis.

2 Base growth projected using 10-year historic CAGR for ANZSIC sub-divisions 18, 23 and 24. See appendix for full methodological details.

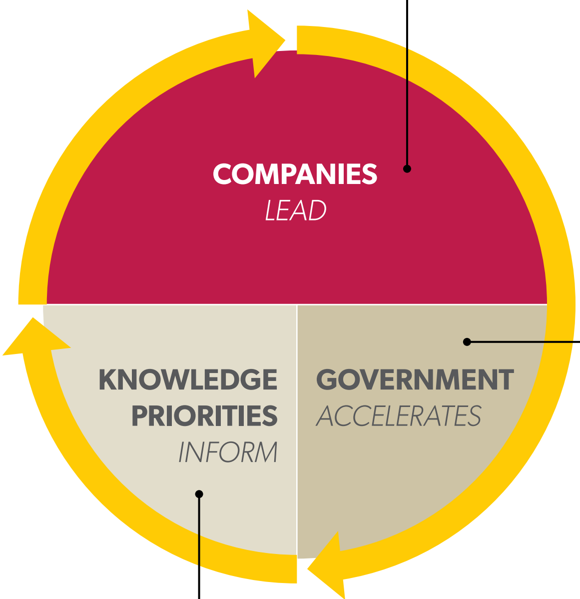
Source: AlphaBeta/McKinsey analysis

1.4 ACTION PLAN FOR AUSTRALIAN MANUFACTURING

The AMGC's vision is to develop an internationally competitive, dynamic and thriving Australian advanced manufacturing sector that boosts the long-term health of the economy and the nation. Achieving this vision will not be easy. While the Plan will require national effort from multiple stakeholders across industry, government and research, the transition, critically, must be led by companies. The Plan identifies key actions for industry to achieve this transformation, and identifies how governments can help accelerate the change and how certain Knowledge Priorities defined by the AMGC can better guide industry and researchers.

Exhibit 4 – Companies must lead the transition to competing on value, supported by government and informed by Knowledge Priorities

Objective: Australian manufacturers need to compete through product and service differentiation, and better target export markets



Companies will lead the transition by:

- Increasing technical leadership
- Increasing value-adding services
- Improving market focus by reaching untapped markets and integrating into global value chains
- Lifting scale and management quality.

Many Australian businesses are already making this transition.

Government can accelerate the transition to new value-based business models by:

- Optimising support for business-led R&D
- Using smarter defence and civil procurement
- Designing assistance to target 'more advanced' characteristics
- Changing measurement of manufacturing.

Knowledge Priorities will inform and fuel the transition by:

- Identifying R&D Priorities: e.g. robotics, advanced materials and composites, digital design and rapid prototyping
- Identifying Business Improvement Priorities: e.g. workforce skills requirements, management capability, building international linkages and driving Industry 4.0 uptake.

Source: Competitiveness analysis

1 EXECUTIVE SUMMARY

Actions for industry: Australia has many world-class manufacturing companies of which we can be proud. However, industry as a whole must evolve to focus on rapid innovation, develop new business models to include services across the value chain, engage in global supply chains and build highly skilled workforces.

This Plan articulates an industry-led transformation focused around four objectives, with a series of actions that will support achieving the objectives:

- **Enhance value differentiation by increasing the technical leadership of Australian manufacturing.** When Australian firms succeed in global markets, it is usually by providing the best products rather than just the cheapest products. Australian manufacturers tend to be most competitive when they have distinctive products offering superior performance that deliver value for money. The single biggest opportunity for Australian manufacturing is to increase our technical leadership and improve the distinctive value of our products across the manufacturing industry. To achieve technical leadership, Australian manufacturers should focus on lifting their technical leadership in three ways. First, they must increase expenditure on R&D, which is a core enabler of value differentiation. Australian businesses' expenditure on R&D as a proportion of gross domestic product (GDP) is well below that of many key OECD competitors. Second, Australian firms should increase their collaboration with research institutions. This is particularly important for smaller businesses that exhibit lower levels of collaboration, potentially constraining the development of technical leadership. Seeking out project-specific partnerships, and sharing personnel and investing resources can all assist in ensuring Australian companies can access and build on the latest ideas and technical leadership. Third, Australian manufacturing companies can exploit Australia's cost advantage in high-skilled labour and drive technical leadership and service offerings by lifting the skill mix of their workforce.
- **Enhance value differentiation by increasing service offerings within Australian manufacturing.** Australia has a significant opportunity to complement our manufactured products with value-adding services that open growing revenue streams and improve the value differentiation of our products. With a highly skilled, English-speaking workforce, Australia's manufacturing

industries are well placed to execute the shift to service-enhanced offerings. Manufacturing sub-industries that have already made the shift are growing faster than those industries still focused on the production parts of the value chain. To achieve this, Australian firms will need to focus on developing compelling service offerings, identifying and building new markets for their services and shifting the mix of their workforce towards service skills.

- **Improve market focus by reaching untapped markets and segments, and integrating into global value chains.** Australian manufacturing firms should not only focus on improving the cost and value of what they produce today; they should also continue to identify new markets and product segments. There is a significant opportunity for Australian companies to grow by identifying niche products or service markets, or under-served export markets. Australian manufacturers are underweight in a number of key export markets, including for intermediate goods. Australian companies are currently poorly linked into global value chains, using among the lowest levels of foreign inputs in generating output that is then exported.

- **Lift scale and management quality to improve cost competitiveness.** While cost will usually not be the main reason Australian manufacturing firms are successful in global markets, efficiency is always important to ensure sustainable profitability. To improve their cost competitiveness, Australian firms have three priorities. The first is closing the management skill deficit, as Australian manufacturing companies have a lower share of high-performing managers than other successful economies. Reducing the deficit is vital to reducing cost and improving productivity. The second is collaborating more with other companies and pooling resources to cover their relative size disadvantage. Collaboration should help improve capital efficiency and reduce overhead costs. The third is to take advantage of Australia's significant cost advantage in skilled labour to increase the focus on technical leadership.

1 EXECUTIVE SUMMARY

Actions for governments: While companies must be the lead players, federal and state governments can play a significant role in supporting the actions that companies need to undertake and accelerate the transformation. This report articulates a number of areas for government action, including several priority actions:

- **Improve government support for business-led R&D and encourage industry–research collaboration:** Support for R&D and research collaboration have underpinned Australia's export successes, particularly in sub-industries like medical technology. If more companies are to experience similar success, governments should improve the R&D Tax Incentive to increase support for R&D activity that would have not otherwise happened (i.e. increase 'additionality') and boost support for both medium-risk, short-term R&D through the Tax Incentive, and higher-risk, longer-term R&D through more direct forms of grant assistance. For the government to achieve these objectives it would need to tighten eligibility criteria and consider using the savings to both simplify application processes to drive take-up and shift the mix of support towards more direct forms of grant assistance. Further, with tighter leadership and collaboration between companies and universities, Australia's strong research pipeline will be better translated into commercial outcomes.
- **Use smarter procurement and smarter programs to drive advancement:** Federal and state governments have the opportunity to leverage their procurement to drive innovation and collaboration between firms, and to create opportunities for Australian firms in global supply chains. Government procurement support should be focused on boosting technical leadership, ideally in areas where Australian manufacturing has a current or potential future comparative advantage, which could be developed to scale through guaranteed demand. Critically, support should not be provided to prop up industries that were once competitive but are no longer viable in their current setting. Innovation requirements can be established so that the technology or product will be a globally distinctive offering. Other industry assistance and capability-building programs offered by federal and state governments could also be better designed to target the characteristics associated with advancement in manufacturing.

- **Change the lens on the role and measurement of manufacturing in the economy:** Governments and the public at large must recognise that manufacturing is more than production. A dynamic manufacturing sector might include more services and less local production output, more offshoring and less domestic assembly. Rather than measure the manufacturing sector narrowly through production output in a set of Australian and New Zealand Standard Industrial Classification (ANZSIC) codes, new metrics are needed to establish whether manufacturing is advancing and identify its wider impact on the economy. This includes tracking whether the prevalence of key 'advanced' characteristics is increasing and the indirect impact of manufacturing on employment.

Taken together, these policy changes amount to a fundamental shift in the focus, balance and operation of government support, to help ensure that Australia's manufacturing sector is able to thrive in the future.

Knowledge Priorities: The company-led transformation can be supported by further investigation of knowledge gaps in R&D and business capabilities identified by the sector. The Knowledge Priorities were identified through a competitiveness analysis, a literature review and industry consultation, including a survey of more than 50 industry respondents.

- **R&D priorities:** The sector has identified detailed knowledge gaps in the fields of robotics and automated production processes; advanced materials and composites; digital design and rapid prototyping; sustainable manufacturing and life cycle engineering; additive manufacturing; sensors and data analysis; materials resilience and repair; bio-manufacturing and biological integration; nano-manufacturing, micro-manufacturing and precision manufacturing; and augmented or virtual reality systems.
- **Business improvement priorities:** The sector has identified detailed knowledge gaps about business capabilities in the areas of drivers of the management capability gap; understanding current and future workforce skills requirements; building better international linkages; driving Industry 4.0 uptake; and leveraging government procurement.

1.5 ROLE OF THE AMGC AND NEXT STEPS

The role of the AMGC is to harness its unique capacity as an industry-led but government-supported Growth Centre to help advance Australian manufacturing. There are three key ways that the AMGC will deliver on this promise:

- **Direction:** The AMGC will set a direction to advance manufacturing in Australia through its annual Sector Competitiveness Plan, complementary sub-annual analytical investigations, and materials on Knowledge Priorities. Over the next 12 months, the AMGC will undertake a number of specific actions to progress this role, including conducting additional sub-industry analysis, regularly updating the Knowledge Priorities, mapping employer demand for skills to build an evidence-based industry-led skills plan and assessing Australian manufacturing against 'advanced' characteristics.
- **Demonstration:** The AMGC will demonstrate ways to achieve this direction through projects and hubs. It will co-fund projects that implement the identified priorities for the sector. These projects will serve as 'demonstrations' of best practice to advance manufacturing in Australia and pave the way for other actors in the sector to replicate. The AMGC will use hubs to demonstrate how firms can develop shared technical leadership and collaborate to overcome scale challenges. The AMGC has already supported two hubs (the Australian Carbon Fibre and Composite Technologies Hub, and the Additive Manufacturing Collaboration Hub), which are leveraging the geographical proximity of firms in key industrial areas in Victoria. Over the next 12 months, the AMGC will identify further projects and hubs in other states and content areas.

- **Impact:** To pursue this direction, the AMGC will seek to influence the strategies pursued by companies and governments. Companies, which will lead the transition, require a comprehensive understanding of the capabilities and requirements needed to shift towards more advanced manufacturing. Over the next 12 months, the AMGC will seek to assist companies by creating tools for companies to benchmark themselves against the key characteristics of advanced manufacturers, communicate the characteristics associated with advancement, communicate the findings laid out in the Plan, showcase examples of businesses that have servitised, and communicate the skills needed today and in the future. Likewise, governments are able to accelerate the transition that companies need to undergo. As an industry-led but government-supported body, the AMGC is well positioned to ensure that government policy and assistance best supports the transition. The AMGC will work with the relevant government departments to improve their support for business-led R&D; inform procurement officers about key levers of competitiveness; ensure a strong industry-policy role in upcoming defence procurement; ensure evaluation criteria for relevant assistance are aligned with 'advanced' characteristics; ensure programs that offer capability-building target the development of 'advanced' characteristics; and modify how manufacturing is measured.

The analysis and actions contained in this report will help lift the Australian manufacturing sector to another level. The AMGC will work with companies, governments and other stakeholders to implement this Plan and harness the under-utilised potential of Australian manufacturing.

> The Plan will require national effort from multiple stakeholders across industry, government and research, the transition, critically, must be led by companies.

> The importance of skill mix suggests that a shift towards higher-skill composition or skill-intense production will be important if Australian manufacturers are to be more competitive in the future.

2 SECTOR COMPETITIVENESS DIAGNOSIS

2 SECTOR COMPETITIVENESS DIAGNOSIS

2.1 RETHINKING COMPETITIVENESS

> The biggest force acting on our business is low-cost competition from foreign producers. The only way we can succeed is by building smarter versions of our product and finding smarter ways to deliver it.

Industry participant, AMGC consultation[2]

Cross-country studies of manufacturing capability focus primarily on cost as the main driver of competitiveness. While cost is undoubtedly important, it is far from the only dimension of competitiveness, especially for Australian manufacturers in global markets. Australian products normally succeed in global markets because they offer something different – perhaps innovative features, or an exceptional reputation for reliability, or outstanding after-sales service. The reality of Australia's high-wage economy and distance from global markets is that its manufacturers often succeed by being better, not just cheaper, than their competitors.

The framework for competitiveness in this section of the Plan includes not only product cost competitiveness (costs that drive final price), but also value differentiation (sources of value beyond unit cost) and market focus ('where we play' in the value chain, in global markets and in skill-intense products) – see Exhibit 5.

1. **Product cost:** The composition of costs that drive the final price of a produced good, including variable costs (labour, materials, energy and transport), tax and fixed costs (capital and overheads). Product cost has been the commonly prioritised concept in manufacturing competitiveness studies.

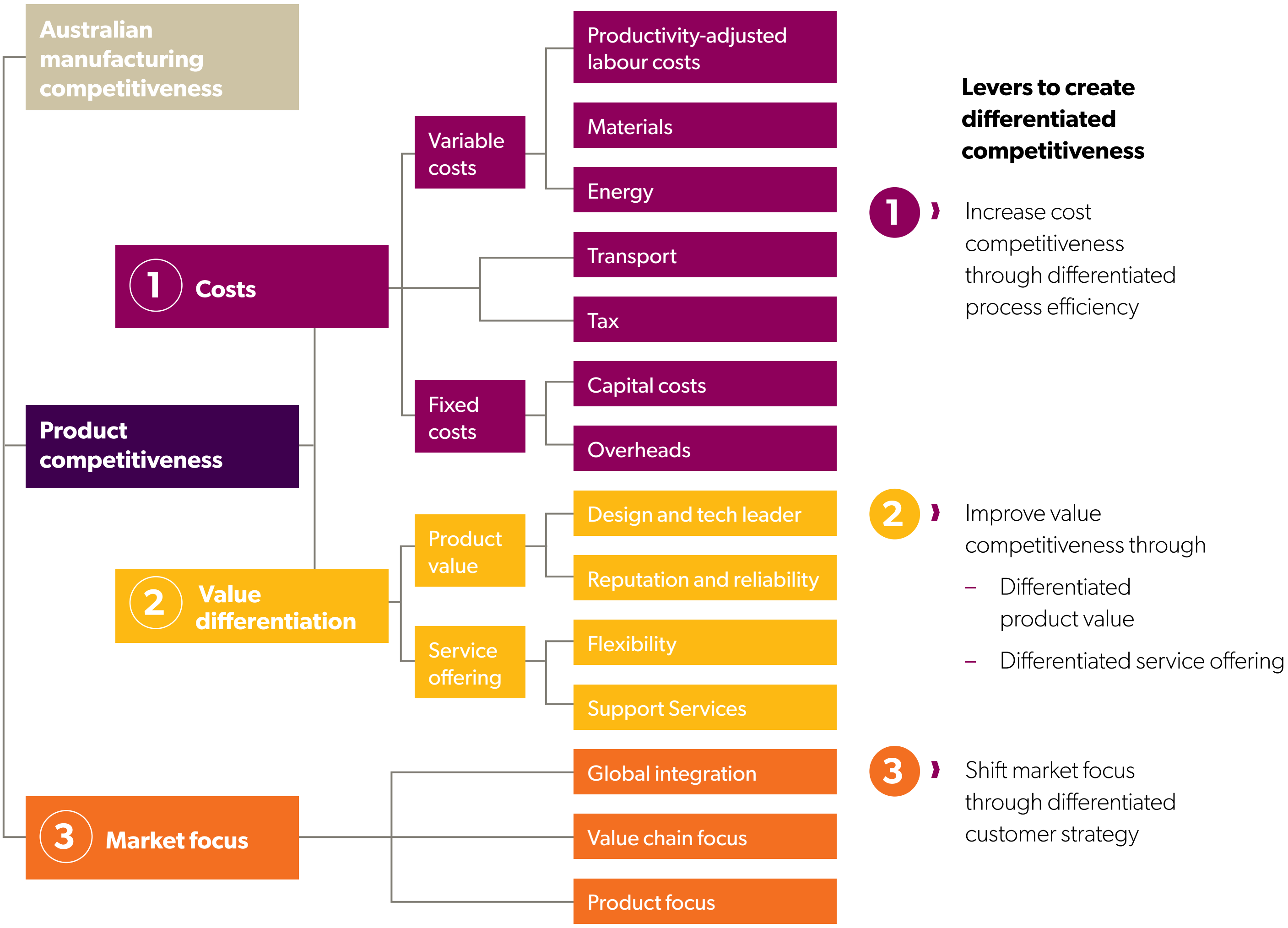
2. **Value differentiation:** The sources of value creation for customers beyond product cost, such as product leadership, reputation and reliability, flexibility and service offering. Hard-to-replicate sources of differentiation (such as world-leading technology protected by patents, or a reputation for unrivalled quality or reliability) can create a source of competitive advantage, resulting in larger and more sustainable margins than those that can be achieved by manufacturers who compete on production cost alone.

3. **Market focus:** How manufacturers can boost competitiveness by changing where they 'play'. This includes whether they serve growing customer segments or markets, and whether they are focused on skill-intensive product niches. Shifting to the highest potential markets that play to Australian manufacturing's strengths can significantly increase value and our overall competitiveness.

2 This comment was recorded during AMGC's early consultation with industry members. It was made by the manager of an Australian SME engaged in mechatronics manufacturing.

Exhibit 5 – We better understand ways Australian manufacturers can boost competitiveness by thinking more broadly than cost, looking also to 'value' and 'market focus'

Competitiveness framework



Source: Based on >25 interviews with final customers/international purchasing managers about what matters most and analysis of successful characteristics of 3,040 global manufacturing firms. AlphaBeta/McKinsey analysis

This framework was developed for the purposes of this Plan and to guide the AMGC's approach. It has been developed using information from an international panel of manufacturing purchasing managers and customers, analysis of the success characteristics associated with more than 3,000 global firms[3], and other research conducted in the process of creating this Plan.

In order to analyse the current competitiveness of Australian manufacturing, we have initially focused on two specific sub-industries: aerospace and medical technology. We do so in recognition of the fact that manufacturing is a broad sector made up of numerous sub-industries that exhibit very different characteristics, but also that any analysis of the drivers of competitiveness demands the investigation of real data at the sub-industry level. Medical technology and aerospace were selected for a number of reasons. First, these sub-industries are often considered 'more advanced' and we were eager to examine what was working in more successful, export-oriented industries and how to expand this success. Second, they offered variation in insights due to different industry structures, barriers to success, and innovation models. Going forward, the AMGC will conduct further sub-industry analyses to ensure actions are informed by every part of the industry.

The analysis of manufacturing competitiveness summarised in this Plan reveals that Australia has competitive advantages as well as opportunities for improvement in three dimensions of competitiveness: cost, value differentiation and market focus.

> Skill mix, management practice and business size help to explain Australia's disadvantage in labour costs.

2.2 LIFTING COMPETITIVENESS BY REDUCING COSTS

2.2.1 Australian manufacturing has a product cost disadvantage relative to the international benchmark

Product cost refers to the composition of costs that drive the final price of a produced good, including variable costs (labour, materials, energy and transport), fixed costs (capital and overheads) and tax. In order to estimate the landed cost, this Plan used a range of data sources to identify relative costs for Australian manufacturers versus an international benchmark.[4]

Australian manufacturing has a product cost disadvantage relative to the international benchmark of between 15.1 percentage points in aerospace and 7.1 percentage points in medical technology, due primarily to differences in labour costs, transport costs and overheads (see Exhibit 6). The US was selected as the benchmark country for both aerospace and medical technology because it is a leading developed competitor and exporter in each category. A sizeable proportion of the gap compared with the international benchmark (3.0–9.1 percentage points) is driven by labour costs.[5]

Productivity-adjusted labour costs are a combination of both wage levels and labour productivity. Importantly, Australian manufacturing's labour unit cost disadvantage is not primarily the result of higher wages but more the nature of production in Australia. Specifically, factors such as Australian manufacturing's skill mix, management practice and business size help to explain Australia's disadvantage in labour costs (see Section 2.2.3).

3 Standard & Poor's (2016), Compustat Database (accessed: August 2016).

4 The model calculated the price required to generate a fixed return on invested capital equivalent to the cost of capital. The relative size of each cost category for aerospace and medical technology companies was estimated using detailed data from the 2014 US Census of Manufacturers. For each cost category, industry-specific benchmarks were used to identify the relative cost (higher or lower) for Australian firms, resulting in an overall product cost comparison. This research draws on data sets including the OECD STAN database, EU KLEMS database, ABS and BLS data, and other reports on manufacturing.

5 AlphaBeta/McKinsey manufacturing product cost competitiveness model.

Exhibit 6 – Product cost benchmarking suggests that Australian manufacturing has a cost disadvantage of 15.1 percentage points (ppt) in aerospace and 7.1 ppt in medical devices

	Aerospace			Medical technology		
	Share of unit cost	Gap to benchmark	Total ppt contribution	Share of unit cost	Gap to benchmark	Total ppt contribution
Productivity adjusted labour	28%	+32%	9.1	30%	+9.8%	3.0
Materials	48%	+3%	1.5	44%	+2.2%	1.0
Energy	1%	+48%	0.5	1%	+48%	0.5
Transport	8%	+13%	1.1	4%	+11%	0.4
Tax	1%	7 ppt	0.6	1.5%	7 ppt	0.5
Capital	4%	+33%	1.3	5%	+9.8%	0.5
Overheads	10%	+11%	1.0	14%	+10.0%	1.4
		Total unit cost difference =	**15.1**		Total unit cost difference =	**7.3**

Australia's unit labour cost disadvantage is **driven by lower labour productivity** (value added per hour), **not wages**. In both aerospace and medical devices, Australian productivity is lower than in the US; while in medical devices Australia has a **wage advantage**

Transport cost differential driven by relative cost to export to key EU markets, including internal freight. For **small, high-value medical devices the difference is smaller**

Higher overheads for Australian firms driven by **significantly smaller average firm size**, where overheads are a greater proportion of cost

In **aerospace**, the total cost difference is 15.1 ppt, driven primarily by differences of 9.1 ppt in labour, 1.1 ppt in transport and 2.3 ppt in capital/overheads.

In **med tech**, the total cost difference is 7.3 ppt, driven primarily by differences of 3.0 ppt in labour, 1.9 ppt in capital/overheads and 1.0 ppt in inputs.

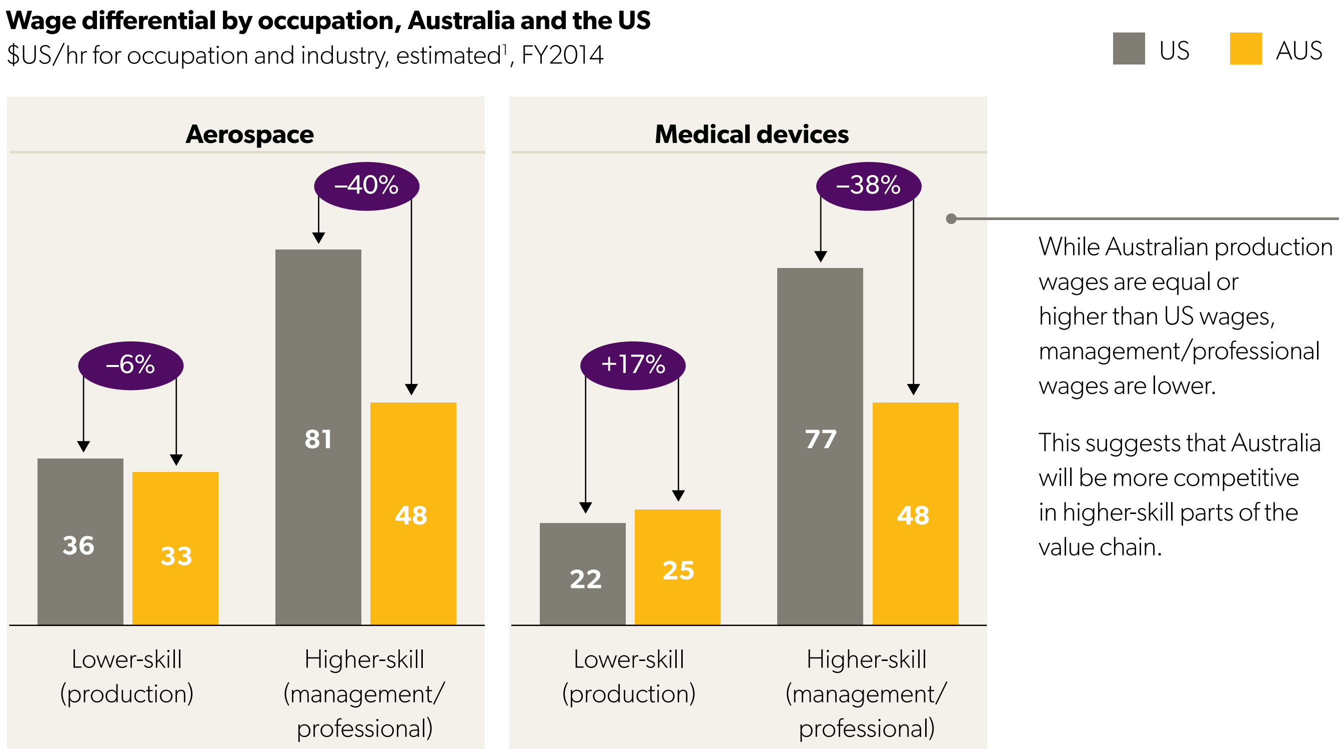
Source: McKinsey/AlphaBeta competitiveness model; various cost input sources

2.2.2 Australian manufacturing has a cost advantage in high-skill labour, which some sub-industries do not exploit

In general, Australian manufacturing is unlikely to be able to compete on labour cost for low-skill jobs. Even relative to high-cost countries such as the US, Australian low-skill labour is comparatively more expensive: 9.8% higher than benchmark in medical technology and just under benchmark in aerospace. However, Australia has a wage cost *advantage* for high-skill workers: 38% below benchmark in medical technology and 40% below in aerospace (Exhibit 7).[6] This means that the most competitive Australian manufacturing companies will often be those that have higher proportions of high-skill workers than foreign competitors. The decision by Ford to retain over 1,000 design and engineering staff despite ceasing production offers evidence of this cost advantage in Australia.

This can be seen in the cases of aerospace and medical technology. Australia's competitiveness in medical technology can be partly explained by its higher proportion of high-skill workers (26% of workers have a bachelor's degree or higher versus 18% in the US).[7] By contrast, the larger gap in labour costs in aerospace can be partly explained by the relatively low-skill composition of the aerospace workforce (17% with a bachelor's degree or higher versus 44% in the US), thereby failing to capitalise on our labour cost advantage (Exhibit 8).[8] The importance of skill mix suggests that a shift towards higher-skill composition or skill-intense production will be important if Australian manufacturers are to be more competitive in the future.

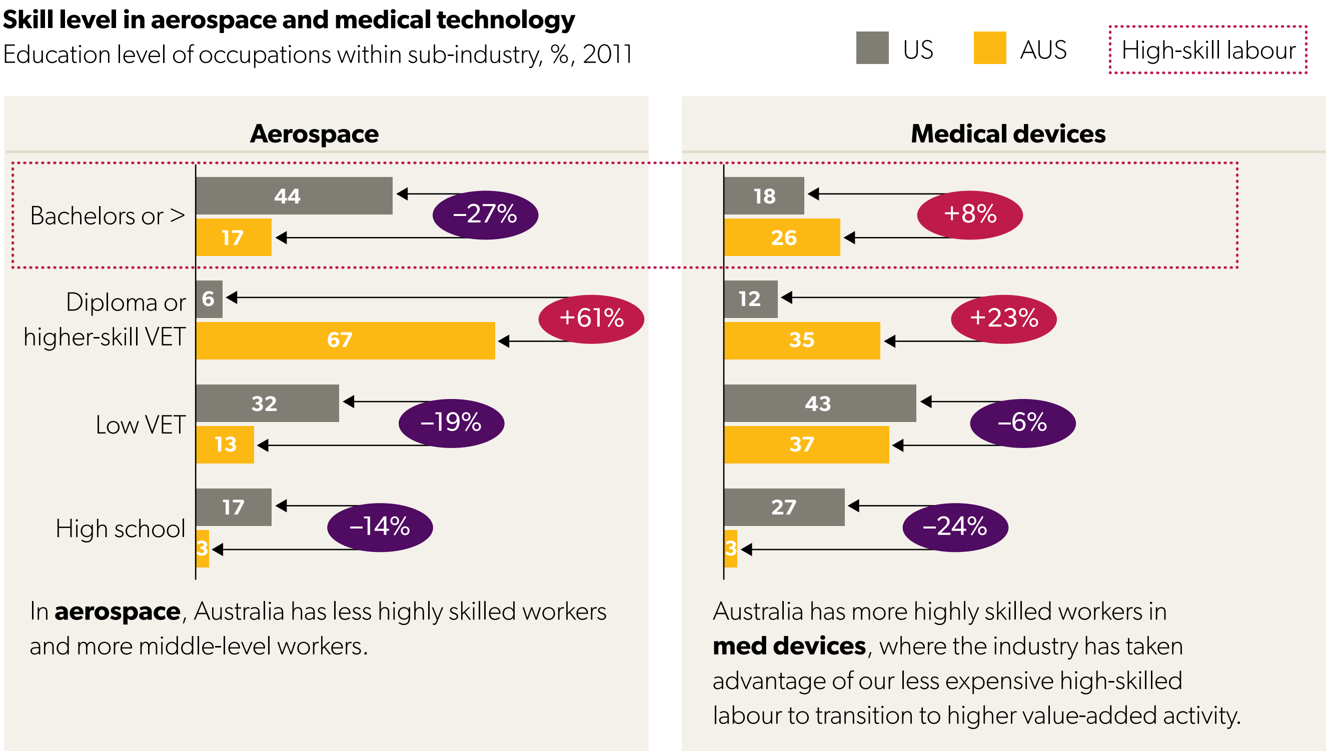
Exhibit 7 – Australia has a significant cost advantage in higher skill workers



1 US estimates based on US Census Bureau's Annual Survey of Manufactures.
2 Australian estimates based on mapping average wages for roles to mix of roles in each industry; 10-year average exchange rate of $0.88 AUD/USD.
Source: ABS series 6306; US Census Bureau Annual Survey of Manufacturers (ASM) 2014; RBA Forex data; McKinsey/AlphaBeta analysis

6 ABS series 6306, US Census of Manufacturers 2014, RBA Forex data, McKinsey/AlphaBeta analysis.
7 Australian Census (2011), US BLS Occupation-Industry Matrix (2011), calculated by mapping education levels to occupations at 1-digit level, AlphaBeta/McKinsey.
8 ibid.

Exhibit 8 – Some Australian industries do not take advantage of our cost advantage in high-skill workers



Note
Higher-skill VET defined as Cert III or IV in Australia and 'Some college, no degree' in US.
Source: Australian Census (2011); US BLS Occupation-Industry Matrix (2011). Calculated by mapping education levels to occupations at 1-digit level. AlphaBeta/McKinsey analysis

2.2.3 Capital efficiency and productivity are lower, in part driven by challenges around management quality, firm size and Industry 4.0

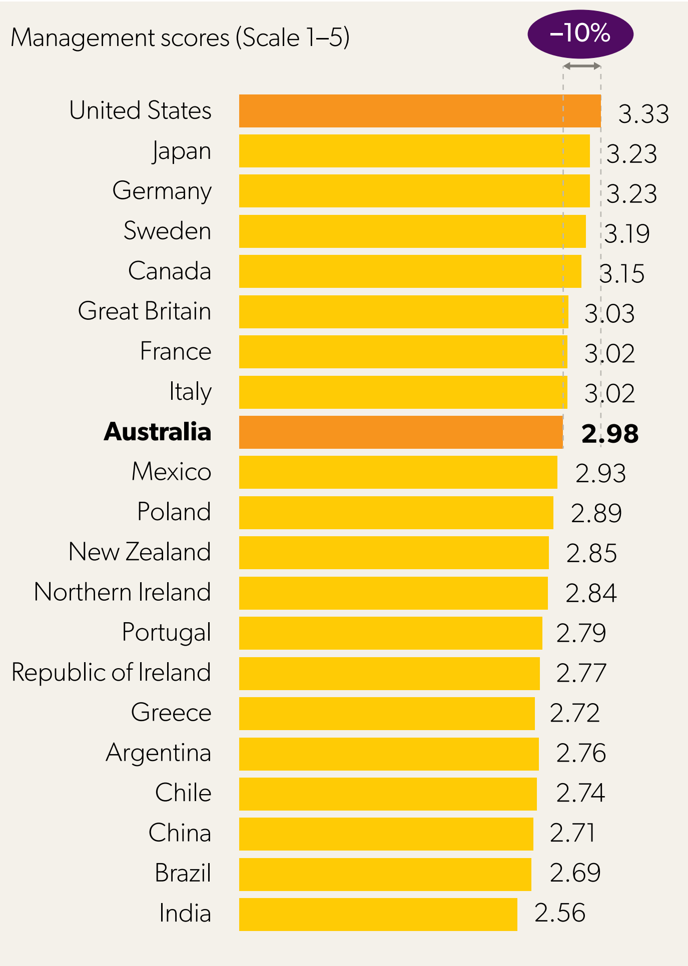
Labour productivity in Australian manufacturing is only 60–65% the level of the international benchmark[9], more than offsetting the wage cost advantage in high-skill workers. Key drivers of this include management capability, which impacts efficiency; and firm size, which impacts economies of scale and potentially the uptake of automation, capital intensity and Industry 4.0 processes.

A study of more than 6,000 manufacturers across 21 countries evaluated national management performance against a set of common benchmarks including lean operations, performance management and talent management.[10] This research revealed that Australia has a larger tail of low-performing manufacturing companies than other advanced economies (Australian scores were 10% lower than US scores on average, for instance; see Exhibit 9) and a shortage of managers with university degrees. Other countries have sought to boost the skill level and proportion of the workforce with tertiary education through such policies as encouraging greater enrolment in STEM subjects, attracting more workers into manufacturing, and skilled migration.[11]

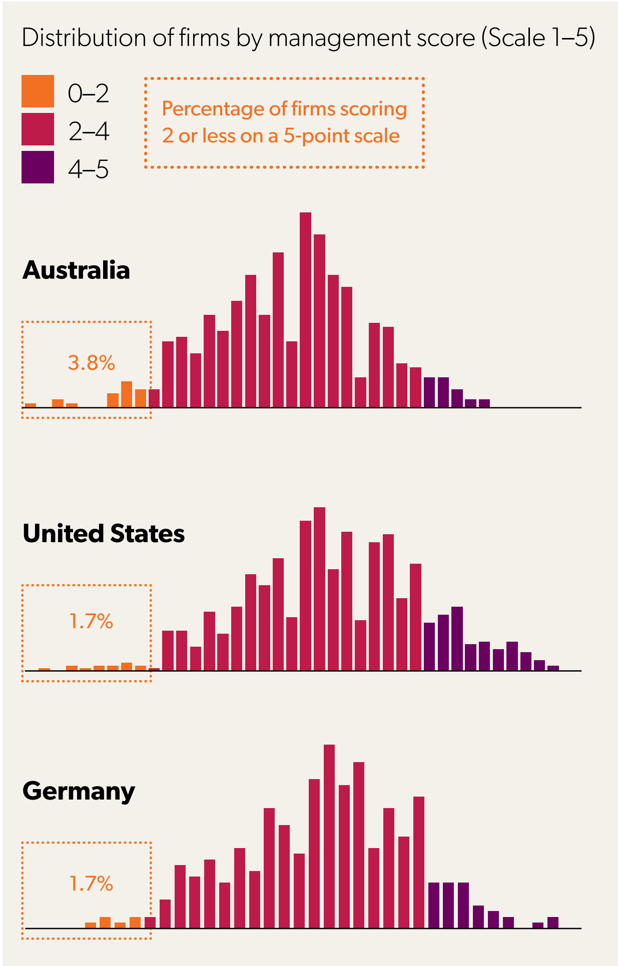
9 AlphaBeta/McKinsey manufacturing product cost competitiveness model.
10 Bloom, Nick et al. (2007), 'Management Practice and Productivity: Why They Matter', *Management Matters*. Available at: http://www.growingjobs.org/downloads/management_practice.pdf
11 McKinsey & Company (2009), *Management Matters*.

Exhibit 9 – Management practice among Australian manufacturers requires improvement

Australia lags significantly behind the US in manufacturing management practice …



… with a larger share of underperforming managers compared with other countries



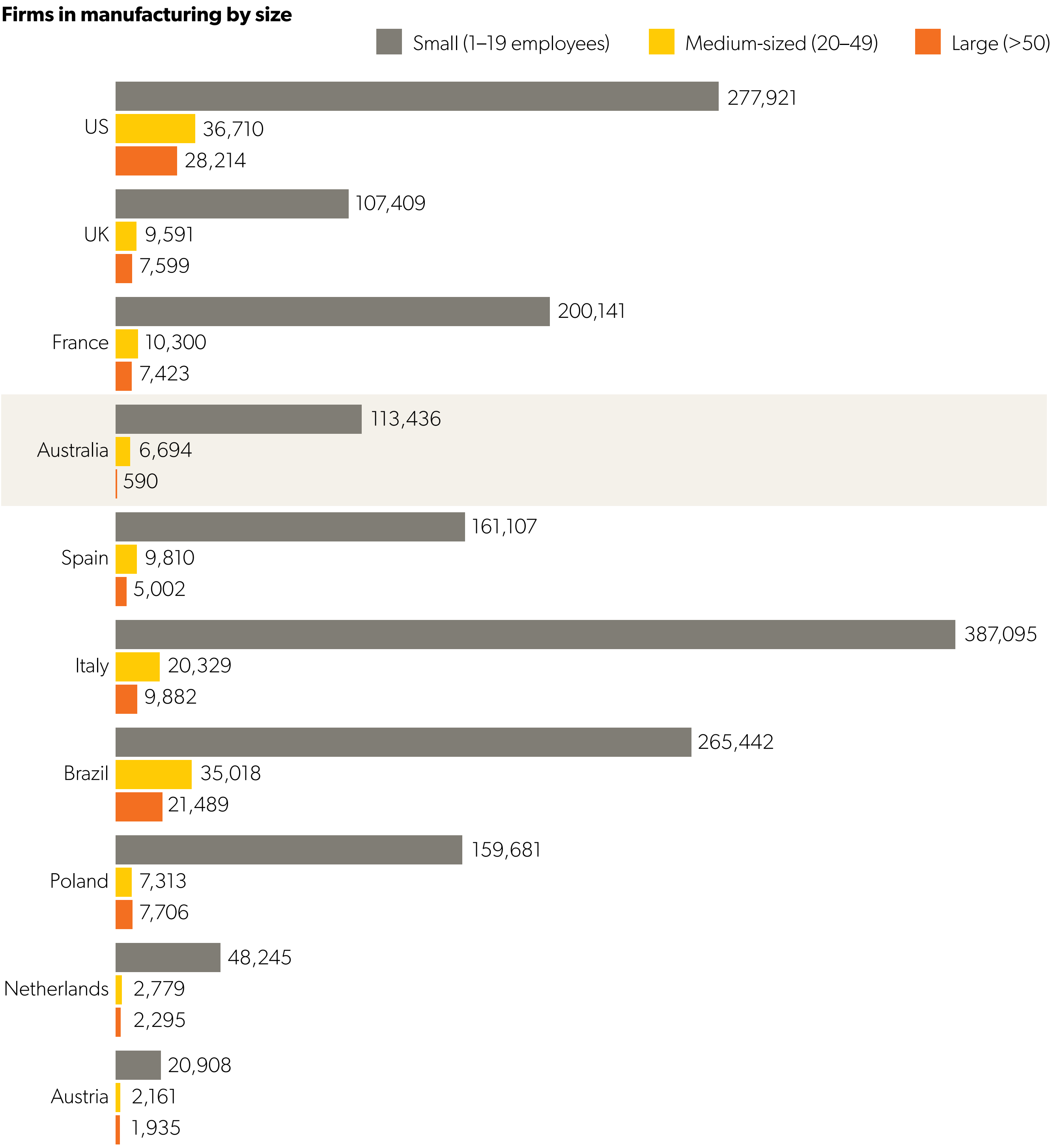
Source: McKinsey & Company, *Management Matters* 2008, 2009

Firm size: Achieving economies of scale in manufacturing has been a challenge for Australia, driven by limited local demand and distance from world markets. This, coupled with a system that encourages sole traders to incorporate, has resulted in a market dominated by small firms (see Exhibit 10). In aerospace manufacturing, Australia has 42 medium-sized companies and two large companies versus 472 medium-sized companies and 280 large companies in the US.[12] In medical technology manufacturing, Australia has 44 medium-sized companies and six large companies, compared with 792 medium-sized companies and 667 large companies in the US.[13] The implication is that overheads are not spread across large volumes, and shorter production runs make it harder to optimise production. Other countries have sought to overcome scale challenges by encouraging collaboration between companies, consortium formation in bidding for government contracts or entering export markets, and the pooling of R&D resources.

12 OECD Structural and Demographic Business Statistics (2012).

13 ibid.

Exhibit 10 – Australia has a reasonable number of manufacturing SMEs but very few large firms



Note

Australia has numerous small firms in part as a result of a system which encourages sole traders to incorporate.

Source: OECD Structural and Demographic Business Statistics (2012)

Automation, capital intensity and Industry 4.0: The gap between Australian manufacturing productivity and that of our peers can be partially explained by differences in capital intensity, automation and the uptake of Industry 4.0 technologies and processes. A number of key commentators in Australia have suggested that Australian firms lag in their capital investment and intensity.[14] 'Industry 4.0' refers to the suite of digital technologies augmenting industrial processes, including '1) the rise of data volumes, computational power and connectivity; 2) emergence of business-intelligence capabilities; 3) new forms of human-machine interactions; 4) improvements in transferring digital instructions to the physical world, e.g. 3D printing'.[15] Studies in international contexts have indicated potential productivity gains of up to 25% in excess of conversion costs, and an overall gain of 5–8% from the adoption of Industry 4.0 technology.[16] While similar studies are yet to be completed in an Australian context, and we do not have good-quality data on the uptake of Industry 4.0 in Australia versus other countries, the possibilities enabled by Industry 4.0 map closely with the sources of competitiveness identified by our analysis. The greater integration of digital production, automation and data analysis will improve production processes and allow more distinct value offerings.

> Australia needs to appeal to international purchasing managers.

2.3 LIFTING COMPETITIVENESS BY INCREASING VALUE DIFFERENTIATION

2.3.1 Overview of value differentiation strategies

In addition to making better use of potential cost advantages in high-skill labour, Australian manufacturers can compete by offering differentiated sources of value. This is most often driven by some kind of technology or design innovation that results in materially improved performance or an enhanced bundled service offering that makes products easier to use, upgrade or tailor to customer needs.

2.3.2 International customers care about value differentiation including technical leadership and service offering

To understand sources of value to customers beyond product cost, we asked a panel of approximately 30 industry experts and international purchasing managers to identify and weight other factors that influenced the selection or procurement of a final good or intermediate component from Australia. These factors included product innovation, design, reputation, flexibility and service support (see Exhibit 11).

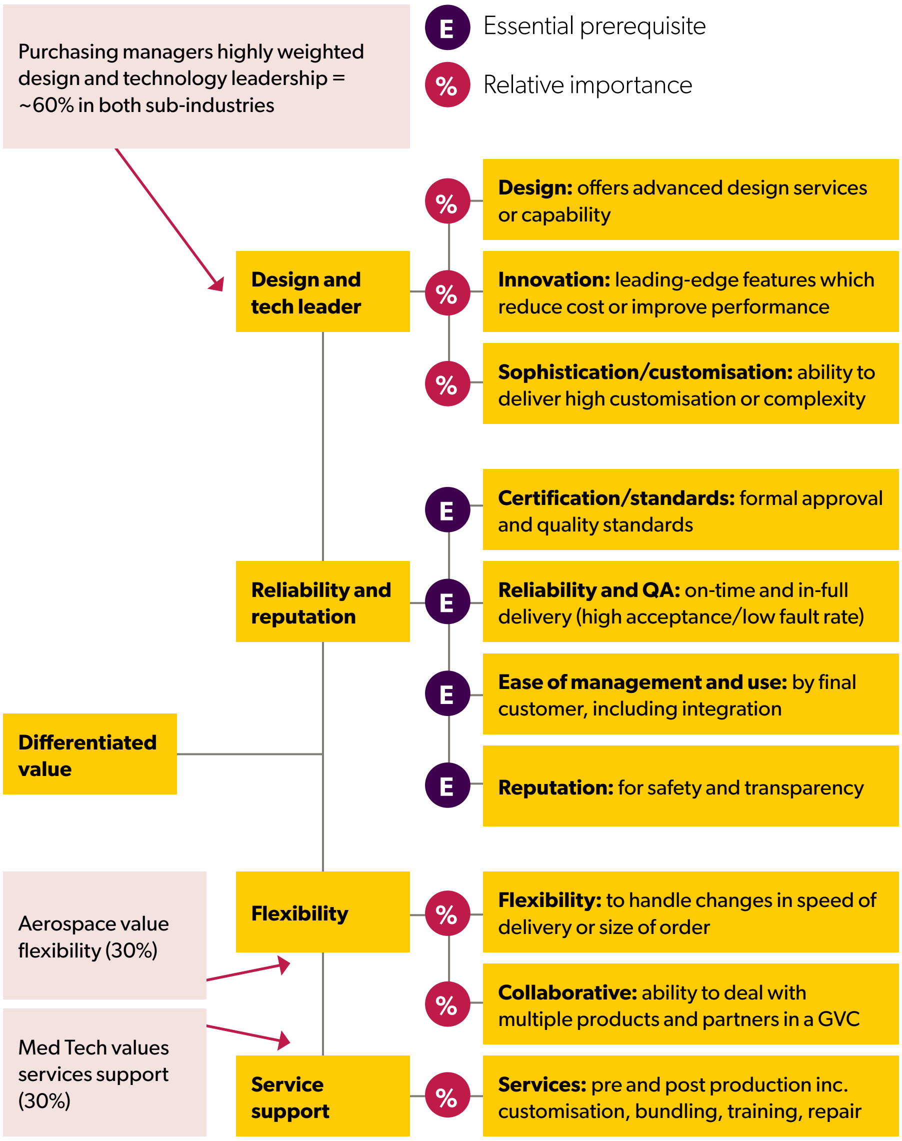
Purchasing managers and customers identified technology and performance leadership as the most important factors other than cost, with an approximate 60% weighting collectively. With a small domestic market and cost disadvantages, Australia needs to appeal to international purchasing managers with innovative design and leading technology across a smaller-scale and niche product line. Flexibility and services were respectively considered key for aerospace and medical technology customers, with an approximate 30% weighting collectively.

14 AiG and AAMC have commented that Australian manufacturers urgently require capital investment and upgrades.

15 McKinsey & Company (2015), *Manufacturing's Next Act*. Available at: http://www.mckinsey.com/business-functions/operations/our-insights/manufacturings-next-act

16 Boston Consulting Group (2015), *Industry 4.0: The future of productivity and growth in manufacturing industries*. Available at: https://www.bcgperspectives.com/content/articles/engineered_products_project_business_industry_40_future_productivity_growth_manufacturing_industries/

Exhibit 11 – International purchasing managers report that technical leadership and the availability of service support are the main reason they buy Australian products



Key insights and quotes

- **Aerospace:** *"Companies need to develop solutions targeting real problems facing the industry"*
- **Aerospace:** *"Value to end user is critical in competitive aircraft market, e.g. weight reduction can be worth far more than the component itself"*
- **Med Tech:** *"Hospitals of tomorrow will want equipment customised to their information systems"*
- **Aerospace:** *"Certification to required standards is a given"*
- **Med Tech:** *"This is essential given poor patient outcomes"*
- **Aerospace:** *"This is table stakes" "There are high-costs to faults and schedule disruption"*
- **Med Tech:** *"Purchasing managers care most about product safety, given risks of poor patient outcomes"*
- **Aerospace:** *"Assessing bid proposals ultimately boils down to trust"*
- **Aerospace:** *"Ability to ramp up production quickly is of great value but rarely need to ramp down"*
- **Aerospace:** *"The ability for suppliers to work with other suppliers makes things much easier for the prime or OEM"*
- **Med Tech:** *"Final customer cares a lot about simplicity in accessing services and managing product. This is a key differentiating factor."*

Notes:
For aerospace, relevant experts were international purchasing managers in OEMs and primes. For med tech, relevant experts were final customers and exporters' view of what mattered to their final customers.
Source: Interviews

2.3.3 Australian companies do not spend highly on R&D or employ a large share of high-skill workers

Despite the clear importance of technical leadership, Australian companies do not spend a lot on R&D and, compared with the US, many Australian manufacturing sub-industries do not employ a large share of high-skill workers.

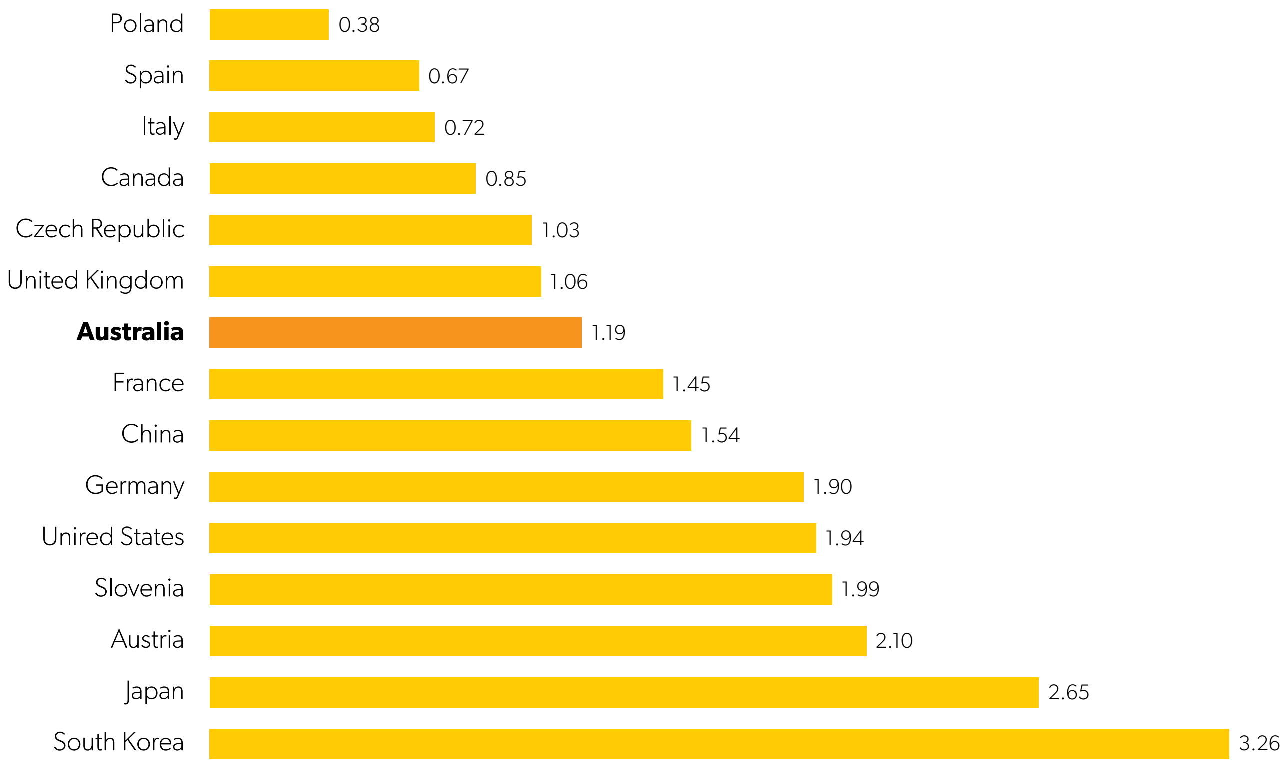
While Australian businesses spend more on R&D as a proportion of GDP than peers like Canada or the United Kingdom (UK), Australian firms index well below many key OECD competitors (see Exhibit 12). For example, Australian businesses' expenditure on R&D is the equivalent of 1.19% of GDP, while in Germany it is 1.90%, US 1.94%, Japan 2.65% and South Korea 3.26%.

In a number of manufacturing sub-industries, Australia has a low utilisation of high-skill workers relative to the US (see Exhibit 13). The proportion of workers with higher skills is larger in the US than in Australia in computer and electronics manufacturing (by 46 ppt), photographic and optical manufacturing (by 34 ppt), and aircraft manufacturing (by 31 ppt). These skill deficits are particularly stark given that Australia has a significant cost advantage in higher-skilled workers: as much as 40% in some industries. Given our wage advantage in higher-skill roles, shifting a larger proportion of our employment into non-production roles and more skill-intense sub-industries represents an opportunity to improve competitiveness and increase productivity.

Exhibit 12 – Australian business expenditure on R&D is weaker than that of many key OECD competitors

Business expenditure on R&D (BERD) as a proportion of GDP

%, 2013

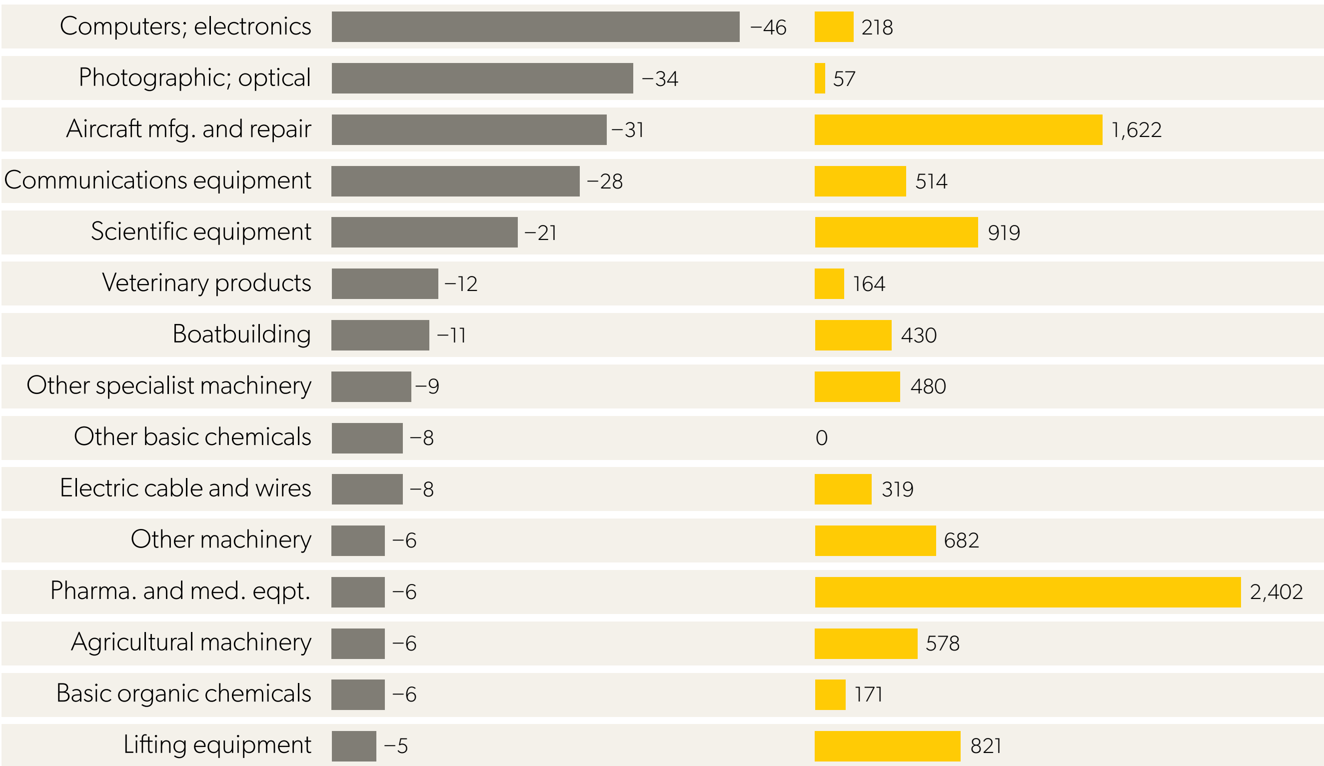


Source: OECD Main Science and Technology Indicators

Exhibit 13 – A number of sizeable manufacturing industries in Australia have large skill gaps compared with US equivalents, implying significant upside from boosting skill levels

Top 15 advanced manufacturing sectors by skills gap
Delta % in proportion of high skill workers

Australian size
2014 GVA, A$ millions



Source: ABS table builder OCCP – 1 Digit Level by INDP – 4 Digit Level; ABS 8155.0; BLS statistics; AlphaBeta/McKinsey analysis

2.3.4 Government and industry-led 'ingredients' can support technical leadership, but current R&D programs are not optimally designed

To understand which government and industry-led actions matter most to companies developing their technology and performance, we analysed 50 successful Australian aerospace and medical technology companies. Specifically, we looked at whether public research, government support for commercial R&D, collaborative R&D with universities, industry collaboration, government procurement, private financing or policy changes materially contributed to the development of their initial position of technology or performance leadership (see Exhibit 14).

This firm-level analysis of Australian success stories revealed five key ingredients that have helped to create technology leadership in Australia's top firms: public research funding, commercial R&D support, university collaboration, capability transfer from another industry, and strategic government demand. However, despite the prevalence of these 'success ingredients', there were significant differences across the two sub-industries. In aerospace, 44% of successful exporters had technology or performance leadership support from capability transfer, 28% from university collaboration, 20% from strategic government procurement and 20% from Australian content requirements (see Exhibit 15).[17] By contrast, in medical technology, 60% had technology or performance leadership support from university collaboration, 56% from R&D grants or tax incentives, and 44% from research grants.[18]

17 AlphaBeta/McKinsey analysis of 50 firms, using expert interviews, company websites and press search.
18 ibid.

2 SECTOR COMPETITIVENESS DIAGNOSIS

Exhibit 14 – To understand what enables technical leadership, we analysed 50 successful Australian aerospace and med tech manufacturers

Question: what materially contributed to the firm developing the technology that made it successful?

Public research	Fundamental research grant	Was there an original grant for fundamental research (e.g. from ARC, NHMRC) that materially contributed to development?
Govt support for commercial R&D	R&D tax incentive	Did an R&D tax incentive materially contribute to development?
	Targeted R&D	Was there a targeted R&D or other grant that materially contributed to development?
Collaborative R&D	University/institute collaboration	Was there a relationship with a university or a research institution (CSIRO, CRC) that materially contributed to development?
	University talent spin-out	Was there a talent spin-out from a university or research institute that materially contributed to development?
Industry collaboration	Cluster	Did a cluster or partnership materially contribute to development?
	Coordination	Was there direction coordination by an industry body that contributed to development?
	Firm spin-out	Did the development come as a spin-out from a local or foreign firm?
	Capability transfer	Did a capability transfer from another industry or company materially contribute to development?
Govt procurement/ participation	Government procurement	Was the development materially supported by a government procurement contract?
	Australian content requirements	Was the development materially supported by Australian or SME participation requirements?
Private financing	Foreign direct investment	Was the development initially funded by foreign direct investment?
	Venture capital	Did the idea receive early-stage/VC funding?
	Anchor private contract	Was the development materially supported by an anchor private contract?
Policy or other	Regulatory change	Was there a regulatory change that supported the development?
	FTA/Export	Did an FTA or export assistance unlock a critical market to enable scale in development?
	Other	Other government or philanthropic assistance

Source: AlphaBeta/McKinsey analysis

Med Tech

Aerospace

Companies

Exhibit 15 – Technical leadership in Australian manufacturing firms was enabled by government R&D support and procurement policies

What factors materially impacted development of technology	Aerospace Proportion of firms	Med Tech Proportion of firms
Fundamental research grant	0%	44%
R&D tax incentive	0%	52%
Targeted R&D	12%	56%
University/institute collaboration	28%	60%
University talent spin-out	8%	28%
Cluster	20%	20%
Coordination	4%	0%
Firm spin-out	0%	20%
Capability transfer	44%	4%
Government procurement	20%	12%
Australian content requirements	20%	4%
Foreign direct investment	8%	0%
Venture capital	8%	56%
Anchor private contract	20%	24%
Regulatory change	0%	12%
FTA/Export	8%	16%
Other	28%	8%

Frequently cited
Less cited factor

In aerospace, the biggest enablers of technology/ performance leadership were government/ private demand, research collaboration and capability transfer from another industry.

In med tech, the biggest enablers of technology/ performance leadership were research grants, commercial R&D incentives, university collaboration and VC funding.

Different innovation models in these sub-industries may explain the different factors. In aerospace, the innovation model relies on complex systems. In med tech, the innovation model relies on advances in science.

Source: Expert interviews; company websites; press search. AlphaBeta/McKinsey analysis

2 SECTOR COMPETITIVENESS DIAGNOSIS

The differences between the factors that contributed to success stories in each sub-industry are likely based on different models for innovation. Academic research has previously identified that sub-industries with different modes of innovation require different policy instruments to help overcome barriers and maximise spillover benefits.[19] Aerospace and medical technology have very different modes of innovation. The mode of innovation in aerospace requires the development of complex systems, which involves high levels of collaboration and high externalities. Potential policy instruments to encourage this mode of innovation include a secure source of demand and improved collaboration with universities. In contrast, the mode of innovation in medical technology requires the application of high-science-content technology, which involves high financing costs for high-risk efforts and the commercialisation of research. Potential policy instruments to encourage this mode of innovation include support for basic research, support for business-led R&D, venture capital, and improved collaboration with universities.[20]

This section has identified the importance of collaboration between research and universities to drive technical excellence, and government support for both basic research and business-led R&D in promoting technical excellence in some sub-industries.

Low rates of industry–research collaboration

International data suggests Australian manufacturing could improve its industry–research collaboration, which would help to drive technical excellence among firms.[21] Australia ranks poorly on OECD measures of industry–research collaboration.[22] However, a number of commentators have noted problems with these statistics. Some have taken issue with the definition of 'innovation-active' businesses. Others have suggested the ranking is driven, in part, by a long tail of sole traders and micro-businesses (0–4 employees) that are not well suited to collaborative research projects with large research organisations due to a mismatch in size and capacity. Similarly, it is argued that the ease of incorporation in Australia has driven many sole-trader service providers to register as manufacturing companies. As such, it is argued, Australia's ranking reflects the make-up of Australia's manufacturing sector rather than underperformance in collaboration.

Instead, we can gain insights from domestic data (not just research) on all businesses collaborating with any institution. If we exclude micro-businesses, we see weak collaboration among small businesses and improved levels of collaboration among medium-sized and larger businesses. Specifically, 18.6% of manufacturing firms with 5–19 employees are estimated to collaborate for the purpose of innovation with any other entity (including other firms and research institutions), compared to 18.4% of firms with fewer than five employees, and 19.7% of all manufacturing firms.[23] Larger firms collaborate significantly more, with 24.6% of firms with 20–199 employees and 34.2% of firms with 200+ employees collaborating with other entities, including researchers. Further, in 2013–14, only 9.5% of companies registering projects under the R&D Tax Incentive program indicated they had collaborated with another organisation.[24] The relatively low rate of collaboration among small businesses is problematic given that the vast majority of Australian manufacturing firms are small.

Sub-optimal design of government support for R&D

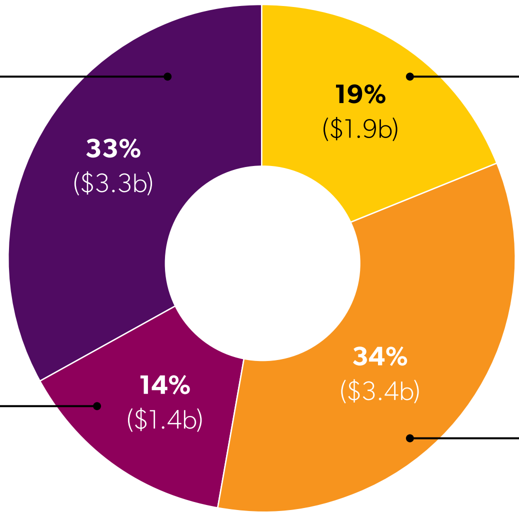
While the importance of government support for R&D is clear, that support is not currently optimally designed to meet the intended objectives. Governments support R&D because "market failures generally cause enterprises to underinvest in research ... [where] the private rate of return to R&D investments is lower than the social rate of return".[25] The Australian Government is providing $10.1 billion in support of research and experimental development in 2016–17, to be delivered via 15 government departments and agencies. This expenditure includes $3.3 billion (33%) for R&D led by businesses, $1.9 billion (19%) for R&D led by government bodies, $1.4 billion (14%) for research led by multiple sectors, and $3.4 billion (34%) for research led by higher education institutions (see Exhibit 16).

19 Martin, S. (2000), 'The nature of innovation market failure and the design of public support for private innovation'. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.196.7452&rep=rep1&type=pdf
20 ibid.
21 Department of Industry (2016), 'R&D Tax Incentive Review Issues Paper', Canberra. Available at: https://www.business.gov.au/~/media/Business/RDTI/Review/Research-and-Development-Tax-Incentive-Issues-Paper-PDF.ashx?la=en
22 OECD (2016), 'Innovation Statistics and Indicators'. Available at: http://www.oecd.org/innovation/inno-stats.htm#indicators
23 ibid.
24 Department of Industry (2016), op. cit.
25 OECD (2003), 'Tax Incentives for Research and Development: Trends and Issues'. Available at: http://www.oecd.org/science/inno/2498389.pdf

Exhibit 16 – Technical leadership in Australian manufacturing firms was enabled by government R&D support and procurement policies

Australian Government support for R&D, by channel
Budget estimate 2016–17, % of total R&D expenditure

Aus Gov research
Higher education
Multi-sector
Business enterprise



Business-led research:
- R&D Tax measures (31%)
- Business innovation and other R&D (2%)

Australian Government-led research:
- CSIRO (8%)
- Defence Science & Tech Group (4%)
- Other Aust Gov (7%)

Multi-Sector-led research:
- NHMRC (Govt, Hospital) (2%)
- Other Health (2.5%)
- CRCs (1.5%)
- Rural (3%)
- Energy & Enviro (3%)
- Other (2%)

Higher education-led research:
- ARC (7%)
- NHMRC (University) (6%)
- Performance-based block funding (20%)

Source: 2016–17 Australian Government 'Science, Research and Innovation' Budget Tables

Government support for business-led R&D

This section has outlined the importance of government support for business-led R&D in many of Australia's success stories. The Australian Government's primary form of support for business-led R&D is the $3.3 billion R&D Tax Incentive scheme (see Exhibit 16), which is complemented by other smaller programs to support business innovation. These include CRCs and CRC-Ps, Accelerating Commercialisation, the new BRII pilot program[26] and the ARC Linkage Projects[27] program. However, the current mix of funding types and the design of the R&D Tax Incentive does not maximise the achievement of objectives including:

- Encouraging investment by firms in R&D with different risk profiles (both medium and higher risk) and different time horizons (both short- and longer-term)
- Ensuring that minimal government funding is provided to R&D activity that would have occurred without the incentive.

The funding mix is not likely to maximise investment by firms in R&D across different risk profiles, spillover benefits and time horizons.

26 The Business Research and Innovation Initiative provides grants to eligible businesses to address five selected challenges. For further information, see: http://www.minister.industry.gov.au/ministers/hunt/media-releases/grants-help-businesses-meet-public-sector-challenges

27 The Australian Research Council's Linkage Projects provide funding to eligible organisations to support R&D initiatives that are undertaken to acquire new knowledge, and that involve collaboration and risk or innovation. For further information, see: http://www.arc.gov.au/linkage-projects

Australia is an outlier when it comes to the mix of assistance it provides for business-led R&D. This assistance can be broadly categorised as 'direct' or 'indirect'. The OECD defines direct assistance as the provision of grants and payments for R&D services, and indirect assistance as the provision of tax incentives including allowances and tax credits.[28] A high proportion (~90%) of the Australian Government's assistance for business-led R&D is provided via indirect means, primarily through the R&D Tax Incentive (see Exhibit 17). This weighting toward indirect assistance is much higher than in other OECD countries such as Germany (0%), the US (27%) and the UK (50%). A peer country with a similar level of indirect assistance, Canada (at 86%), recently opted to streamline its tax incentive and transition to a higher proportion of direct support.[29]

The potential challenge with the existing funding mix is that different types of support for business-led R&D, namely direct assistance versus indirect assistance, are designed to respond to different market failures and stimulate different types of R&D expenditure.[30] Specifically, the OECD suggests that "tax credits are used mostly to encourage short-term applied research, while direct subsidies are directed to more long-term research"[31] and that tax-based measures, "unlike direct funding of business R&D … do not typically allow governments to direct business R&D into areas with high social returns (e.g. technological fields with significant spillovers)".[32] There are still good reasons to use indirect forms of assistance, such as tax credits, allowing markets to determine the allocation of R&D investment and administrative simplicity. However, the current mix may limit the potential for government to incentivise and promote investment by firms in longer-term, higher-risk R&D that might have high spillover benefits and deliver similar successes to those outlined in this Plan.

The current design of the R&D Tax Incentive scheme does not insure against public expenditure on activity that would have happened even without that public support (infra-marginal activity). Analysis conducted by the Centre for International Economics on the R&D Tax Incentive found additionality[33] of 0.3–1.0 per dollar of tax forgone for large companies and 0.9–1.5 per dollar of tax forgone for SMEs.[34] The R&D Tax Review conducted by Finkel, Ferris and Fraser (hereafter 'the Review') noted that "these magnitudes imply that around 10–20 percent of the total R&D registered would not be undertaken in the absence of the program".[35] These figures do not imply strong additionality. While the Review acknowledges that there "are limits in the ability to target additional R&D in a volume-based scheme", there are ways to improve the effectiveness of the scheme, which are explored further in Section 4.

> The OECD suggests that 'tax credits are used mostly to encourage short-term applied research, while direct subsidies are directed to more long-term research'.

28 OECD (2003), 'Tax Incentives for Research and Development: Trends and Issues'. Available at: http://www.oecd.org/science/inno/2498389.pdf

29 OECD (2012), Science, Technology and Industry Outlook, 'Tax incentives for R&D and Innovation'. Available at: https://www.oecd.org/media/oecdorg/satellitesites/stie-outlook/files/policyprofile/STI%20Outlook%2012_%20PP%20Actors_RD%20Tax%20incentives.pdf

30 OECD (2010), 'R&D Tax incentives: rationale, design, evaluation'. Available at: http://www.oecd.org/innovation/policyplatform/48141363.pdf

31 ibid.

32 OECD (2003), 'Tax Incentives for Research and Development: Trends and Issues'. Available at: http://www.oecd.org/science/inno/2498389.pdf

33 Additionality refers to the increased private investment in R&D that occurs due to the program. See: Finkel, Ferris, Fraser (2016), *Review of the R&D Tax Incentive*. Available at: https://www.business.gov.au/assistance/research-and-development-tax-incentive/review-of-the-randd-tax-incentive

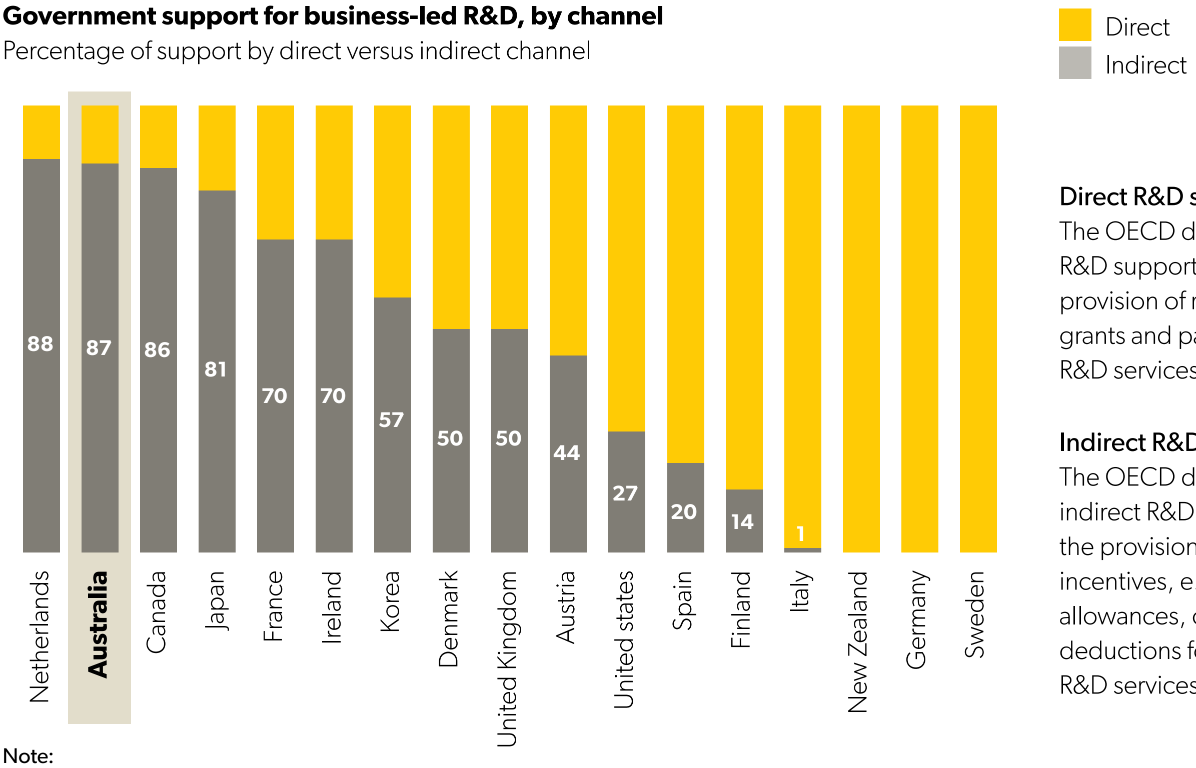
34 Centre for International Economics (2016), *R&D Tax Incentive Programme Review.*

35 Finkel, Ferris, Fraser (2016), *Review of the R&D Tax Incentive*. Available at: https://www.business.gov.au/assistance/research-and-development-tax-incentive/review-of-the-randd-tax-incentive

Exhibit 17 – Australia is an outlier in how it publically supports business-led R&D, with ~90% of funding provided via indirect channels

Government support for business-led R&D, by channel

Percentage of support by direct versus indirect channel



Direct R&D support
The OECD defines direct R&D support as the provision of research grants and payment for R&D services

Indirect R&D support
The OECD defines indirect R&D support as the provision of tax incentives, e.g. tax allowances, credits, deductions for R&D services

Note:
Sample of 17 of 35 countries shown here.
Source: OECD R&D Tax Incentives Indicators, based on 2013 OECD-NESTI data collection on tax incentives support for R&D expenditures and OECD, National Accounts and Main Science and Technology Indicators, 15 December 2014; AlphaBeta/McKinsey analysis

Alignment between public research and business-led R&D

The relationship between public research funding and commercial research could be stronger, in part through increased collaboration. While there are many categories of public research funding, with different societal and economic objectives, a high-level comparison of public research and business-led R&D indicates weak overlap in the areas of expenditure (see Exhibit 18). For example, 10.4% of public research funding (including for research led by not-for-profit, higher education and government institutions) is spent on engineering, versus 39.7% of business-led R&D.[36] Similarly, medicine and health sciences receive 28.8% of public research expenditure, versus 6.0% of business-led R&D expenditure. There are good reasons for this, including Australia's historic research strengths and the societal benefits associated with advances in health care. However, Australian medical technology/pharmaceutical exports account for a significantly smaller share of overall exports – implying a weaker relationship between research investment and our ability to commercialise discoveries in this area.[37]

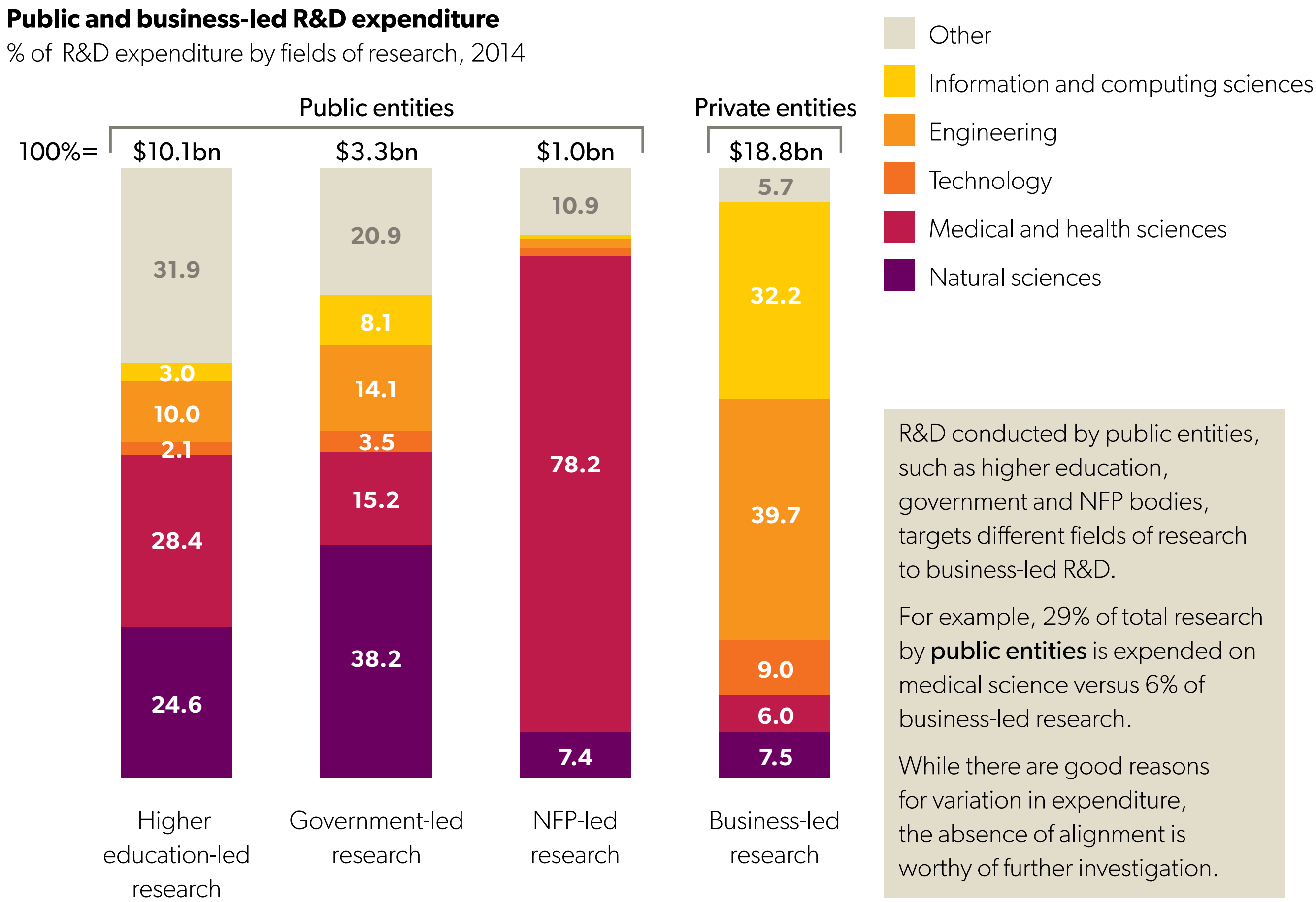
This Sector Competitiveness Plan does not consider whether this alignment is problematic. Further analysis could be undertaken in subsequent plans. However, we note that some other countries allocate funds more widely, to sectors with potential for commercial growth. For example, South Korea has focused more explicitly on advanced manufacturing. Other small countries adopt 'fast follower' strategies in some sectors, with a focus on translational research.[38] The weak alignment in Australia could be explained, in part, by collaboration rates between research and industry.

36 ABS series 'Research & Experimental Development' 8104.0 (Business), 8109.0 (Government & Private NFP), and 8111.0 (Higher Education Institutions).

37 Australian Technology Network/Ai Group (2015), *Innovate to Prosper: Ensuring Australia's Future Competitiveness through University-Industry Collaboration*. Available from: https://www.atn.edu.au/siteassets/publications/atninnovateprosper.pdf

38 The Government of the Republic of South Africa (2002), South Africa's National Research and Development Strategy, Pretoria. Available at: http://www.cepal.org/iyd/noticias/pais/0/31490/Sudafrica_Doc_1.pdf

Exhibit 18 – There is minimal overlap between the fields of research targeted by public research entities and commercial entities



R&D conducted by public entities, such as higher education, government and NFP bodies, targets different fields of research to business-led R&D.

For example, 29% of total research by **public entities** is expended on medical science versus 6% of business-led research.

While there are good reasons for variation in expenditure, the absence of alignment is worthy of further investigation.

Note:
R&D expenditure includes capital expenditure, scholarship and labour costs, experimental product development etc.
Source: ABS series 8111.0 'Research & Experimental Development, Higher Education Institutions'; ABS series 8104.0 'Research & Experimental Development, Business'

2.3.5 Service-enhanced manufacturing is another key source of value

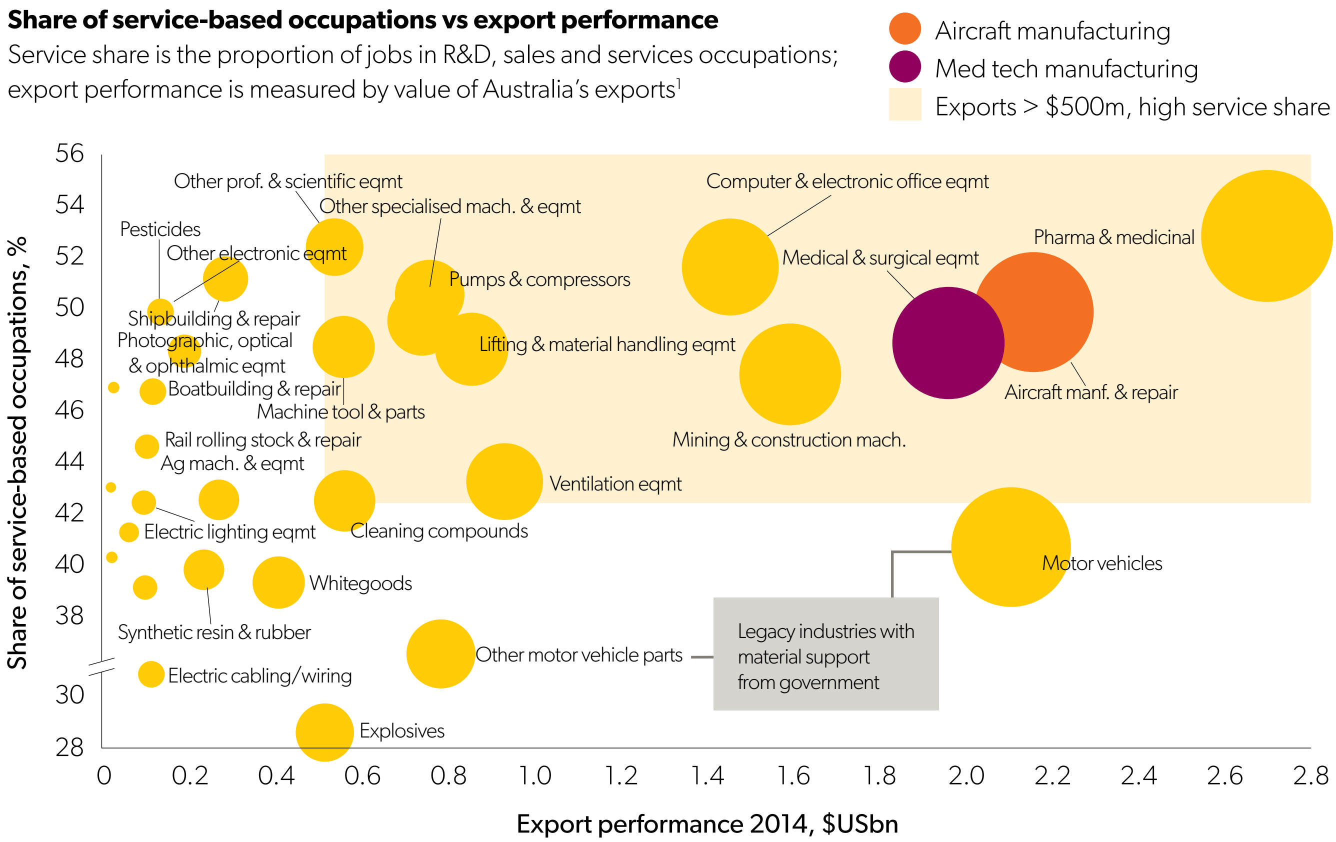
Another avenue to increase competitiveness is to provide customers with value-adding services associated with manufactured goods. Servitisation is the provision of services to clients by manufacturing firms[39], with services typically supporting or complementing products and helping manufacturers to establish long-term relationships with consumers. The shift has comprised both (i) structuring sales to focus on customer needs – for example, providing a capability or solution rather than selling a piece of equipment; and (ii) bundling services that are typically conducted by the customer or third parties in the outbound supply chain – for example, training, support, repairs, data monitoring and analytics. In aerospace, Rolls-Royce has moved to offering its customers 'power by the hour' – monitoring engines remotely, conducting repairs, and providing training and support to local engineers. The company recently reported

39 Visnjic, I. and Van Looy, B. (2012), *Servitization: Disentangling the Impact of Service Business Model Innovation on Manufacturing Firms Performance*, ESADE Business School Research Paper, No. 230. Available at: http://proxymy.esade.edu/gd/facultybio/publicos/1393004444807Servitization_Disentangling_the_impact_of_service_business_model_innovation_on_the_performance_of_manufacturing.pdf

that nearly half of its revenue (49%) is derived from services. This servitisation of manufacturing reduces the impact of high production costs by elevating the need for new skill sets in customer engagement, ICT, data management and analytics. It also encourages the customer to explicitly consider the lifetime benefit of the combined product–service offering.

Australia's strength in service delivery and our highly skilled workforce make us well placed to increase the share of non-production activity such as design, engineering, sales and value-added services. Australian manufacturing has enjoyed export success where firms have transitioned to service-enhanced manufacturing. Exhibit 19 suggests that, apart from legacy industries that have enjoyed material support from the government, such as the automotive industry, the sub-industries that have the highest share of non-production occupations have exhibited the strongest export performance.[40]

Exhibit 19 – Australian manufacturing industries that have created non-production capabilities exhibit the strongest export performance



1. 42 sub-industries defined by the ABS as an interim definition for advanced manufacturing

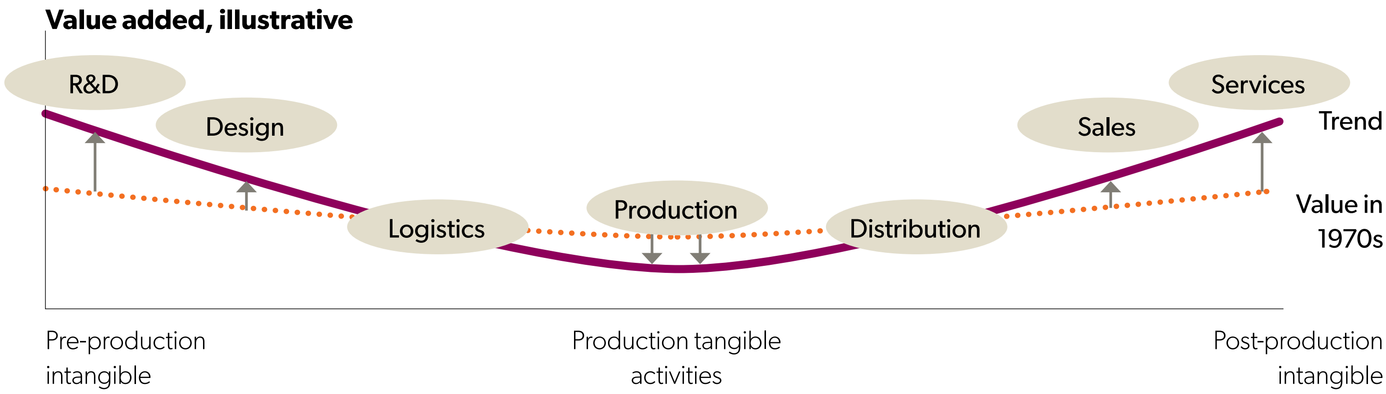
Note:
Bubbles represent size of Australia's exports. The chart draws correlation between share of services and export performance but not a causal relationship.
Source: UN Comtrade; ABS. AlphaBeta/McKinsey analysis

40 UN Comtrade, Australian Bureau of Statistics, AlphaBeta/McKinsey analysis.

Likewise, some sub-industries are making the transition to a service-enhanced manufacturing model faster than others, as can be seen in the comparison of medical technology and aerospace. Here, medical technology is growing at a faster rate in non-production roles such as design (45% growth over 2006–11), sales (40% growth) and services (26% growth). In aerospace, employment is declining fastest in service-based occupations like design, sales and after market services (see Exhibit 20).[41]

A comparison to the US is instructive and reveals the differential performance of the sub-industries. Compared to the US, Australia is relatively weak in R&D and design jobs in aerospace, but on par in medical technology (see Exhibit 20).[42] Likewise, Australian medical technology is transitioning more quickly to service-based occupations than in the US. However, in aerospace, Australia is losing jobs in these parts of the value chain faster than the US (see Exhibit 21).[43]

Exhibit 20 – Compared to the US, Australian manufacturing is relatively weak in R&D/design in aerospace but stronger in medical technology



Proportion of jobs along value chain, % total industry (estimated), 2011

	Design	Logistics	Production	Distribution	Sales	Services
Aerospace						
AUS	8%	4%	36%	4%	9%	38%[1]
US	13%	7%	46%	8%	6%	20%
Med Tech						
AUS	9%	5%	41%	15%	15%	25%
US	7%	6%	48%	7%	13%	18%

1 High share of services in aerospace due to local maintenance and repair of Australian domestic fleets and low levels of domestic production.

Source: Curve adapted from: 'Interconnected economies benefiting from global value chains', OECD 2013; Data for estimation drawn from ABS Census (2011); US BLS (2014); Calculated by allocating occupations to parts of the value chain at 4-digit occupation level; AlphaBeta/McKinsey analysis

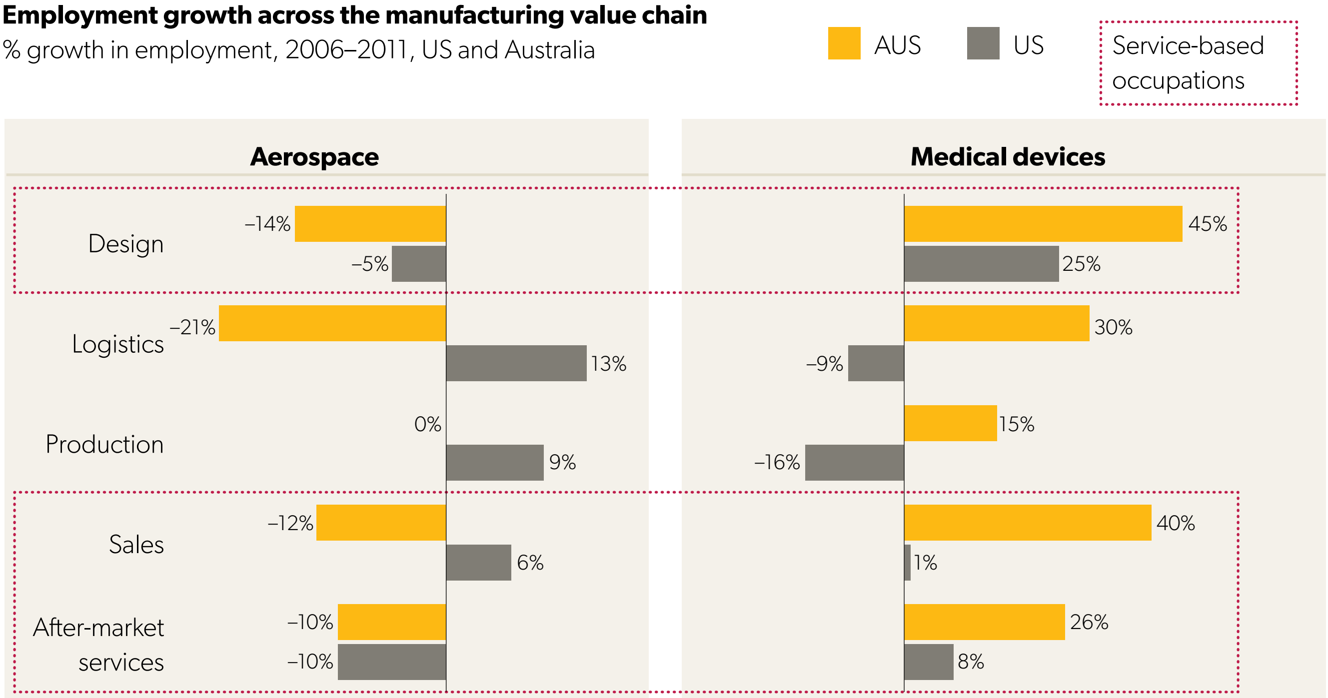
41 Australian Census (2006 and 2011). Calculated by portioning employment at 4-digit occupation level to the 4 digit industry.

42 Curve adapted from: 'Interconnected economies benefiting from global value chains', OECD 2013; data for estimation calculation drawn from ABS Census (2011); US BLS (2014); calculated by allocating occupations to different parts of value chain at the 4-digit occupation level. AlphaBeta/McKinsey analysis.

43 Australian Census (2006 and 2011), US Industry-Occupation matrix, by industry (2011), calculated by portioning employment at 4-digit occupation level to the 4-digit industry. AlphaBeta/McKinsey analysis.
Job loss in aerospace in both the US and Australia is in part due to the life cycle of the industry being related to demand cycles from Tier 1 companies.

Exhibit 21 – In Australia, med tech is transitioning to service-based occupations more quickly than the US, but aerospace lags behind the US

Employment growth across the manufacturing value chain
% growth in employment, 2006–2011, US and Australia



In **aerospace**, we are losing service-based jobs more quickly than in the US.

In **med tech**, Australia is transitioning more quickly than the US to service-based occupations.

Source: Australian Census (2006 and 2011). US Industry-Occupation matrix, by industry (2011). Calculated by portioning employment at 4-digit occupation level to the 4 digit industry. AlphaBeta/McKinsey analysis

2.4 LIFTING COMPETITIVENESS BY SHIFTING MARKET FOCUS

2.4.1 Overview of market focus

Thus far we have analysed Australian manufacturing's competitiveness in terms of its relative cost and its ability to offer differentiated value through product quality and associated services. But there is another dimension of competitiveness which relates less to 'how you compete' and more to 'where you compete'. Specifically, we examine whether Australia serves key export markets and whether it is integrated into global value chains (GVCs).

2.4.2 Australian manufacturing under-serves some key export markets, including for intermediate goods

Australian manufacturers must focus on high-potential export markets, including markets for intermediate goods, if they are to survive. The importance of clear export ambition and orientation to the sustainability of advanced manufacturing is well established. Empirical evidence demonstrates that productivity, profitability and wage benefits accrue to firms that export either directly or indirectly via suppliers to exporters.[44] Analysis of the export markets of Australian aerospace and medical technology manufacturing companies indicates some clear success in export market development and some areas where we do not capture our fair share of exports to key markets.

In aerospace, Australian exports of aircraft components to the US are very strong while our exports to key markets in Europe and Canada are underweight (relative to our total share of global imports in aerospace of 1.3%), as shown in Exhibit 22. While some of this is historic (e.g. after Boeing acquired Hawker de Havilland it stopped selling components to Airbus), these markets represent key leading aircraft manufacturing hubs (Original Equipment Manufacturers) and Tier 1 contractors and strongly imply untapped opportunities for Australian firms.

In medical technology, our exports to the UK and the US are strong, as shown in Exhibit 23, with a reasonable share in the small but growing Indian and Singaporean markets. However, our exports to the powerhouse markets of Germany, Japan and China are underweight, relative to our total share of global imports in medical technology of 0.7%.[45] The other key driver of market access is the progressive removal of trade barriers. For example, China's tariff on hearing aids and implantable medical devices has been removed under the China-Australia Free Trade Agreement.[46] Taking advantage of these opportunities to grow as further trade liberalisation occurs will be critical to claiming a growing share in emerging markets.

Global Value Chains

Firms try to optimise their production processes by locating the various stages across different sites. The past decades have witnessed a strong trend towards the international dispersion of value chain activities such as design, production, marketing and distribution. (OECD)

44 OECD and World Bank Group (2015), *Inclusive Global Value Chains: Policy options in trade and complementary areas for GVC Integration by small and medium enterprises and low-income developing countries*, p. 14. Available at: http://www.oecd.org/tad/tradedev/OECD-WBG-g20-gvc-report-2015.pdf

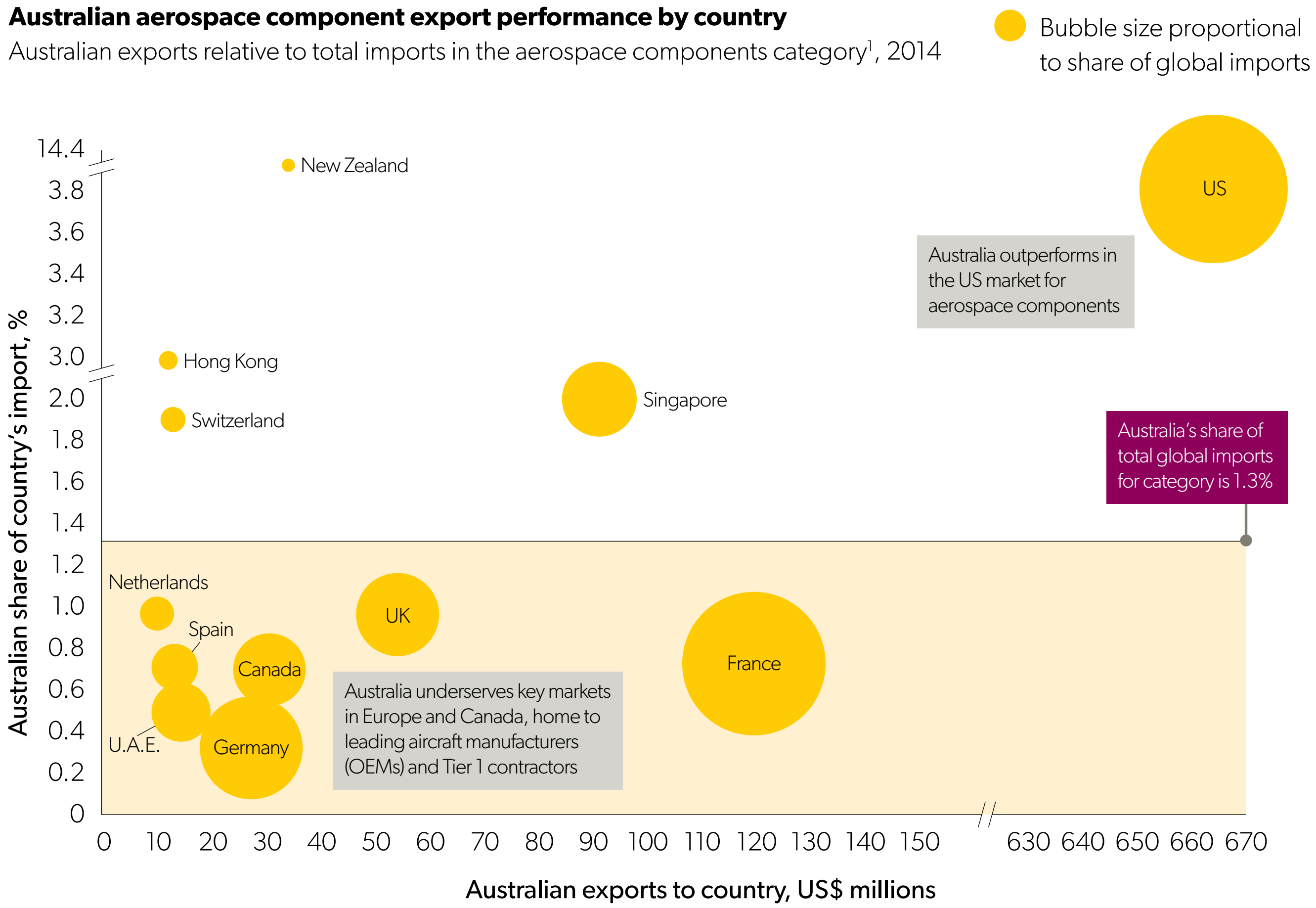
45 UN Comtrade. AlphaBeta/McKinsey analysis.

46 Department of Foreign Affairs and Trade (2016), 'China-Australia Free Trade Agreement Fact Sheet', Canberra. Available at: http://dfat.gov.au/trade/agreements/chafta/fact-sheets/Documents/fact-sheet-investment.pdf

Exhibit 22 – Australian aerospace component exports to the US are strong, but underperform in the key OEM markets of Europe and Canada

Australian aerospace component export performance by country

Australian exports relative to total imports in the aerospace components category[1], 2014



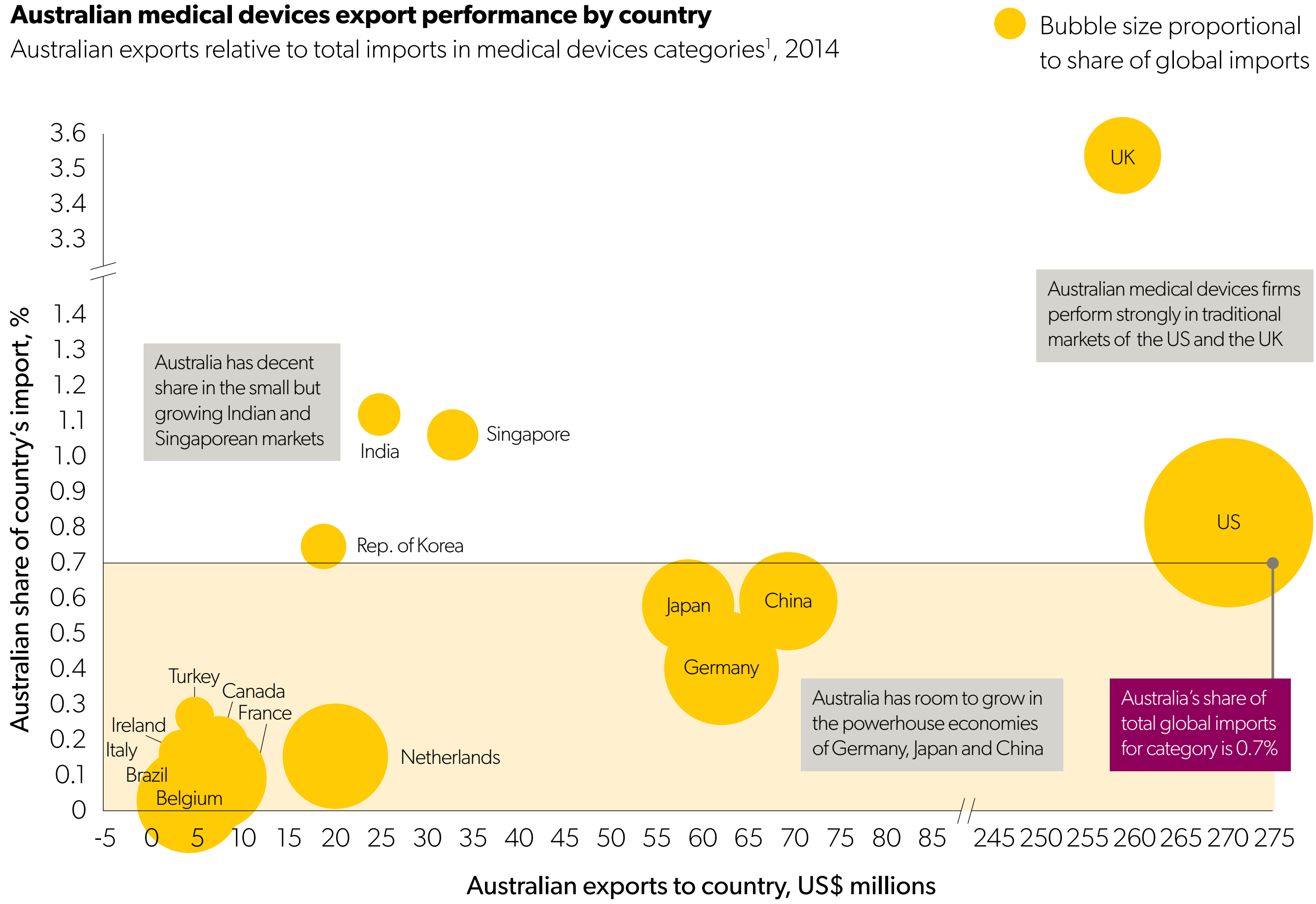
1 'Components' includes parts for aeroplanes, helicopters, spacecraft or spacecraft launch vehicles, corresponding to HS category 8803.

Source: UN Comtrade. AlphaBeta/McKinsey analysis

Exhibit 23 – Australian medical devices exports are still heavily skewed to traditional UK and US markets, with room to grow in Japan, Germany and China

Australian medical devices export performance by country

Australian exports relative to total imports in medical devices categories[1], 2014



1 Medical devices here defined as HS categories 9018 (instruments used in medical, surgical dental or vet. Sciences), 9020 (breathing apparatus), 9021 (orthopedics, implants, hearing aids) and 9022 (X-ray apparatus).

Source: UN Comtrade. AlphaBeta/McKinsey analysis

2.4.3 Australian manufacturing is weakly connected into global value chains

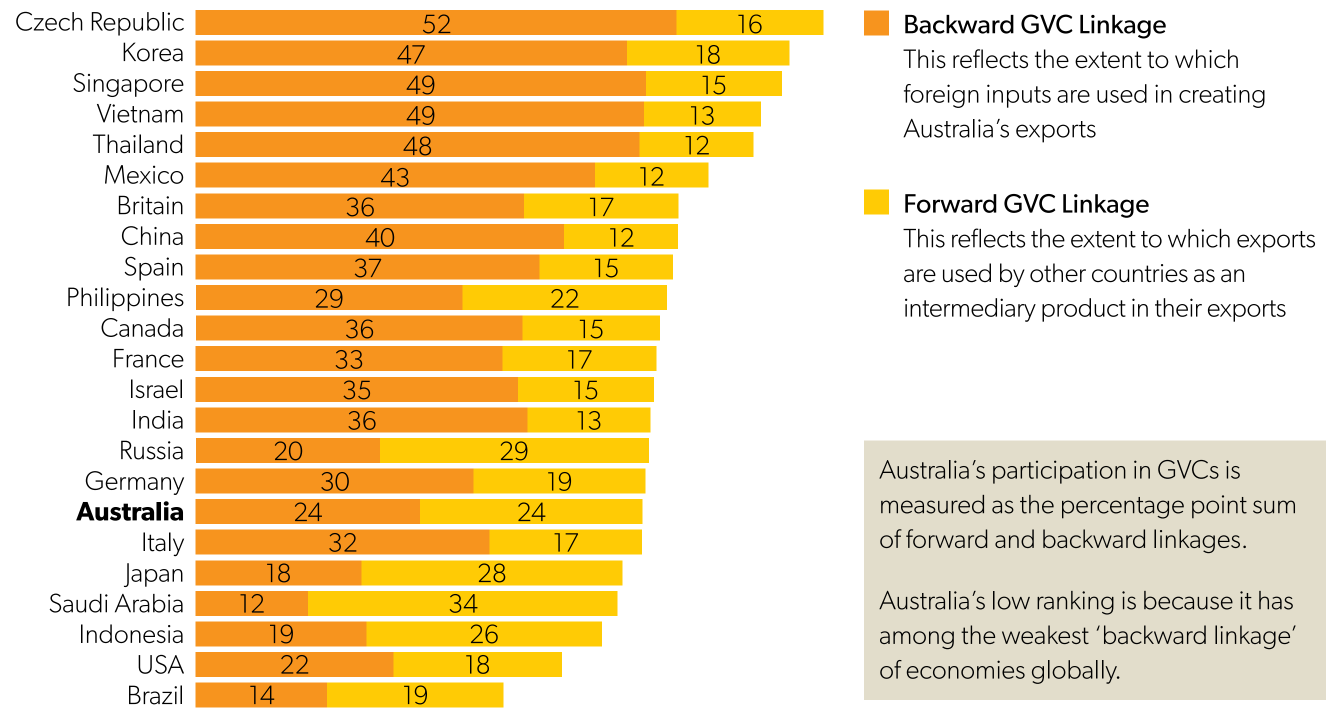
Manufacturing is increasingly occurring across global value chains, where the different functions of design, production, marketing and services occur across different countries. Analysis of Australia's backward and forward linkages helps us to understand the extent of our integration into global value chains. Backward linkages denote the use of foreign inputs to produce goods and services for export. Forward linkages denote the export of domestically produced goods or services to global companies further downstream.

Australia has among the weakest backward linkages of any major economy (see Exhibit 24). This suggests Australian manufacturers are missing opportunities to reduce costs, to drive innovation through the transformation of inputs, and sell into new markets. In particular, the OECD and World Bank argue that imports play an important role in the economic activity of a country by "making available 'world-class' inputs and capital goods … and providing incentives for firms to innovate as they adopt knowledge, ideas, know-how and best practices from abroad".[47]

Exhibit 24 – Australian manufacturing is weakly engaged in global manufacturing value chains, especially with low use of foreign inputs in our exports

Global value chain (GVC) participation in manufacturing

Backward: % of foreign value added in exports; Forward: % of domestic value added in foreign exports, 2011



Australia's participation in GVCs is measured as the percentage point sum of forward and backward linkages.

Australia's low ranking is because it has among the weakest 'backward linkage' of economies globally.

Source: UN Comtrade (2014). AlphaBeta/McKinsey analysis

47 OECD and World Bank Group (2015), *Inclusive Global Value Chains: Policy options in trade and complementary areas for GVC Integration by small and medium enterprises and low-income developing countries*, p. 15. Available at: http://www.oecd.org/tad/tradedev/OECD-WBG-g20-gvc-report-2015.pdf

> The AMGC defines ‘advanced manufacturing’ as the application of leading-edge technical knowledge and expertise to the creation of products, production processes and associated services for the purpose of sustaining high growth and customer satisfaction.

3 THE OPPORTUNITY FOR AUSTRALIAN MANUFACTURING

3 THE OPPORTUNITY FOR AUSTRALIAN MANUFACTURING

Manufacturing can be a force for growth in this country. We have gotten complacent in thinking about it as an old-fashioned industry of the past, but it is becoming obvious globally that advanced countries are fighting to become competitive in this sector.

Industry participant, AMGC consultation[48]

3.1 REDEFINING ADVANCED MANUFACTURING

Global manufacturing data confirms that the world's most competitive companies succeed by increasing value differentiation, improving market focus and optimising product cost. The characteristics used to gauge the success of companies were selected by identifying advanced features of production that were prevalent in the most successful firms, where success was defined in terms of productivity and profitability.[49] Exhibit 25 shows the characteristics that were more prevalent in the top 25% of firms versus the bottom 25% of firms.[50] For example, global firms in the top 25% for productivity, compared with the bottom 25% of firms, exhibit 1.16 times more capital efficiency, 1.50 times newer capital, 1.30 times more automation, 3.17 times higher R&D intensity, 1.75 times the patent portfolio, 1.06 times the wage levels, 1.12 times higher employee qualifications, 1.09 times the STEM skill intensity, and 1.08 times the share of services in revenue. This analysis redefines how we think about advanced manufacturing.

Redefining Advanced Manufacturing

Differentiation is a key factor to Australian manufacturing competitiveness.
This may be offering a product with an innovative design, or having an exceptional reputation for reliability and collaboration, or delivering outstanding services along the entire value chain of manufacturing, not only in production.

48 This comment was recorded during AMGC's consultation with industry members. It was made by the representative of a regional industry association.

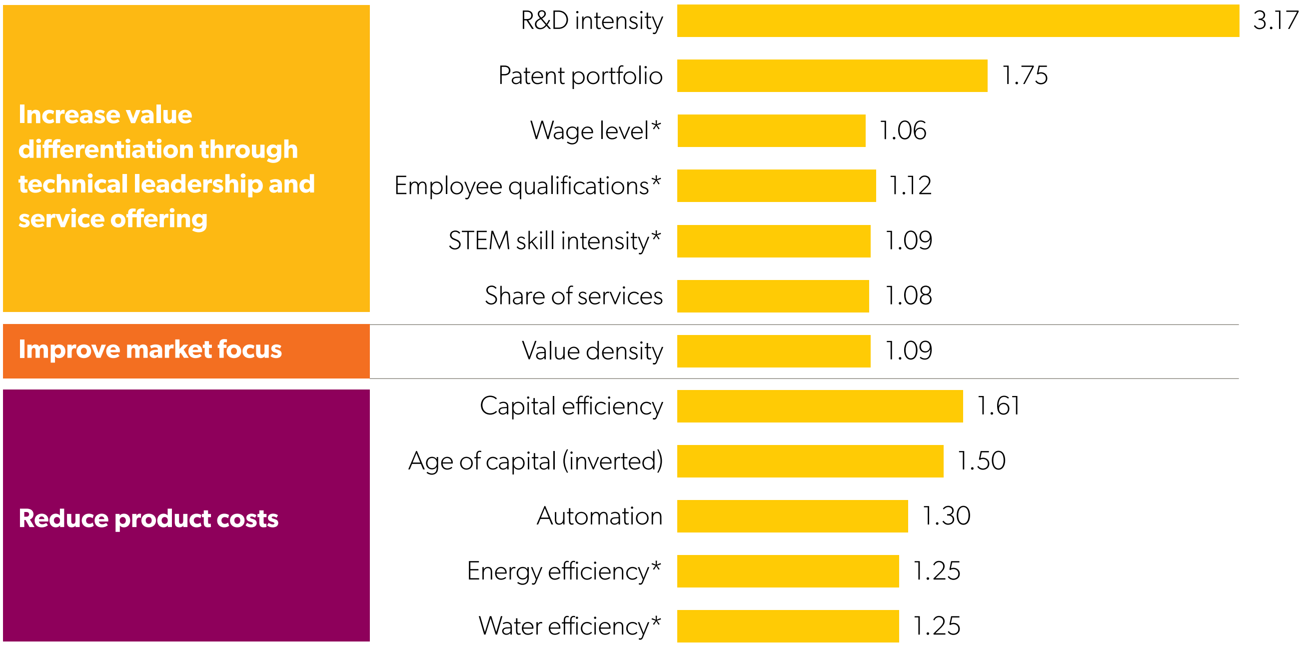
49 Productivity refers to total factor productivity and measures joint productivity of capital and labour. It is not directly observable, and was derived by the residual of the regression of gross value added against capital and labour. Profitability refers to gross margin.

50 Characteristics defined as:
R&D expenditure = ratio of R&D expenditure to total sales
Patent portfolio = number of patents by firms. Linked individual firms in Compustat to patents dataset
Wage levels = industry average wages weighted by the sales shares across industries by each firm
Employee qualifications = industry average of fraction of employees with bachelor's or post-graduate degree weighted by the sales shares across industries by each firm
STEM skill intensity = using O*Net classification of STEM occupations, found share of these occupations in total employment for each industry, and weighted them by the sales shares across industries for each firm
Capital efficiency = ratio of total sales to plant, equipment and machinery
Age of capital = accumulated depreciation/depreciation
Automation = indicator=1 if average growth in capital accumulation and labour productivity in the last 3 years is positive. 0 otherwise
Energy efficiency = used IO table to determine the $ of energy in a $ of sales. Weighted the industries by the sale shares across industries by each firm
Water efficiency = used IO table to determine the $ of water in a $ of sales. Weighted the industries by the sale shares across industries by each firm
Product value density = used 4-digit industry level trade data, calculated value of shipment/weight. Weighted the value densities by the sales shares across industries by each firm
Share of services = sales of services/total sales by industry.

Exhibit 25 – Analysis of >3,000 global manufacturing firms reveals that top performers increase value differentiation, improve market focus and reduce product costs

Ratio of median of more successful to less successful firms[1]

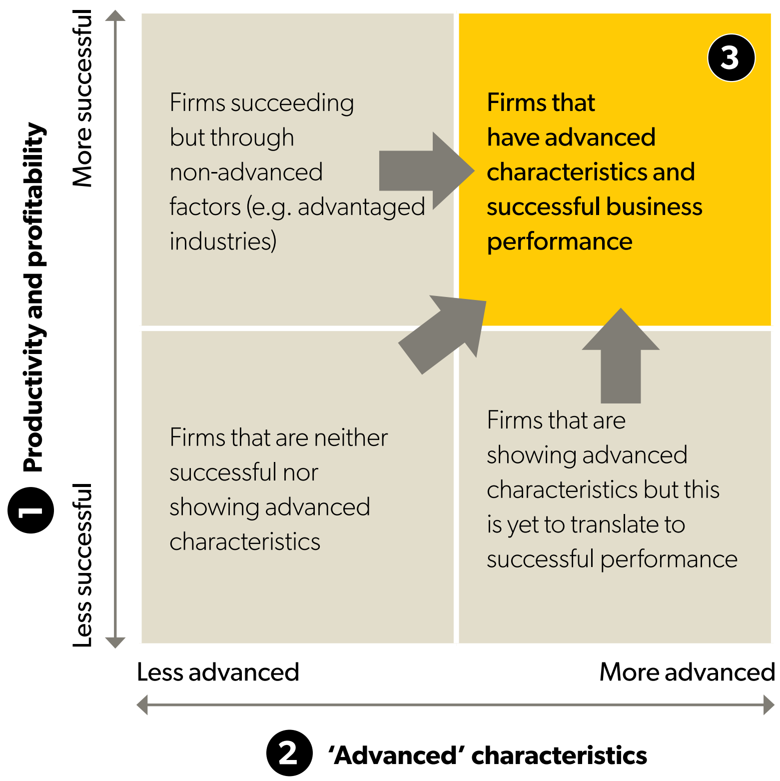
Average prevalence of characteristics in more successful firms where success is measured by total factor productivity and gross margin[2]



1 Where more advanced is classified as top quartile in the respective success metric and less advanced is bottom quartile.
2 Ratio shown is an average of the radio using total factor productivity and then gross margin.
* Metrics calculated using the average of the sub-industry classifications.
Source: Compustat, Alpha/McKinsey analysis

Exhibit 26 – AMGC's mission is to support all Australian manufacturers to succeed by adopting advanced characteristics

Spectrum of Australian manufacturing firms



We aimed to identify 'more advanced' firms by both the characteristics they display and outcomes they achieve.

1 Identify more successful firms

- Defined 'success' by a number of outcome metrics, e.g. Total Factor Productivity
- Used these metrics to develop a subset of the more 'successful' firms

2 Identify 'advanced' characteristics

- Developed 'long list' of characteristics
- Collated expert interviews, workshop and literature

3 Define 'advanced manufacturing'

- Determined the prevalence of these characteristics in more successful firms
- Defined 'advanced manufacturing' by this shortlist of characteristics

Source: AlphaBeta/McKinsey Analysis

Desirable growth area for Australian manufacturing

In putting forward these actions, it is important to recognise that there is no single formula or 'one size fits all' approach to success. Successful Australian manufacturing firms follow a range of different strategies to differentiate themselves from their competitors (see Exhibit 27). These groups are not necessarily mutually exclusive but comprise firms that have a similar approach, which includes:

- Focusing on increasing product performance and value differentiation by being:
  - '*Innovation leaders*': firms that use high skills and cutting-edge technology to develop distinct value in their products. Typical attributes of these firms include a heavy R&D investment in products, highly skilled workforces and high-value products due to superior performance or distinctive features
  - '*Servitised firms*': firms that have evolved their model beyond pure production. Typical attributes include a high share of revenue from services and skilled workforces to deliver services before and after sales
- Focusing on identifying untapped or niche markets by being '*market finders*': firms that skilfully cater to either under-served or niche markets. This includes high-value but small segments or markets in which companies are strategically advantaged and can stay close to key customers. Typical attributes include highly skilled workforces and the use of processes such as mass customisation to meet niche consumer needs
- Focusing on reducing product costs by being '*process winners*': firms that differentiate through process excellence and cost competitiveness. These firms display high levels of advanced characteristics, such as capital efficiency and automation.

Exhibit 27 – Many Australian manufacturers are already succeeding by reducing costs, increasing value or improving market focus

Competitiveness lever	Ways to win	Examples
Increase value differentiation	*Innovation leaders* Design innovation & product leadership	**Cochlear:** World-leading hearing implant technology **Resmed:** World-leading respiratory device technology **Quickstep:** Innovative autoclave-free carbon fibre manufacturing process
	Servitised firms Value-adding services bundled with products	**Invetech:** Engineering design consultancy, with some prototype development **Ford Australia:** After production in Australia ceases, will employ >1,000 designers and engineers
Increase market focus	*Market finders* Highly customised, niche or untapped market offerings	**Codan:** High-value metal detection and mining technology **Cablex:** Tailoring cable harness solutions for small runs of aircraft **Textron Systems Australia:** Design remote piloted aircraft
Reduce product costs	*Process winners* automation, outsourcing	**Amcor:** Compete by efficient production processes – enabled by high levels of plant automation

Source: Company websites; press search, analysis of Compustat data, expert and industry interviews

> … it is important to recognise that there is no single formula or 'one size fits all' approach to success.

3 THE OPPORTUNITY FOR AUSTRALIAN MANUFACTURING

Every Australian manufacturer, big or small, high-tech or lower-tech, can improve their operations by employing advanced techniques, technologies and business models. This concept of 'advanced manufacturing' deliberately departs from the current Australian Bureau of Statistics (ABS) definition, which places all manufacturing firms in either 'advanced manufacturing' or 'basic manufacturing' categories according to industry codes associated with the products they produce.

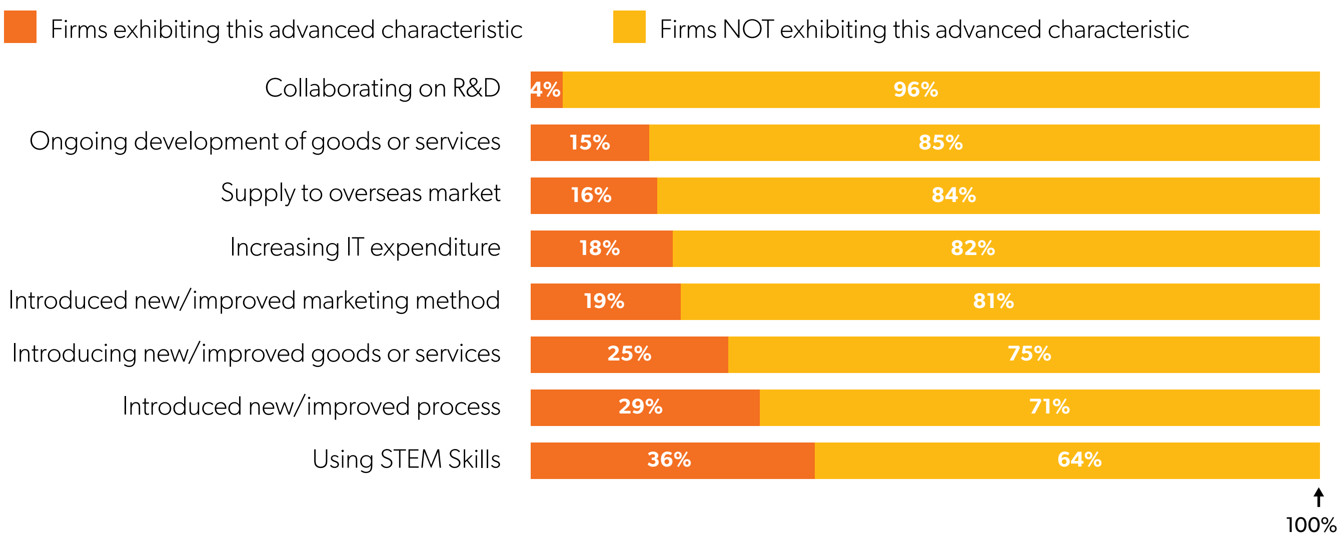
The AMGC defines 'advanced manufacturing' as the application of leading-edge technical knowledge and expertise to the creation of products, production processes and associated services for the purpose of sustaining high growth and customer satisfaction. This definition recognises that manufacturing firms can adopt advanced techniques irrespective of what they produce. It is as possible to employ advanced techniques and business models in furniture manufacturing as it is in aircraft engineering. This definition also recognises there is no hard line separating advanced firms from other manufacturers. Rather, all firms are on a continuum, employing a range of techniques and strategies adapted to their circumstances. Moreover, all firms can aspire to continuously improve their manufacturing processes and evolve their business models. Section 4 recommends changes in how progress in manufacturing is measured to support this definition, and Section 5 outlines how the AMGC will continue to work with the Government on new forms of measurement.

While there are many examples of successful Australian companies, not all Australian manufacturers exhibit the 'advanced' characteristics identified above. In fact, Exhibit 28 demonstrates that a high proportion of Australian firms do not currently optimise cost, value differentiation or market focus. Accordingly, in order to lead the transition, industry will need to take a series of actions that aim to increase value differentiation, improve market focus and reduce product cost.

Exhibit 28 – There is significant room for Australian manufacturers to increase their adoption of advanced techniques

Most Australian manufacturing companies are not engaged in advanced processes and techniques

Weighted average fraction across 2009–13 and 2010–14 panel, %



Source: BCS Survey (ABS) and AlphaBeta analysis

3.2 THE 'SIZE OF THE PRIZE' IS SUBSTANTIAL AND REAL

The rewards for success in advancing manufacturing are substantial. The size of Australia's manufacturing industry in the year to June 2016, in gross value added or output terms, was $97.7 billion.[51] In August 2016, manufacturing employed 886,800 people.[52] It's estimated that an additional 331,000 people are employed in other sectors as a direct result of manufacturing activity.

Analysis of the potential 'size of the prize' in improving manufacturing competitiveness suggests that Australia can capture a 25–35% increase in value added by 2026 (see Exhibit 29).[53] This figure is driven primarily by improvements in value differentiation, which would account for a 14–20% improvement[54], and shifts in market focus, which would account for a 7–9% improvement.[55] Improvements in cost competitiveness would result in a 4–6% increase, the smallest component of the potential uplift.[56] Further detail on the methodology used to estimate the size of the prize is outlined in Annex B.

Manufacturing continues to be an important part of Australia's industry mix; accounting for 6.1 per cent of Australia's GDP and 7.4 per cent of employment. In the 2015–16 financial year, manufacturing generated $100 billion in export income, second only to mining's $117 billion.

51 ABS National Accounts Catalogue 5206.0, Table 6, Manufacturing, seasonally adjusted terms.

52 ABS Detailed Labour Force Catalogue 6291.0.55.003.

53 The base case size of manufacturing in 2026 uses the 2006–14 CAGR as the average annual growth rate through to 2026.

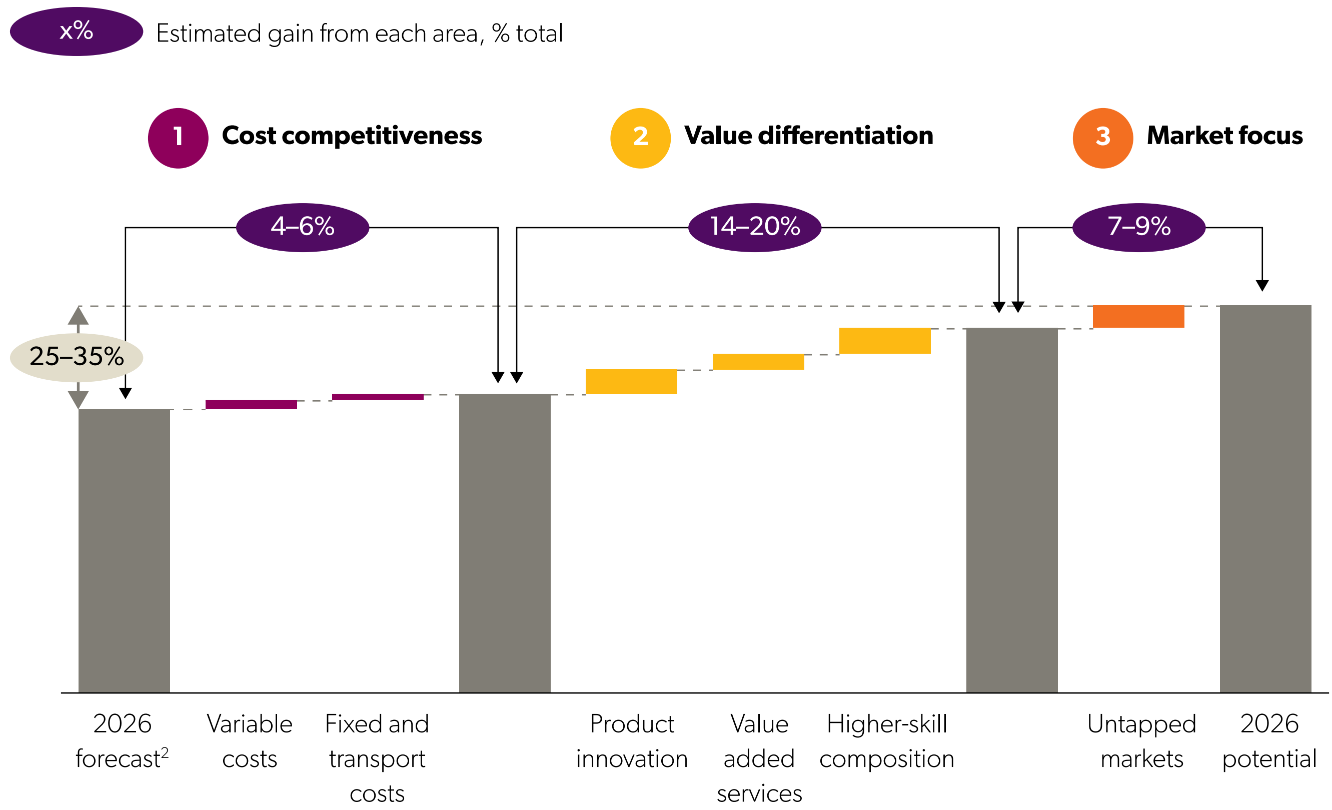
54 The estimated increase through value differentiation was calculated as an average of multiple methods: lifting performance in export categories in select manufacturing sub-industries analysed in the Plan to either the highest or the average level of revealed comparative advantage; closing the gap between the profitability of a sample of successful firms and the average; and increasing the proportion of high-skill workers in select sub-industries to US levels. This is consistent with previous studies that have identified innovation as the key source of competitive advantage for Australian manufacturers. See, for example, Green, R. & Roos, G. (2012), 'Australia's Manufacturing Future: Discussion paper' prepared for the Prime Minister's Manufacturing Taskforce, Sydney. Available at: https://www.uts.edu.au/sites/default/files/Australia's_Manufacturing_Future.pdf

55 The estimated increase through market focus involves closing the gap in select sub-industries in export markets where Australia is underweight relative to Australia's average share for that product category and shifting product mix to more skill-intense sub-industries, where Australia is underweight relative to the US.

56 The estimated increase through product cost was calculated by closing the labour productivity gap for select sub-industries and applying these across the manufacturing sector, and banking the savings alternatively as profit or in the form of a price decrease to customers, with varying elasticities. The annex provides an expanded and detailed methodology on how we estimated the size of the opportunity.

Exhibit 29 – Growth in manufacturing can be achieved by focusing on greater value differentiation and improved market focus, not cost alone

Estimated potential value gain across advanced manufacturing
Percentage of value added in 2026 relative to straight-line trend projection[1]



Notes
- Benchmarking 'landed' product cost against other high-cost countries revealed a 9–14% cost gap
- Improvement estimates based on different scenarios of closing the cost gap and either banking savings as profit or passing through lower prices
- Value estimate triangulated through assessing sub-category export improvement potential in each vertical, and through comparing firm-level profit margins for highly innovative vs average firms
- Product focus from matching US proportion in high skill industries
- GVC integration based on uplifting exports in key markets to Australian average category share.

1 Increase based on extrapolation from aerospace and med tech analysis.
2 Base growth projected using 10-year historic CAGR for ANZSIC sub-divisions 18, 23 and 24. See appendix for full methodological details.
Source: AlphaBeta/McKinsey analysis

> Companies must lead the transition by taking a series of actions to compete on value.

4 ACTION PLAN FOR MANUFACTURING

4 ACTION PLAN FOR AUSTRALIAN MANUFACTURING

4.1 OVERVIEW: COMPANIES MUST LEAD THE TRANSITION TO COMPETING ON VALUE

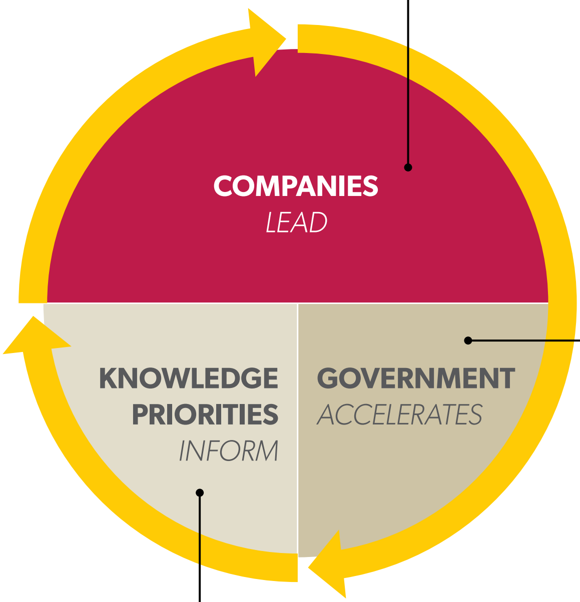
The competitiveness analysis in sections 2 and 3 showed that Australian manufacturers can succeed and grow by competing through product and service differentiation and by better targeting export markets. Achieving this vision will not be easy. It will require a national effort from multiple stakeholders, working together around a clear plan. This report identifies the key actions for industry to achieve this transformation, and identifies how governments can help accelerate the change and how Knowledge Priorities can better guide industry (see Exhibit 30).

> It will require a national effort from multiple stakeholders, working together around a clear plan.

- Companies must lead the transition by taking a series of actions to compete on value. They must focus on rapid innovation, develop new business models to include services across the value chain, engage in global supply chains and build highly skilled workforces. Many Australian businesses are already successfully adopting advanced techniques, but many are yet to make the transition and even the early adopters have room for improvement.
- While the transformation of advanced manufacturing must be industry-led, the Government can accelerate the transition by pursuing key reforms that support actions taken by industry. Suggested reforms relate to improving support for business-led R&D, pursuing smarter procurement and altering the way that progress in manufacturing is measured.
- Regular renewal of Knowledge Priorities will also support and guide the transition. The industry has identified both R&D Knowledge Priorities and knowledge gaps related to business improvement.

Exhibit 30 – Companies must lead the transition to competing on value, supported by government and informed by Knowledge Priorities

Objective: Australian manufacturers need to compete through product and service differentiation, and better target export markets



Companies will lead the transition by:

- Increasing technical leadership
- Increasing value-adding services
- Improving market focus by reaching untapped markets and integrating into global value chains
- Lifting scale and management quality.

Many Australian businesses are already making this transition.

Government can accelerate the transition to new value-based business models by:

- Optimising support for business-led R&D
- Using smarter defence and civil procurement
- Designing assistance to target 'more advanced' characteristics
- Changing measurement of manufacturing.

Knowledge Priorities will inform and fuel the transition by:

- Identifying R&D Priorities: e.g. robotics, advanced materials and composites, digital design and rapid prototyping
- Identifying Business Improvement Priorities: e.g. workforce skills requirements, management capability, building international linkages and driving Industry 4.0 uptake.

Source: Competitiveness analysis

4 ACTION PLAN FOR AUSTRALIAN MANUFACTURING

4.2 ACTIONS FOR INDUSTRY

4.2.1 Overview of actions for industry

The analysis in the previous section identified a number of opportunities to increase Australia's manufacturing competitiveness. Realising these opportunities will require an industry-led transformation focused around four objectives:

- Increase the technical leadership of Australian manufacturing to improve value differentiation
- Increase value-adding services within Australian manufacturing to improve value differentiation
- Improve market focus by identifying under-served segments and linking into global value chains
- Lift scale and management quality to improve cost competitiveness.

These objectives will be achieved through a series of actions, some of which are identified in Exhibit 31. Many will support multiple objectives. For example, increasing skill intensity helps to improve technical leadership (which increases value differentiation) as well as how efficiently the business is run (which will help to reduce product cost per unit). The actions also have differing effects on a company's revenue, costs and cost per unit, which determine the overall impact of an action on profitability. For example, while increasing skill intensity may increase costs, revenue and cost per unit should improve.

> Realising these opportunities will require an industry-led transformation.

Exhibit 31 – Companies must lead the transition with a series of actions

4 objectives ...

- **A** Increase technical leadership
- **B** Increase servitisation
- **C** Improve market focus
- **D** Increase scale and management

... jointly supported by 8 actions	Objectives	Firm-level impacts: REVENUE	COST	COST PER UNIT
Increase business-led R&D	A D	↑	↑	↓
Increase skill intensity	A B D	↑	↑	↑
Collaborate with researchers	A D	↑	↑	↓
Develop service offers	B D	↑	↑	↑
Reach untapped markets and segments	B C	↑	↑	↓
Integrate into global value chains	C	↑	↑	↓
Improve management capability	A B D	↑	↓	↓
Collaborate to 'play bigger'	C D	↑	↓	↓

Source: Competitiveness analysis

4.2.2 Increase the technical leadership of Australian manufacturing

The analysis in Section 2 concludes that Australia's strongest opportunity in manufacturing is to improve our technical leadership. Australian manufacturing firms succeed on a global scale when they offer unique products that provide customers with distinctive value.

To achieve technical leadership, Australian manufacturing firms should prioritise:

- **Lifting business-led R&D:** Company-led R&D is a core driver of long-term success in manufacturing firms and represents a key channel for developing technical leadership and improving value differentiation. As outlined in Section 3, global manufacturing companies in the top 25% for productivity, compared with the bottom 25%, exhibit 3.17 times higher R&D intensity and 1.75 times the number of patents. As outlined in Section 2.3.3, Australian business expenditure on R&D as a proportion of GDP is well below many key OECD competitors. There is a ripe opportunity for Australian manufacturers to increase expenditure on R&D. This Plan also details suggested actions for Government to drive greater business-led R&D.

VALUE DIFFERENTIATION

ResMed

Company background

ResMed is a medical technology company founded in Australia that has captured approximately 40% of the global market for sleep-aid devices. It employs more than 5,000 employees globally, with manufacturing facilities in Australia, France, Singapore and the US.

Product and service differentiation

In addition to personal products treating sleep apnea, ResMed has developed testing and data collection services such as ApneaLink Air and myAir which helps doctors and patients track the progress of sleep problems. The company's products and treatment options heavily integrate sensors and monitoring technology so that treatment can be monitored in real time. For example, its sleep lab titration system is able to relay information in real time between its testing and treatment devices. The company invested over $114 million in R&D during 2015, and has acted to acquire new expertise when necessary, including the purchase in January 2016 of Inova Labs Inc, which provides innovative oxygen therapy products.

Source: Company websites; press search, analysis of Compustat data, expert and industry interviews

- **Capitalising on Australia's ~40% cost advantage in high-skill labour:** Given Australia's cost advantage in high-skill labour and the need for high-skill labour to drive value differentiation, Australian companies have a substantial opportunity to increase their mix of higher skills. Analysis in Section 2.2.2 identified that some Australian manufacturing sub-industries employ workers with a lower education mix compared with their international counterparts. A workforce with greater levels of formal training and qualifications is the indispensable ingredient in transitioning towards more advanced manufacturing. The AMGC's consultation with companies and other industry representatives repeatedly highlighted the value derived from investing in a highly skilled workforce. In addition to hiring tertiary-educated staff on a permanent basis, companies could consider hiring interns in exchange for an educational scholarship. This strategy was used by a mining equipment manufacturer. Its manager reported: "Two scholarship students were brought on board to automate a key process. Even though it required knowledge outside of their specialty, their aptitude and ability to learn allowed us to get done in-house what would have cost us thrice as much to outsource."[57] This Plan details further action for the AMGC to investigate current and future skill priorities and whether the industry is transitioning.
- **Collaborating with research institutions:** As outlined in Section 2.3.4, Australia could improve the collaboration between the research sector and industry. A lack of such collaboration can constrain the development of technical leadership.[58] Collaboration between universities and industry requires action from both parties. Research by McKinsey & Company into the organisational health of Australian firms found that they performed particularly poorly on building networks of external partnerships and on enabling collaboration and knowledge sharing.

Collaboration can work, and there are great examples internationally and in Australia. These include the collaboration between MDB and the University of Sheffield to develop cutting-edge titanium machining processes to win work on the Boeing 787, and the partnership between Deakin University and Quickstep to develop advanced carbon fibre manufacturing techniques (see Exhibit 32). By engaging proactively on priority projects and investing to support research, and by including international universities, companies can help to ensure that Australia is in the flow of the latest global ideas. This Plan details further action for Government to encourage collaboration.[59]

57 AMGC industry consultation, August 2016.

58 Department of Industry (2016), 'R&D Tax Incentive Review Issues Paper', Canberra. Available at: https://www.business.gov.au/~/media/Business/RDTI/Review/Research-and-Development-Tax-Incentive-Issues-Paper-PDF.ashx?la=en

59 Aggregate analysis of more than 18,000 individual Australian responses to McKinsey's Organisational Health Index (OHI): Lydon, J. et al. (2014), Compete to Prosper: Improving Australia's global competitiveness, McKinsey & Company. Available at: http://www.mckinsey.com/global-locations/pacific/australia/en/latest-thinking/compete-to-prosper

Exhibit 32 – Many global firms have achieved success in advanced manufacturing through industry collaboration and through industry-university collaboration

Aerospace example collaborations	Overview	Key aspects of approach
United Launch Alliance	**Industry–Industry:** A 50–50 joint venture between Lockheed-Martin and The Boeing Company for space launch systems	› Joint venture between two previously staunch competitors › Recognising high-costs and scale effects in space launch, formed joint venture to significantly reduce costs › Regulators approved the joint venture subject to conditions protecting launch access for small satellite manufacturers
Marand/BAE/ Quickstep	**Industry–Industry:** Marand, BAE Australia and Quickstep collaborating to produce ~700 F–35 vertical tail sets	› Marand won contract for ~700 F–35 vertical tails with BAE Systems Plc (UK), sub-contracting titanium components to BAE Australia and carbon fibre components to Quickstep › BAE Systems collaborating with Australian companies on qualification processes
MDB & the University of Sheffield	**Industry–University:** MDB and the University of Sheffield collaboration on advanced titanium manufacturing processes to win 787 landing gear work	› MDB engineers and researchers from Sheffield's Advanced Manufacturing Research Centre worked together to develop advanced titanium machining processes. › This enabled increased use of titanium in main landing gear systems, a weight-saving performance feature, and led to winning the 787 contract for main and nose landing gear
Deakin Carbon Nexus and Quickstep	**Industry–University:** Deakin University and Quickstep collaboration on advanced carbon fibre manufacturing processes	› Quickstep has established its automotive division and global R&D centre on Deakin's Geelong campus, associated with Deakin's Carbon Nexus facility, which brings together 11 industry partners from nine countries › Geelong Region Innovation and Investment Fund provided $1.76 million to establish the automotive division at Deakin

Source: Company websites; *Wall Street Journal*; *Australian Defence Magazine*; UK Government (2012) 'Lifting off: implementing the strategic vision for UK aerospace'; Deakin University; ARC website

- **Closing the deficit in management quality in order to improve productivity and reduce cost:** As outlined in Section 2.2.3, Australia has fewer high-performing managers than other successful countries. Specifically, research by the London School of Economics reported that just 4.7% of Australian firms received a high management grade, compared with 15.5% of firms in the US and 8.0% of firms in Germany.[60] Accordingly, there is an opportunity for Australian manufacturers to address the management quality deficit. Positively, efforts to increase skill intensity have been proven to improve the management capability of Australian manufacturers.[61] This Plan details further investigation that is required to understand drivers of the management capability gap (see Section 4.4.3).

4.2.3 Increase value-adding services within Australian manufacturing

The opportunity for Australia to transition into higher-value service offerings is significant. Analysis in Section 2 revealed that some of Australia's advanced manufacturers are increasing R&D, engineering design, and sales and service roles more quickly than others. To accelerate the transition to services, Australian manufacturers should:

- **Develop compelling service offerings that complement Australia's comparative advantages:** In order for industry to transition to higher-value segments, firms need to develop compelling service offerings that complement products, accelerate their uptake of new manufacturing techniques and secure the talent pipeline. Analysis in Section 2.3.2 revealed that value differentiation through service offerings was a key factor in making Australian manufacturers globally competitive. The transition to services in leading manufacturing firms requires changes to culture, skill mix, and contracting and financing arrangements. Some Australian firms have already transitioned to service differentiation, including MiniFAB and Textron Systems Australia.

VALUE DIFFERENTIATION

miniFAB™
MICRO-ENGINEERING / MEDICAL / MANUFACTURING

Company background

Micro-engineering firm miniFAB produces predominantly medical device solutions, along with food packaging and aerospace products. miniFAB was established in 2002 and now has offices in Europe and the US along with clients worldwide.

Product and service differentiation

miniFAB's services span the length of the value chain, from design and prototyping through to manufacture, assembly and supply chain logistics. The company relies on providing highly customised solutions, working with clients to select the right materials, design and processing solutions. miniFAB has to date worked on over 900 projects.

Source: Company websites; press search, analysis of Compustat data, expert and industry interviews

60 See for example, Green, R. & Roos, G. (2012), 'Australia's Manufacturing Future: Discussion paper', prepared for the Prime Minister's Manufacturing Taskforce, Sydney. Available at: https://www.uts.edu.au/sites/default/files/Australia's_Manufacturing_Future.pdf

61 ibid.

VALUE DIFFERENTIATION

TEXTRON

Company background

Textron Systems Australia is an aerospace company with 50 employees and annual revenue of $5 million to $10 million. It produces small unmanned aircraft for military and civilian use, but adopts a business model that also proactively sells support services.

Product and service differentiation

The company differentiates on service offering in a number of ways. First, its Support Solutions business provides operational support to keep assets functioning, and includes personnel who are directly embedded with their clients worldwide to support their missions. Second, the company offers supply chain management and logistics support which helps the customer track assets, reduce the cost of storage and ownership, and engage in obsolescence planning. Third, the service offering also includes a flight operations business which uses its own unmanned aerial vehicles.

Source: Company websites; press search, analysis of Compustat data, expert and industry interviews

- **Lifting skill intensity, particularly in service-oriented roles:** More jobs within service-enhanced and increasingly digitised manufacturing will require higher educational levels. International studies of workforce growth in manufacturing have noted that "the evidence on the future demand for skills in manufacturing suggests that over the period to 2020 more people, proportionately, will be employed in jobs where a degree is required to gain entry".[62] The shift into greater provision of services will require firms to demand skills related to customer engagement, ICT, data management and analytics. Many of the relevant tertiary qualifications will involve STEM subject matter.[63] Analysis in Section 2.3.3 revealed that Australian firms are not currently employing a sufficient share of high-skill workers. In order to attract these candidates, companies may need to take steps to improve the attractiveness of manufacturing, including showcasing careers as part of courses and connecting with education providers to offer experiential or activity-based learning (including internships, placements and short project-based assignments).

  The shift to greater provision of services will also likely require improved readiness among graduates to deploy work-ready skills. The Productivity Commission recently attributed current rates of STEM under-employment post-graduation to the lack of readiness among graduates to use problem-solving skills in technology-rich work environments.[64] Changes to teaching methods that develop problem-solving skills such as experiential, project-based or employer-connected learning are considered most likely to develop work-ready skills. This Plan details actions for the AMGC to showcase examples of servitisation and to map which parts of the industry have servitised, using job ads data (see Section 5.4).

62 Foresight (2013), 'What type of future workforce will the UK need?', the Government Office for Science, London. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/283910/ep36-manufacturing-future-workforce.pdf

63 ibid.

64 http://www.pc.gov.au/research/completed/digital-disruption/digital-disruption-research-paper.pdf

4.2.4 Improve market focus

> The most important thing we can do is be nimble, because we know we need to follow the customer and give them what they want but are not yet getting.

Industry participant, AMGC consultation[65]

Top-performing firms globally exhibit a high level of integration into export markets and offer products with a high-value density (with the top 25% of firms exhibiting a value density 1.09 times the bottom-performing firms). Australian manufacturing firms will need to set high aspirations to enter new markets, and deliver new products and services that offer meaningfully better performance for their customers. One clear message from stakeholder engagement is that Australia's successful exporters were either 'born global' – with export ambitions from day one – or at some point made a very deliberate choice to enter new markets or transform their capabilities.

Improving Australian manufacturing's market focus will require action to:

- **Identify and reach untapped markets and segments (see Section 2.4.2):** Section 2 demonstrates Australian manufacturers are underweight in a number of key export markets, including for intermediate goods. Companies can work further with Austrade and other assistance programs to identify their under-served markets and develop strategies for market entry.

  With regard to niche markets and segments, Australian manufacturers can increase their overall competitiveness by focusing on those products and markets that naturally play to our high-skill workforce and cost advantage in high-skill workers. Australian companies can create a competitive edge by identifying niche markets they are advantaged to serve (e.g. through a highly customised or specialised offering or by finding an under-served market). Some Australian companies, such as Codan, have improved their market focus and found market niches. This Plan proposes actions for Austrade to identify under-served markets, including for intermediate goods, by sub-industry.

MARKET FOCUS

CODAN

Company background

Codan designs and manufactures electronic products predominantly for the telecommunication and mining sectors. The company has been in operation for over 50 years and has customers in 150 countries.

Product and service differentiation

The company engages in global value chain analysis to identify key markets or sectors in which it could offer a comparative advantage. It is then able to cater to these markets with customised design and off-the-shelf products or through outsourcing. Over 90% of Codan's revenue is derived from exports, a fact which reflects the success of Codan's strategy in integrating itself into various global value chains. To maintain cost competitiveness while maximising its advantages, the company produces its low-volume, high-value products in the Australian markets, while outsourcing its high-volume, low-complexity products to an outsourced facility in Malaysia.

Source: Company websites; press search, analysis of Compustat data, expert and industry interviews

- **Link into global value chains (see Section 2.4.3):** Manufacturing is increasingly occurring across global value chains, where the different functions of design, production, marketing and services occur across different countries. Analysis of Australia's backward and forward linkages helps to understand the extent of our integration into global value chains. Backward linkages denote the use of foreign inputs to produce goods and services for export. Forward linkages denote the export of domestically produced goods or services to global companies further downstream. Australia is poorly connected into global value chains, with among the weakest backward linkages of any major economy. In order to reduce product costs and improve value differentiation, companies could use a higher proportion of foreign inputs in their goods and services produced for export.

65 This comment was recorded during the AMGC's consultation with industry members. It was made by the representative of an advanced SME.

4.2.5 Lift scale and management quality

While few Australian firms achieve global success by trying to compete on cost alone, the analysis in Section 2 revealed a number of opportunities for Australian manufacturing to improve its cost position. These included:

- **Increasing company scale to improve capability to deliver complex systems:** This will require collaboration and potentially consolidation within the industry, as well as collaboration with research institutions. As noted in Section 2.2.3, Australian firms may struggle to make substantial investments in capital intensity, in part due to their disproportionately smaller size. In smaller firms, overheads are not spread across large volumes, and shorter production runs make it harder to optimise production. These scale challenges can be mitigated at least partially by firms collaborating, including by pooling R&D resources or capital investments. The AMGC's collaboration hubs represent a mechanism for facilitating the sharing of resources and capabilities between firms that operate in certain geographical areas and are part of similar value chains. To date, hubs have been announced in Clayton and Geelong in Victoria.

  Top global manufacturing firms exhibit high levels of advanced processes, which aim to drive process reliability and quality, as well as cost efficiency and competitiveness. As outlined in Section 3, global companies in the top 25% for productivity, compared with the bottom 25%, exhibit 1.61 times the capital efficiency, 1.50 times newer equipment, 1.30 the rate of automation, and 1.25 times higher energy and water efficiency. In order to shift to advanced processes, Australian manufacturing companies will need to invest in higher capital intensity, newer equipment and higher rates of automation.

- **Improving management quality to lift productivity and reduce cost:** As outlined in Section 2.2.3, Australia has a lower share of high-performing managers than other successful countries. Improving management quality will require proactive investment in the workforce and continued investment in management training and skills. Management skills can be understood as a mix of operations management (adopting lean manufacturing processes), performance management (clear and effective goal-setting), and talent management (incentivising top performance, as well as sustaining innovative workplace cultures and a strong talent mindset).[66] As well as improving technical leadership, as discussed in the previous section, stronger management also supports efficiency and productivity. This Plan details further investigation that is required to understand the drivers of the management capability gap (see Section 4.4.3).

4.3 ACTIONS FOR GOVERNMENT

4.3.1 Overview of actions for Government

Successful Australian businesses have already made the transition to competing more on value and targeting export markets. However, the transition will involve challenges for many individual businesses, including the large up-front costs of investing in innovation and market entry, and small firm size. While industry is the lead player, governments can play a role in accelerating the transformation by helping firms to overcome the barriers required for industry to increase value differentiation, reduce product costs and improve market focus. Exhibit 33 demonstrates how government actions can support what industry must do to transform.

In order to support industry's transition, governments can take action in three areas:

- Improve government support for business-led R&D and encourage industry–research collaboration
- Use smarter procurement and smarter funding programs to drive advancement
- Rethink how progress in the manufacturing sector is measured.

Taken together, these policy changes amount to a fundamental shift in the focus, balance and operation of government support, to help ensure that Australia's manufacturing sector is able to thrive in the future.

> While industry is the lead player, governments can play a role in accelerating the transformation.

66 See, for example, Department of Innovation, Industry, Science and Research (2009), *Management Matters in Australia*. Available at: http://worldmanagementsurvey.org/wp-content/images/2010/07/Report_Management-Matters-in-Australia-just-how-productive-are-we.pdf

Exhibit 33 – Government supporting actions and knowledge priorities can accelerate the transformation by supporting these company actions

What companies must do to transform		Improve support for business-led research	Pursue smarter procurement and smarter programs	Change measurement of manufacturing	R&D knowledge gaps	Business improvement and knowledge gaps
		What government and research can do to support change				
		Government supporting actions			**Knowledge priorities**	
Increase technical leadership	Increase business-led R&D	✓	✓	✓	✓	
	Increase skill intensity	✓	✓	✓	✓	✓
Increase servitisation	Collaborate with researchers	✓				
	Develop service offerings		✓	✓		✓
Improve market focus	Reach untapped markets and segments		✓			✓
	Integrate into global value chains		✓			✓
Increase scale & management	Improve management capability					✓
	Collaborate to 'play bigger'		✓		✓	

Source: Competitiveness analysis

4.3.2 Improve government support for business-led R&D and encourage industry–research collaboration

As Australia's most successful exporters demonstrate, achieving technical leadership is one of the most critical drivers of competitiveness for Australian manufacturers. As noted in Section 2.3.2, this was overwhelmingly cited by purchasing managers as the key source of value to end customers. Support for R&D and research collaboration have underpinned Australia's export successes, particularly in industries that rely on advances in science and technology as their drivers of innovation.

For more firms to develop technical leadership, the Australian Government must encourage business-led R&D and greater collaboration with research institutions. This does not necessarily need to involve additional funding, but instead requires a redesign of current government support for business-led R&D. Further, with tighter leadership, collaboration and alignment between industry and universities, Australia's strong research pipeline will better translate to commercial outcomes.

Proposed action:
Improve the design of Australian Government support for business-led R&D

Government support for business-led R&D is not optimally designed to achieve different R&D objectives. Section 2 outlined a number of R&D objectives that governments seeks to achieve, including:

- Encouraging investment by firms in R&D with different risk profiles (i.e. both medium and higher risk) and different time horizons (i.e. both short- and longer-term)
- Ensuring that minimal government funding is provided to R&D activity that is infra-marginal (i.e. to investment that would have occurred without the incentive).

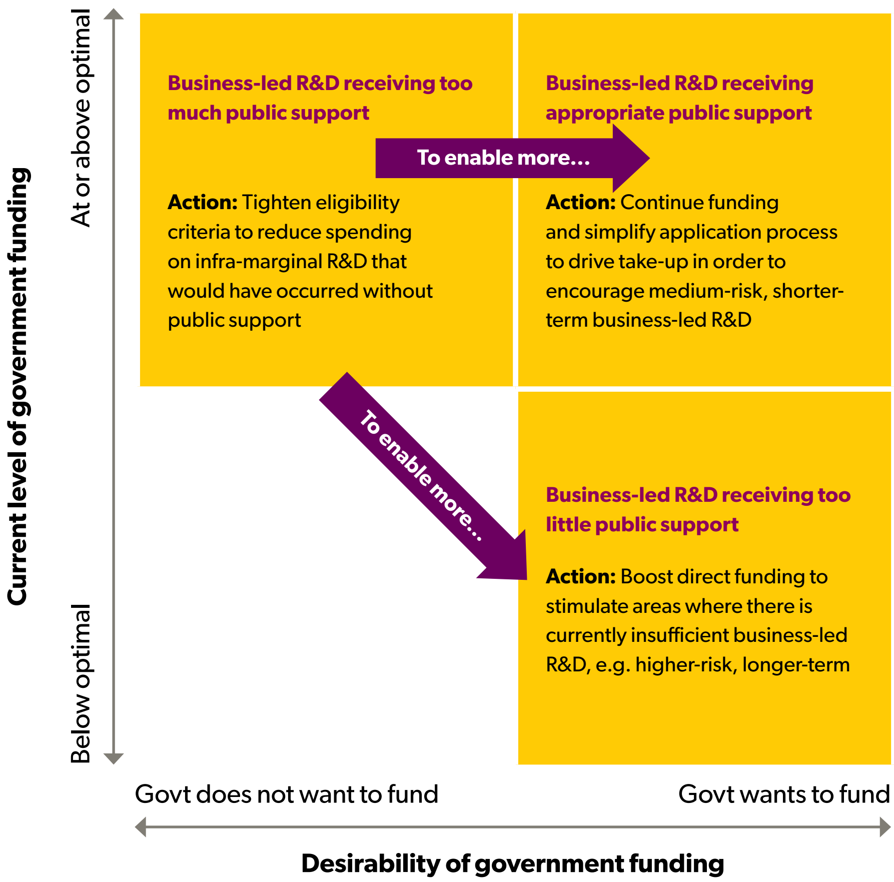
In order to best achieve these objectives, the Australian Government should reduce support for infra-marginal activity and boost support for both medium-risk, short-term R&D through the Tax Incentive, and support higher-risk, longer-term R&D through more direct forms of grant assistance. In order to achieve these objectives (see Exhibit 34):

- Government should tighten eligibility criteria to reduce support for infra-marginal business-led R&D. While acknowledging the challenge of targeting additionality through a volume-based scheme, the recent Review of the R&D Tax Incentive sensibly recommended introducing an intensity requirement to better target larger companies' access to the scheme.[67] The AMGC will publicly support the recommendations related to additionality that were made in the Review.
- Governments could consider using the savings generated from tightened eligibility criteria to encourage investment by firms in R&D with different risk profiles and time horizons.
  - In order to encourage medium-risk or shorter-term business-led R&D, the Government could continue funding under the R&D Tax Incentive but simplify application processes to encourage take-up. The Review of the R&D Tax Incentive sensibly recommended a single application process rather than the current separation of registration and claims.[68]
  - In order to encourage higher-risk or longer-term business-led R&D, which often enjoys high spillover benefits, the Government should consider shifting the mix of government support for business-led R&D away from indirect channels (see Exhibit 35). As outlined in Section 2, Australia is an outlier in the proportion of government support for business-led R&D that is provided via indirect rather than direct channels. This affects the types of R&D that is encouraged. To ensure that higher-risk and longer-term R&D is incentivised, the Government could boost the mix of funding targeted at direct channels, such as by expanding the current pilot BRII or CRC programs.[69]

67 Finkel, Ferris, Fraser (2016), *Review of the R&D Tax Incentive*.
68 ibid.
69 See Footnote 28 in Section 2.3.3 for further information.

There are successful examples of direct R&D funding in many countries (see Exhibit 36). For example, the US SBIR program provides grants to small businesses in two phases, without matched funding requirements: small grants for feasibility and proof of concept work to 'establish the technical merit, feasibility and commercial potential of the proposed R&D effort', and larger R&D grants for projects shown to have high potential.[70] Other examples of direct funding organisations include Japan's NEDO, which provides targeted grants for translational research in areas that can 'enhance Japan's competitiveness'[71], and Singapore's NRF, with a grant portfolio including proof-of-concept grants for business.

Exhibit 34 – Government support for business-led R&D could be modified to better enable achievement of different R&D objectives

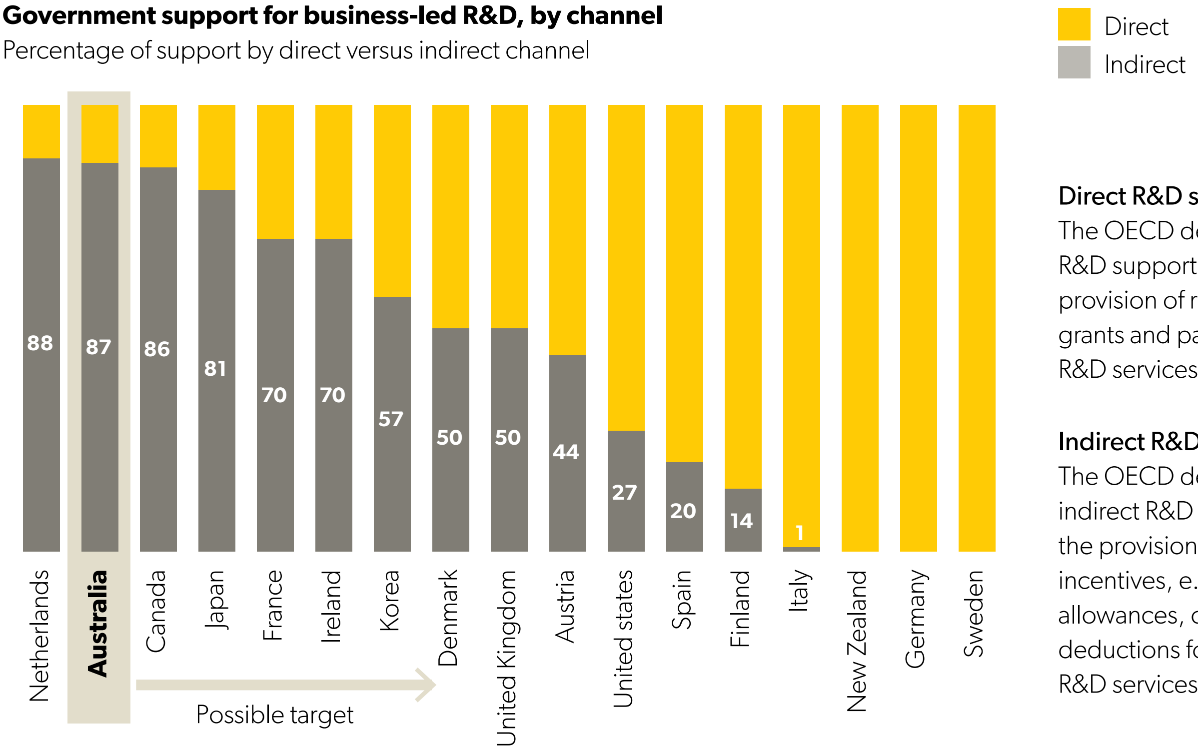


70 US Department of Health and Human Services, National Institutes of Health, Small Business Innovation Research. Available at: https://www.sbir.nih.gov

71 For example, investment by NEDO has facilitated the growth of the solar power industry in Japan: Yamashita, M. et al. (2013), *Impact evaluation of Japanese public investments to overcome market failure: Review of the Top 50 NEDO Inside Products*, Research Evaluation, Vol. 10, No. 13, Available at: http://www.nedo.go.jp/content/100799089.pdf

Exhibit 35 – Australia should shift to a higher proportion of direct R&D funding so as to improve policy impact and correct Australia as an outlier

Government support for business-led R&D, by channel
Percentage of support by direct versus indirect channel



Direct R&D support
The OECD defines direct R&D support as the provision of research grants and payment for R&D services

Indirect R&D support
The OECD defines indirect R&D support as the provision of tax incentives, e.g. tax allowances, credits, deductions for R&D services

Note:
Sample of 17 of 35 countries shown here.
Source: OECD R&D Tax Incentives Indicators, based on 2013 OECD-NESTI data collection on tax incentives support for R&D expenditures and OECD, National Accounts and Main Science and Technology Indicators, 15 December 2014; AlphaBeta/McKinsey analysis

Exhibit 36 – Direct funding approaches are used around the world to drive innovative R&D

Example organisations	Overview	Key aspects of approach
US Advanced Research Projects Agency – Energy	The Advanced Research Projects Agency – Energy is the US Government's R&D investment agency for early-stage transformational technologies in energy	› Funds projects too early for investment from the public sector, through grants or cooperative agreements (greater scope for supervision/intervention), with tangible deliverables agreed for quarterly milestones › Focuses on a limited number of priority areas, with individual projects vetted by a panel including subject matter experts
Japan New Energy and Industry Technology Development Organisation	Japan's New Energy and Industrial Technology Development Organisation funds research in energy and industrial technology	› Explicit commitment to 'enhancing Japan's industrial competitiveness' › Focused on translational research (TRL4-6) in areas set through examination of trends and expert consultation, such as fuel cells, robot technology, power electronics and energy conservation
Singapore National Research Foundation	Singapore's National Research Foundation supports investments to create new industries and enable growth	› Focus on economic impact, with four priority areas 'where Singapore has competitive advantages and/or important national needs': advanced manufacturing, health and biomedicine, urban solutions and sustainability, and services and digital economy › Grant mechanisms include proof-of-concept grants for researchers to develop commercialisable prototypes and a technology incubation scheme (co-investment)
US Defense Advanced Research Projects Agency	The US Defense Advanced Research Projects Agency pursues breakthrough technologies for national security	› Invests across the spectrum of technological readiness from scientific investigation to integration in systems, explicitly pursuing high-risk, high-reward projects › Focus areas determined on an ongoing basis through a) program managers looking for areas with revolutionary potential, and b) requests from the military

Source: ARPA-E website; ARPA-E budget; DARPA website; BusinessWeek; NRF website and reports; NEDO website and report

4 ACTION PLAN FOR AUSTRALIAN MANUFACTURING

Proposed action: Encourage greater collaboration between research and industry

As outlined in Section 2, Australia could improve its rate of collaboration between the research sector and industry to drive technical leadership among manufacturers and potentially improve alignment between public research and commercial opportunity.[72] There are a number of potential mechanisms for improving these rates including incentivising researchers who collaborate[73] and building collaboration requirements into existing government assistance for R&D, including business-led R&D.[74]

With regard to incentives and recognition, one approach is to ensure researchers who collaborate with industry are recognised professionally, with industry impact included in key metrics for performance evaluation. As highlighted by the Academy of Technological Sciences and Engineering, current incentives result in a focus on research excellence, 'often at the expense of [...] university collaborations with the private and public sectors, entrepreneurial behaviour and knowledge transfer'. As such, it is essential that 'research engagement is appropriately recognised and rewarded alongside research excellence'.[75] The new engagement and impact metric currently being developed by the Australian Research Council may help to promote collaboration under the Excellence in Research for Australia evaluation process[76], or explicitly recognise commercialisation outcomes in sector rankings.[77]

With regard to collaboration requirements, existing government support for R&D, including business-led R&D can be redesigned to require collaboration. For example, governments could increase sector-wide research funding that incentivises collaboration design, such as the Australian Government's investment in National ICT Australia (NICTA), now Data61 at CSIRO.[78] Or, as the recent Review of the R&D Tax Incentive by Finkel, Ferris and Fraser recommends, a collaboration premium could "provide additional support for the collaborative element of R&D expenditures undertaken with publically funded research organisations".[79] This recommendation is directed at lifting the current rate of collaboration under the Tax Incentive, with only 9.5% of projects registered under the R&D Tax Incentive in 2013–14 indicating collaboration with another organisation.[80]

"The new engagement and impact metric currently being developed by the Australian Research Council may help to promote collaboration.

72 Department of Industry (2016), 'R&D Tax Incentive Review Issues Paper', Canberra. Available at: https://www.business.gov.au/~/media/Business/RDTI/Review/Research-and-Development-Tax-Incentive-Issues-Paper-PDF.ashx?la=en

73 Bell, J. et al. (2015), 'Translating research for economic and social benefit: country comparisons', ACOLA, Melbourne. Available at: http://acola.org.au/PDF/SAF09/SAF09%20Full%20report.pdf

74 In addition to improving formal collaboration, the creation of informal spaces for 'integrative thinking' has been noted as a key ingredient for increased innovation. See, for example, Green, R. & Roos, G. (2012), 'Australia's Manufacturing Future: Discussion paper' prepared for the Prime Minister's Manufacturing Taskforce, Sydney. Available at: https://www.uts.edu.au/sites/default/files/Australia's_Manufacturing_Future.pdf

75 Bell, J. et al. (2015), 'Translating research for economic and social benefit: country comparisons', ACOLA, Melbourne. Available at: http://acola.org.au/PDF/SAF09/SAF09%20Full%20report.pdf

76 ATSE 2015, op. cit.

77 McKeon, S. et al. (2013), 'Strategic Review of Health and Medical Research', DCRC & CHeBA, University of New South Wales, NSW. Available at: https://cheba.unsw.edu.au/sites/default/files/presentations/McKeon%20SRHMR_130603%20(2).pdf

78 Stanford, J. (2016), 'Manufacturing (Still) Matters: Why the Decline of Australian Manufacturing is NOT inevitable, and What Government Can Do About It'. Australia Institute. Available at: http://www.tai.org.au/content/manufacturing-still-matters

79 Ferris, Finkel, Fraser (2016), *Review of the R&D Tax Incentive*.

80 Department of Industry (2016), 'R&D Tax Incentive Review Issues Paper', Canberra. Available at: https://www.business.gov.au/~/media/Business/RDTI/Review/Research-and-Development-Tax-Incentive-Issues-Paper-PDF.ashx?la=en

4.3.3 Use smarter procurement and smarter programs to drive advancement

Proposed action:
Use smarter civil and defence procurement to drive innovation, collaboration and export focus

Australian federal and state governments have the opportunity to leverage both their defence procurement and civil procurement to drive innovation and collaboration between firms, and to create opportunities for Australian firms in global supply chains. Australian governments can channel spending to provide greater domestic demand and craft the procurement requirements to enable firms to scale faster into niches where they can be globally competitive. To do this well, policy should be focused on:

- **Driving technical leadership:** Innovation requirements should be established to drive technical leadership and ensure that the technology or product will be a globally distinctive offering. This could be coupled with grants to help firms build capability and strengthen the domestic supply base, to make it easier for global contractors to include Australian firms in their supply chains. For example, the New Air Combat Capability – Industry Support Program of the Department of Defence enabled Australian firms to win work in the supply chain of the F-35 fighter plane by providing customised grants to Australian companies to upskill in key capability areas.[81]

  Procurement support should be focused on areas where Australia has comparative advantage, via either current capability or the ingredients for future capability, that could be developed to scale through guaranteed demand. Critically, support should not be provided to prop up industries that were once competitive but are no longer viable. This type of government support is not without risk, as government efforts to support industries without comparative advantage tend to fail. While it was delivered through a different mechanism, some of the support provided to the automotive industry highlights the risks involved in offering government support. In 2014, the Productivity Commission found that the costs of supporting the automotive industry outweighed the benefits.[82]

- **Ensuring export opportunities and global supply chain integration:** Government procurement can create opportunities to connect with global supply chains. As an example, Israeli defence procurement often requires a reasonable investment in building local capacity to engage with global supply chains, built on the principle that projects should be of mutual benefit and result in long-term strategic joint ventures or alliances. The Israeli Government has helped create partnerships and entry points to the global supply chains of leading aerospace companies, resulting in inbound investment in excess of the original mandate.[83] A clear pitfall here is escalating the cost of procurement and compromising capability through excessive focus on Australian content. Capability building should be focused on realistic opportunities on a case-by-case basis. Industry participation schemes that have focused on import substitution tend to make firms *less competitive* due to the explicit protection afforded.

- **Collaboration opportunities:** One method to achieve scale used in many advanced economies is strategic procurement. Australia has few strategic procurement programs to help companies develop scale in niche areas, particularly compared to other developed countries.[84] When government organisations in Australia have used strategic procurement, they have tended to focus more on the perceived

81 Department of Defence, New Air Combat Capability – Industry Support Program, Canberra. Available at: http://www.defence.gov.au/dmo/DoingBusiness/Industry/IndustryPrograms/JSF-ISP/; AlphaBeta/McKinsey interviews with industry experts.

82 Productivity Commission, 'Australia's Automotive Manufacturing Industry – Inquiry report'. Available from: http://www.pc.gov.au/inquiries/completed/automotive/report

83 AIDN (2014), Industry Involvement for Defence in Australia, Melbourne. Available at: http://www.aidn.org.au/documents/aidn%20australian%20industry%20involvement%20paper%20-%20may%202014.pdf

84 ibid.

value of final assembly. As an example, during a recent defence aircraft procurement negotiation, the government initially pushed for final assembly to occur in Australia even though it would have been difficult to achieve efficiency at low volumes and would have provided little benefit in terms of capability transfer. This push was despite the manufacturer's offer to invest in building local capability to maintain advanced systems throughout the life of the aircraft, which could have helped to build competitive scale in a high-skill field.

- **Limited reliance on targets:** Many countries have decided to set a target for the amount of mandated foreign assistance that is tied to procurement contracts. If a government chooses do so, they would need to be confident the target was modest, initially realistic and wouldn't create unintended consequences such as those described above. A good example is Israel's modest targets of 35–50%, which are regularly exceeded by ensuring local firms participate meaningfully in global supply chains.[85] Australian levels are currently closer to 5–10% in F-35 acquisition[86]; targets would need to be initially set low and ratcheted up to enable time for industry to build capacity. This Plan outlines further actions by the AMGC to tailor civil and defence procurement opportunities (see sections 4.4.3 and 5).

> The future submarine build offers a 'moon shot' opportunity for Australia, provided we play our cards right.

Proposed action:
Harness existing government assistance programs to drive advancement

Having uncovered the characteristics associated with successful and more advanced global manufacturing firms, federal and state government policy and programming can better target the promotion of these characteristics in Australian firms. A suite of federal government assistance programs is currently available to Australian manufacturers, including the Entrepreneurs' Programme, the Industry Skills Fund, the ARC Industry Transformation Research Programme, Austrade, the R&D Tax Incentive and CRCs. There are also numerous state-based industry assistance funds and capability-building or facilitation programs that provide assistance to manufacturers or are available to manufacturing firms. There is an opportunity for both federal and state governments to ensure that these programs are best aligned to advancing manufacturing:

- Where these programs are capability-building, the capabilities could be targeted towards building the types of characteristics associated with successful, more advanced firms. These include advanced knowledge (such as R&D intensity and wage levels), advanced process (such as capital intensity and automation levels) and advanced business models (such as share of services in revenue).
- Where these programs offer incentives or support, the evaluation criteria could be oriented towards ensuring higher prevalence of key characteristics – e.g. share of services, R&D intensity and capital intensity.

85 AIDN, *op. cit.*

86 As of December 2015, Australian industry had won US$554.5 million in production and development contracts (source: Department of Defence (2016) 'F-35 Program Key Facts & Milestones – March 2016'). With average costs of A$90 million per aircraft (source: ibid) and orders for 72 aircraft, the total order is worth ~US$6.5 billion for direct acquisition alone. Australian industry currently has an ~8.5% share.

4.3.4 Rethink how manufacturing and progress in manufacturing are measured

Measurement of progress in the sector should be designed to fulfil the dual objectives of measuring whether firms are advancing, and capturing the wider impact of manufacturing on the economy. These objectives of a revised measurement system will ensure that Australia is tracking what we desire to achieve in manufacturing. Are we transitioning to sustainable, high-value-added manufacturing and are we capturing the impact that manufacturing has on other industries? Accordingly, the Australian Government should make three changes to the way in which progress of the sector is currently measured (see Exhibit 37).

Proposed action:
Measure the prevalence of key 'advanced' characteristics

Currently, progress in manufacturing is primarily measured by whether value added, jobs and exports have increased for the subset of ANZSIC classes defined as 'advanced'. Rather than using these traditional metrics alone, we recommend measuring whether or not the sector is advancing by tracking the prevalence of key characteristics associated with 'advancement' across all manufacturing sub-industries. For example, advancement of manufacturing could be tracked by whether there have been changes in advanced knowledge, advanced processes or advanced business models. Specifically, this could involve measuring whether there have been changes in skill mix; average level of qualifications or proportion of high qualifications; research and development intensity; patent/trademark portfolio; wage levels; capital efficiency; automation rates; collaboration rates; the value density of products; and the share of revenue represented by services. Most of these metrics are currently used as part of the ABS's Expanded Analytical Business Longitudinal Database, except for the share of revenue represented by services, which we recommend be added to one of the existing survey formats such as the Business Characteristics Survey.

Proposed action:
Report modified versions of value-added and jobs growth

The department currently measures progress of the sector primarily against employment, value added and exports.[87] It reports progress against a number of characteristics-related metrics including innovation and business performance. These metrics are reported at the 1-digit level (e.g. manufacturing) and for the sub-industries currently classified as 'advanced'.

We recommend reporting modified versions of value-added and jobs growth at the 1-digit level of manufacturing. There are some challenges with traditional metrics like value added and employment, given the rate of servitisation and flexible sourcing of labour across the economy for services like design, accounting, marketing and cleaning. Where these jobs are directly linked to manufacturing activity, there is value in making the connection to manufacturing, albeit imprecisely. There are international examples of attempts to attribute value added and employment to different sectors. For example, in the US, the Bureau of Labor Statistics constructs annual employment tables for 168 sub-industries, which indicate the employment supported directly and indirectly per $1 million of sales of goods and services to final users. The BLS also provides input–output tables annually, which show sales generated in a range of sectors by demand from other sectors. This allows for reallocation of value added to upstream sectors to be observed.[88] Accordingly, we recommend reporting a modified version of value added and jobs that captures the direct and indirect impact of manufacturing (see Exhibit 38).

87 As per international documents from the Department of Industry, including the advanced manufacturing data pack.

88 US Bureau of Labor Statistics. Available at: http://www.bls.gov/emp/ep_data_emp_requirements.htm

89 For example, see https://d3n8a8pro7vhmx.cloudfront.net/theausinstitute/pages/536/attachments/original/1464819264/Manufacturing_Still_Matters___Centre_for_Future_Work.pdf?1464819264, pp. 4–6.

Even this modified reporting of employment is likely to understate the employment impact of manufacturing. The transitions occurring in the new economy mean that new economy manufacturing activity may not appear in either the manufacturing codes or in input–output tables related to manufacturing. For example, in an era of digitally delivered textbooks, jobs in printing and distribution might be lost but jobs in technology development, maintenance and support will emerge and not necessarily appear linked to the manufacturing industry.

Proposed action: Measure 'spillover' benefits

In addition to the common metrics outlined above, we recommend measuring the 'spillover' benefits of manufacturing, or its broader contribution in the economy. Specifically, given the important role of manufacturing in supporting innovation, productivity and exports[89], we recommend tracking the share of R&D, productivity growth and total exports represented by the manufacturing sector.

Exhibit 37 – We recommend three changes to how the sector is measured

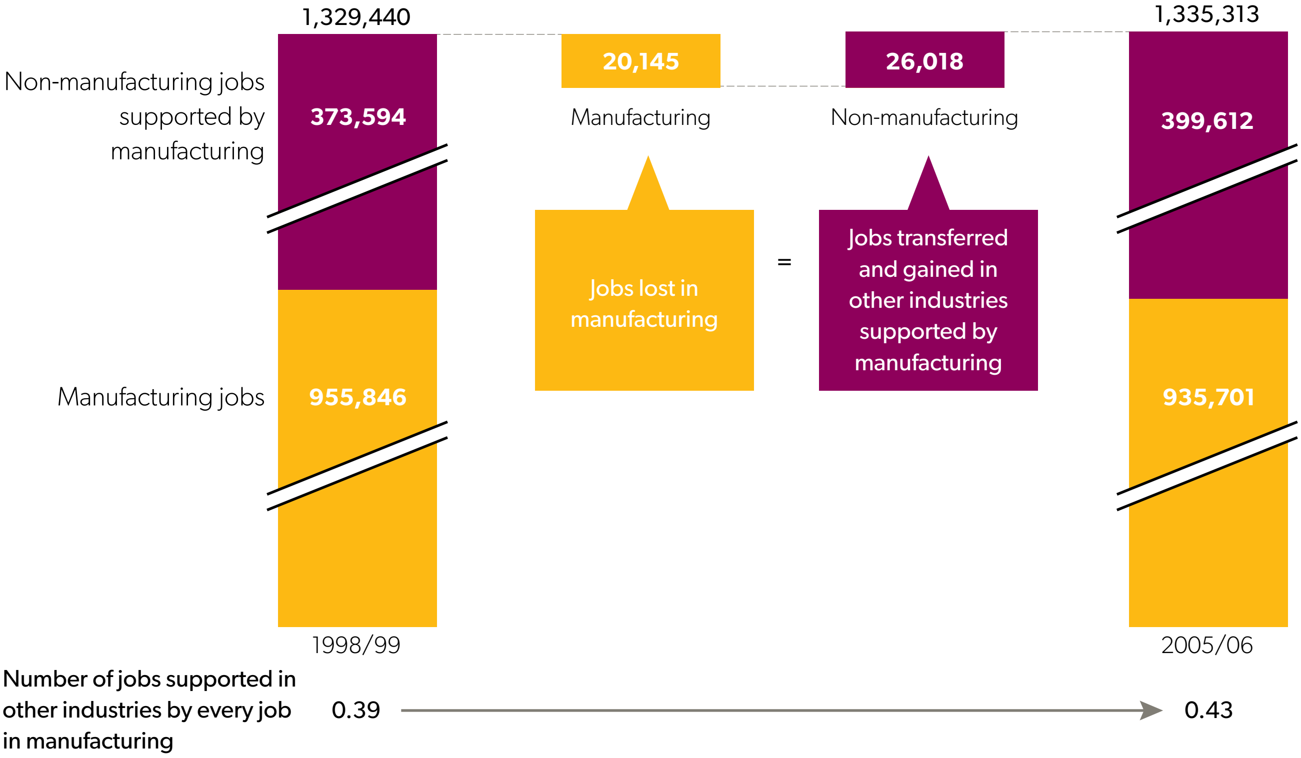
1. Measure the prevalence of key characteristics	2. Report modified versions of value-added and jobs growth	3. Measure 'spillover' benefits
Track 'advancement' of sector by the **prevalence of characteristics** associated with being more advanced such as: • Advanced knowledge: skills (by type); qualifications (by level); research and development intensity; patent/trademark portfolio; wage levels; collaboration (by type) • Advanced processes: capital efficiency; automation • Advanced business models: value density; share of services	**Report modified version of key metrics of interest (e.g. value-added, jobs, exports) across the Growth Centres** including: • For 1-digit manufacturing • A modified version of value-added and jobs for 1-digit manufacturing, which captures the impact of manufacturing on other industries (see Slide 9) • For a set of firms found to be 'more advanced' according to prevalence of key characteristics • Establishing thresholds for characteristics in Year 1 that capture 50% of firms as 'more advanced' (e.g. overall advancement index of 1.2) • Aggregate incremental jobs growth of all firms in Year 2 that meet criteria (including new entrants and minus exits)	**Track 'spillover' benefits of manufacturing** or why manufacturing matters to wider economy such as: • Share of business expenditure on R&D • Share of total exports • Share of total productivity growth

89 For example, see https://d3n8a8pro7vhmx.cloudfront.net/theausinstitute/pages/536/attachments/original/1464819264/Manufacturing_Still_Matters___Centre_for_Future_Work.pdf?1464819264, pp. 4–6.

Exhibit 38 – Rethinking the way that manufacturing is measured will help to better understand progress and the broader impact of manufacturing

Direct and indirect employment from Australian manufacturing

Number of jobs



Note:

Non-manufacturing jobs supported by manufacturing are calculated from IO tables and employment/value added ratios. The period selected (1998/9 to 2005/6) deliberately excludes the global financial crisis and automotive industry decline.

4.4 KNOWLEDGE PRIORITIES

4.4.1 Overview of Knowledge Priorities

Industry's leadership in the transition to advanced manufacturing can be further guided and informed by investigating key Knowledge Priorities. Developing and disseminating knowledge is key to helping Australian manufacturing differentiate itself on value and technical leadership. The AMGC has identified two types of Knowledge Priorities that will need to be addressed in order to enhance the competitiveness of the Australian manufacturing sector:

- R&D priorities – these are technological and scientific gaps that can help to improve manufacturing processes or drive product innovation
- Business improvement priorities – these are analytical priorities aimed at better understanding business capability gaps and the best ways to overcome these gaps.

The Knowledge Priorities outlined in this section are the product of our competitiveness analysis, a review of the existing literature, and industry engagement including consultations and an industry-wide survey with more than 50 respondents from companies, industry associations, government bodies and research organisations.[90] Annex B provides further detail on the methodology used to identify the priorities.

90 Survey participants were asked to evaluate the relevance of the proposed priorities, identify additional priorities and offer further comment on the R&D and business improvement issues most affecting the industry. More than 50 organisations and companies responded to the survey.

4.4.2 Australian manufacturing's R&D priorities

Australian manufacturing businesses, industry associations and the research community have identified a number of R&D priorities to help Australian manufacturing become globally competitive. These will help by increasing technical leadership in products and expanding associated value-adding services.[91]

Robotics and automated production processes

Robotics and automated production processes refer to the design and operation of robots in manufacturing[92], enabling greater productivity, lower costs, improved workplace safety and higher product quality. Examples of knowledge gaps include:

- How can error detection and reduction rates be improved so that automated processes continue to provide a reliable output?
- How can advanced materials improve the functionality of robots and the enablement of 'soft robotics'?[93]
- How can robots better develop situational awareness (vision and sensors) to interact with workers and customers and in controlled environments?
- How can software be improved to enable robots to communicate with one another and other manufacturing equipment/processes?

> Australian manufacturing businesses, industry associations and the research community have identified a number of R&D priorities to help Australian manufacturing become globally competitive.

Advanced materials and composites

Advanced materials and composites refer to new materials developed to provide superior performance across a variety of dimensions (e.g. strength, weight and flexibility)[94], enabling greater product differentiation and customisation for manufacturers. Examples of knowledge gaps include:

- How can flow chemistry increase reproducibility, scale and safety?
- Are there new bonding techniques that can improve the speed of manufacturing and the resilience of existing materials and composites?
- What new materials exist at the molecular or nano scale that can herald new opportunities?
- How can self-healing or flexible materials better allow for remote repair?
- How can the development and application of wear resistant materials be enhanced?

Digital design and rapid prototyping

Digital design and rapid prototyping refer to the product development cycles enabled by ICT visualisation and analytic tools[95], providing lower product development costs and greater product customisation opportunities to manufacturers. Examples of knowledge gaps include:

- How can software platforms be improved to make it easier for Australian manufacturers to complete new product designs?
- What production processes or business services will allow increased rapid prototyping so as to enable manufacturers to create highly customised products?
- How can small-scale production be made more cost-effective so that smaller Australian manufacturers can viably engage in design-led production?

91 The following list is ranked in order of importance and impact as identified by the survey and sources listed in the previous section. For greater detail on a number of these priorities, we recommend referencing the CSIRO's Industry Roadmap for Advanced Manufacturing.

92 CSIRO (draft: October 2016), 'Future of the Australian Advanced Manufacturing Industry - An Industry Roadmap'.

93 'Soft robotics' refers to the use of soft or deformable materials in robotics systems, enabling safer interaction with their environment and improved performance (Source: IEEE Robotics & Automation Society, at http://softrobotics.org/basic-information/).

94 CSIRO (draft: October 2016), 'Future of the Australian Advanced Manufacturing Industry – An Industry Roadmap'.

95 CEDA (April 2014), 'Advanced Manufacturing: Beyond the Production Line', http://www.ceda.com.au/research-and-policy/research/2014/04/30/advancedmanufacturing; CSIRO (draft: October 2016), 'Future of the Australian Advanced Manufacturing Industry – An Industry Roadmap'.

Sustainable manufacturing and life cycle engineering

Sustainable manufacturing and life cycle engineering refer to the development of products with lower energy consumption, improved durability or maintenance costs, and higher potential for recycling or collaborative consumption.[96] Sustainable manufacturing presents an opportunity to reduce costs and greater ability to meet eco-conscious market demand. Examples of knowledge gaps include:

- How can we identify and take advantage of waste capture opportunities in the production cycle?
- How can new and existing recycling methods be expanded across more parts of the value chain and to more industries?
- How can products and production processes be designed to maximise recycling opportunities?

Additive manufacturing

Additive manufacturing refers to the use of digital 3D design data to make a component by successively depositing layers of material, enabling mass customisation and on-site printing. Examples of knowledge gaps include:

- How can uniformity be improved in mass manufacturing using 3D printing processes?
- How can composites and dissimilar materials be manufactured reliably using additive techniques?
- What are effective ways to combine additive and subtractive processes?

Sensors and data analytics

Sensors and data analysis refers to the use of devices to monitor, control and diagnose issues with production lines in real time, enabling increased production volumes and reduced downtime.[97] Examples of knowledge gaps include:

- Can relevant sensors be embedded into more parts of the production process and final product, especially where this involves exposure to harsh operating environments?
- What kinds of battery and data storage solutions will be needed to make the use of sensors more widespread and viable?
- How can the analysis of data gathered from sensors be made more user-friendly for manufacturers as well as clients?
- How can sensors be made more self-powering, biodegradable, bio-compatible and wirelessly connective?
- How can systems increase data storage and security to handle higher capture and security threats?

Materials resilience and repair

Materials resilience and repair refers to the ability of a material under stress to absorb energy and return to its original state[98], enabling product performance characteristics including strength, flexibility and durability. Examples of knowledge gaps include:

- How can material behaviour and complex processes such as flow chemistry be better modelled to increase material resilience?
- How can scanning or other methods be enhanced to better detect stress points and weaknesses in composite materials or assembled products?
- Are there new or substitute materials that can increase the resilience of a product line?

96 CSIRO (draft: October 2016), 'Future of the Australian Advanced Manufacturing Industry – An Industry Roadmap'.

97 ibid.

98 White, M. A. (2011), *Physical Properties of Materials*, 2nd Edn, CRC Press; Princeton University Press, *The Properties of Materials*, Ch 1, http://press.princeton.edu/chapters/s9638.pdf

Bio-manufacturing and biological integration

Bio-manufacturing and biological integration refer to the use of biological systems to produce molecules that cannot be extracted or synthesised directly[99], enabling the development of innovative products and materials. Examples of knowledge gaps include:

- Can more advanced resilient bio-degradable packaging solutions be found?
- What high-value compounds and new materials can be created by using biological instruments, e.g. algae?
- How can biological processes, including the breakdown of materials for easy recycling, be incorporated into the production processes of traditional products?

Nano-manufacturing, micro-manufacturing and precision manufacturing

Nano-manufacturing, micro-manufacturing and precision manufacturing refers to production that uses very small-scale components and materials or applies high-precision tools[100] to improve product performance characteristics, enabling a high degree of product differentiation and customisation opportunity for manufacturers. Examples of knowledge gaps include:

- How can the resilience and reliability of precision manufactured items be enhanced?
- What is required for the system-level integration of precision manufacturing innovations?
- What computational and modelling innovations will better enable precision manufacturing?

Augmented or virtual reality systems

Augmented or virtual reality systems refers to technology that engages workers with a computer-generated representation of the physical world, enabling remote control of machinery or guiding workers through operations on-site[101] and ultimately improving cost and safety outcomes. Examples of knowledge gaps in include:

- How can augmented reality be used to allow closer human–machine interaction in product design and manufacture, including through advanced sensors?
- How can improved processing power, download size, resolution, frame rates and depth sensors allow for more complex visualisations?
- What kinds of wearable virtual reality technologies are best suited to manufacturers in different contexts: on the factory floor, exhibiting to a client or in testing product use?
- How can the computability of software platforms be enhanced?

4.4.3 Australian manufacturing's business improvement Knowledge Priorities

The competitiveness analysis detailed in Section 2 and our industry survey identified a number of areas where further investigation is required to understand business capability gaps and how to correct these gaps.[102]

Drivers of the management capability gap

Recent studies have demonstrated that Australia has a long tail of manufacturing companies that perform poorly on management capability[103] and a shortage of managers with higher qualifications. Examples of knowledge gaps include:

- How do different manufacturing sub-industries perform on management capability?
- How does management capability vary by firm size?

99 White House (April 2016), 'Advanced Manufacturing: A Snapshot of Priority Technology Areas Across the Federal Government'; Industry Canada (2006), 'The Canadian Biopharmaceutical Industry Technology Roadmap', http://publications.gc.ca/collections/Collection/Iu44-31-2006E.pdf

100 US National Science Foundation (2002), 'Workshop on Nanomanufacturing and Processing: Summary Report', https://www.nsf.gov/mps/dmr/nsfec_workshop_report.pdf

101 CSIRO (draft: October 2016), 'Future of the Australian Advanced Manufacturing Industry – An Industry Roadmap'.

102 Proportion of survey respondents identifying each business improvement knowledge priority as having high impact or very high impact on their business: management (94%); workforce skills requirements (85%); international engagement (73%); industry 4.0 (63%); engaging in government procurement processes (52%).

103 Bloom, N. et al, (2007), 'Management Practice and Productivity: Why They Matter', *Management Matters*, available at: http://www.growingjobs.org/downloads/management_practice.pdf; and McKinsey & Company (2009), *Management Matters*.

- What are the key drivers of management capability gaps?
- What are the most effective ways for Australian manufacturers, especially SMEs, to drive improvement in management capability?

Understanding workforce skills requirements

Understanding the strengths and weaknesses of the current Australian manufacturing labour force, as well as future requirements, is key to developing an evidence-based skills plan. Examples of knowledge gaps include:

- Which parts of manufacturing are making the shift to higher skills and which are not?
- Is there a mismatch between the supplied and demanded labour skills in particular sub-industries? For example, companies have indicated a shortfall of device physics and composites engineering knowledge.
- What specific qualifications are manufacturers demanding and what common skills are manufacturers demanding across qualifications? What commercial skills are most complementary for graduates with technical qualifications who are headed for the manufacturing sector?
- What skills are most likely to be demanded in the jobs of the future?
- How can we match, transfer and transform skills in declining manufacturing sub-industries with skills in growing manufacturing sub-industries?
- How can education service providers be more responsive to future economic needs?

International linkages

As outlined in Section 2, some sub-industries in manufacturing currently under-serve key export markets, including for both intermediate and finished goods. Australia also has among the weakest backward linkages[104] of any major economy. Examples of knowledge gaps include:

- Which export markets are most under-served by each of the manufacturing sub-industries?
- What strategies should Australian manufacturing firms follow to identify and access international opportunities in these under-served markets?
- How can Australia improve its backward linkages in different sub-industries? What markets are most reputable and accessible for sourcing foreign components by sub-industry?

Driving Industry 4.0 uptake

Australian manufacturing has the opportunity to improve cost competitiveness and value differentiation by taking advantage of technologies transforming production processes and customer understanding. Many countries around the world are moving towards Industry 4.0 as a means of harnessing the opportunities afforded by cyber-physical production systems made up of smart machines, logistics systems and production facilities. Examples of knowledge gaps include:

- What opportunities does Industry 4.0 have to offer Australian manufacturers? How can current trends in automation and data analysis best be scaled and made relevant and accessible to the operations of Australian manufacturers, especially SMEs?
- What key actions can manufacturers pursue to ensure the successful take-up of Industry 4.0 methods and technologies?
- How can government initiatives, such as the Prime Minister's Taskforce on Industry 4.0, be made most relevant to the commercial opportunities and challenges facing manufacturers?

104 Backward linkages refer to the use of foreign inputs to produce goods and services for export.

Leveraging government procurement

Government procurement provides Australian manufacturers with a large market opportunity, especially in industries like defence, and in infrastructure investment such as rail. Similarly, Australian governments have the opportunity to leverage their procurement to drive innovation and collaboration between firms, and to create opportunities for Australian firms in global supply chains. Examples of knowledge gaps include:

- How can manufacturers be better appraised of upcoming procurement opportunities?
- How can Australia ensure a strong industry policy role in the forthcoming defence capability acquisition?
- What are the best ways to create spillover benefits through government procurement processes from industries with traditionally intensive procurement processes (e.g. defence) to other industries?
- How can value differentiation and integration into global supply chains be prioritised and incentivised through civil and defence procurement processes?

> Australian governments can leverage their procurement programs to create opportunities for Australian firms in global supply chains.

4.5 CHANGE CAN START IMMEDIATELY, BUT THE TIME TO PAYOFF WILL VARY

The transition can start immediately but the time to payoff for action will vary depending on the action (see Exhibit 39). In the short term, there are a number of quick wins that can be actioned by companies, governments, the AMGC and the wider community:

- The AMGC, governments and industry associations can communicate the benefits of optimising costs, differentiating value and improving market focus to manufacturers.
- Governments can redirect a higher proportion of funding to commercial R&D.
- The AMGC, industry and researchers can identify technology priorities for the sector and expand collaboration hubs.
- Governments can rethink how manufacturing is measured to gain a better understanding of whether the sector is advancing and its impact on other industries.

Australia has a real opportunity to advance its manufacturing sector. The analysis and actions contained in this report will help to take Australian manufacturing to another level. As we have observed, some firms have already made the transition to improve their differentiated value and shift focus to higher-value market segments. Actions by companies and governments, along with further investigation into key Knowledge Priorities, can help other companies to make this transition and high-performing companies to further advance. The AMGC will work with companies, governments and other stakeholders to implement this Plan and harness the full potential of Australian manufacturing.

Exhibit 39 – Change should start across all actions immediately, with a number of quick wins expected in the short term

Quick wins	Medium time-to-impact	Longer time-to-impact
Sell the 'benefits of change'	Encourage smarter procurement	Industry 4.0 applications
Improve government support for business-led R&D	Increase commercial collaboration	Integrate into global value chains
Identify projects and collaboration hubs	Identify under-served markets and GVCs	Reach untapped markets
Accelerate the shift to servitisation	Collaborate to play bigger	Improve management capability
Change the measurement of manufacturing	Increase skill intensity, including STEM	Extend technology leadership

Time to payoff

KEY

Industry actions | Government support | Knowledge Priorities

Source: Competitiveness analysis

> The AMGC will advance manufacturing by setting direction, demonstrating the direction through projects and collaboration hubs, and generate impact by influencing companies and government.

5 THE ROLE OF THE AMGC AND NEXT STEPS

5 THE ROLE OF THE AMGC AND NEXT STEPS

5.1 OVERVIEW OF THE AMGC'S ROLE

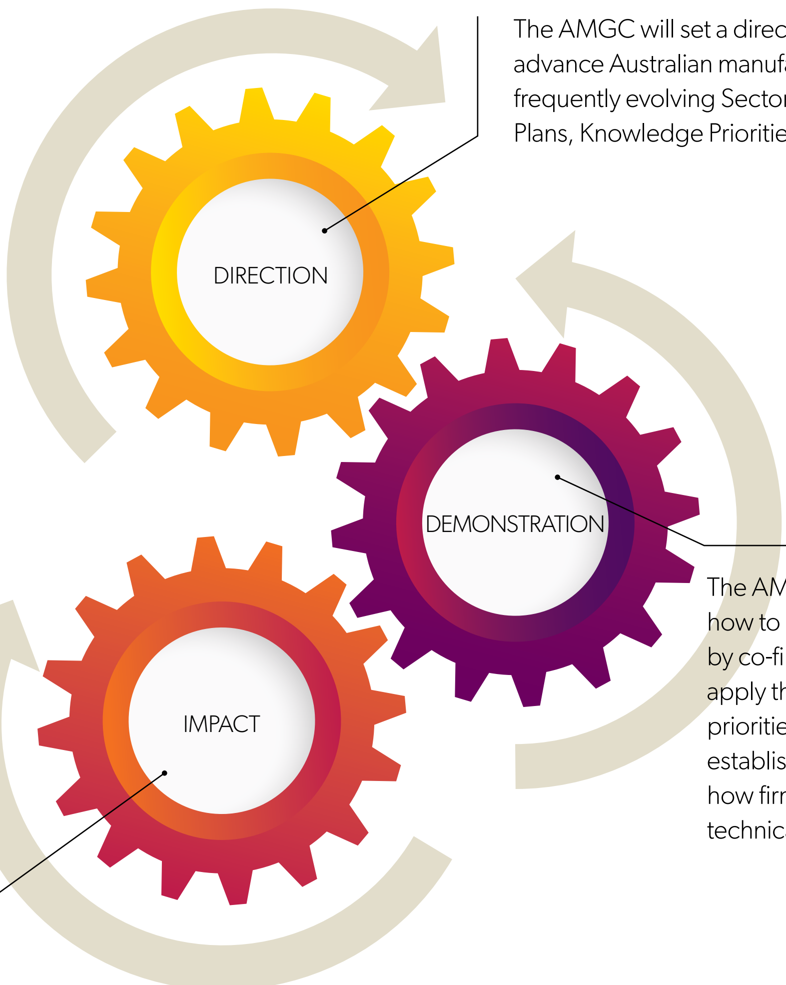
The role of the AMGC is to harness its unique capacity as an industry-led but government-supported Growth Centre to help advance Australian manufacturing. There are three key levers by which the AMGC will pursue this role (see Exhibit 40):

- **Direction:** Set the direction to advance manufacturing in Australia
- **Demonstration:** Demonstrate ways to achieve this direction through projects and hubs
- **Impact:** Work with companies and governments to help them play their key roles in pursuing the set direction.

To perform all three of these levers, the AMGC will maintain close engagement with industry associations, companies, governments and their agencies, and research institutions. AMGC members will stand to gain priority access to the AMGC's initiatives, including participation in demonstration projects and collaboration hubs. The AMGC acknowledges the important role of industry associations in assisting the AMGC in its consultation activities and looks forward to continuing to work with the existing bodies in the sector.

For further detail on the background of the Growth Centres Initiative, please see Annex A.

Exhibit 40 – AMGC will advance manufacturing by setting direction, demonstrating the direction through projects and hubs, and generate impact by influencing companies and government



The AMGC will set a direction for how to advance Australian manufacturing through its frequently evolving Sector Competitiveness Plans, Knowledge Priorities, and other analysis

The AMGC will demonstrate how to pursue its direction by co-financing projects that apply the identified strategic priorities for the sector and establishing hubs to show how firms can jointly develop technical leadership

The AMGC will share knowledge and tools with companies, who need to lead the transition. The AMGC will also work with government to ensure that assistance is optimised to support the transition

5.2 SET DIRECTION FOR AUSTRALIAN MANUFACTURING

5.2.1 Overview of the role to set direction

The AMGC will set a direction for advancing Australian manufacturing through its annual Sector Competitiveness Plan, other complementary sub-annual analytical investigations and through material outlining the sector's Knowledge Priorities.

The Plan will outline actions for companies, governments and research institutions to help advance Australian manufacturing. It will be based on a detailed analysis of the competitiveness of the Australian manufacturing sector, including challenges and opportunities. The Plan will detail near-term activity that the AMGC will undertake.

The AMGC will also annually publish and refresh a list of Knowledge Priorities for the manufacturing sector to inform the research community and governments about R&D priorities and inform analytical activities designed to improve the sector's business capabilities.[105]

The Plan and Knowledge Priorities will be made available to the whole industry in order to set direction. Members will enjoy priority access to detailed insights and further analysis that is generated as a result of this work.

5.2.2 Near-term actions for the AMGC to set direction

Over the next 12 months, the AMGC will undertake a number of specific actions to set the direction for advancing the manufacturing sector.

- **Additional sub-industry analysis:** The AMGC will update its Sector Competitiveness Plan in 2017. Where possible, analysis will be conducted at the whole-of-manufacturing level, but the investigation of the barriers and opportunities facing manufacturers will often require analysis at the sub-industry level. In this Plan, some of the lessons were drawn from detailed analysis of the aerospace and medical technology manufacturing sub-industries. Over the next 12 months, the AMGC will undertake competitiveness analysis of additional sub-industries to build a more comprehensive view of the challenges and opportunities facing manufacturing.

  The AMGC is currently in discussion with other Growth Centres about opportunities to conduct sub-industry analysis involving relevant parts of their industries. Other sub-industries of particular strategic importance are also being considered for analysis.
- **Refresh Knowledge Priorities:** The AMGC recently consulted industry representatives and conducted a widely distributed survey to test its proposed Knowledge Priorities for the manufacturing sector. Over the next 12 months, the AMGC will continue to test these priorities in its meetings with companies and industry associations and will conduct an annual survey to refresh and update the priorities. The published list of priorities on the website will be updated following industry consultation and surveys, and a revised list will be included in each annual Sector Competitiveness Plan. These Knowledge Priorities will be used to inform the research community about the R&D priorities of industry; inform selection processes for government R&D assistance; direct the efforts of businesses, industry associations and policy makers; and inform the future work of the AMGC.
- **Map employer demand for workforce and skills to build an evidence-based, industry-led skills plan:** Section 2 outlined the need for the sector to lift its skill intensity to drive value differentiation and optimise Australia's labour cost advantage. To support this transition, the sector needs a thorough analysis of the workforce skills that will be required in manufacturing for the future, detailed analysis of whether Australian manufacturing firms are transitioning their workforces to incorporate these workforce and skills (compared with other countries), analysis of the size of the current skills gap in different parts of the industry and by geography, an understanding of the drivers of this workforce skills gap and barriers to progression, and a clear plan to provide these skills for the future. This analysis will also need to take into account how the existing skillset in the Australian workforce can be transferred to new opportunities as the Australian manufacturing sector undergoes structural change.

105 Knowledge Priorities will be used to inform the research community about the R&D priorities of industry; inform selection processes for government R&D assistance in manufacturing; direct the analytical and service delivery efforts of policy makers, industry associations and business support services that target improved business capabilities in manufacturing; advise manufacturing firms seeking direction on how best to invest in building knowledge; and inform the future work of the AMGC.

5 THE ROLE OF THE AMGC AND NEXT STEPS

- **Assess Australian manufacturing against 'advanced' characteristics:** Section 3 described analysis of top global manufacturing firms to help understand the characteristics associated with advancement and successful manufacturers. Over the next 12 months, the AMGC will assess advances made by Australian manufacturers against the key characteristics associated with 'more advanced' global manufacturers. This will provide a picture of the performance of Australian manufacturing and distribution of manufacturing firms by the characteristics that we care about, including advanced knowledge, advanced processes and advanced business models. Specifically, the AMGC will use a detailed ABS database of companies (BLADE) to assess the historical and current performance of Australian manufacturing firms against R&D expenditure, patent portfolio, collaboration with research institutions, collaboration with other firms, wage levels, STEM skill intensity, ICT and technology asset intensity, capital intensity, level of plan automation, marketing spend, the introduction of new products or services, and trade intensity.[106] This will provide a clear picture of how Australian manufacturing is currently tracking against these key 'advanced' characteristics that we care about, as well as how these characteristics have trended over time.
- **Further investigate Australia's industry–research collaboration:** Encouraging greater industry–research collaboration is a key part of the AMGC's mandate as a Growth Centre and a key part of AMGC's identified actions to drive technical leadership in the sector. However, views within the sector vary on the extent of the challenge of industry–research collaboration. Prior to the release of the next Plan, the AMGC will used a detailed ABS database (BLADE) to further investigate the industry–research collaboration challenge and better understand the distribution of collaboration among companies.

5.3 DEMONSTRATE THE DIRECTION THROUGH PROJECTS AND HUBS

5.3.1 Overview of the role of demonstrating direction

The AMGC will use demonstration projects and hubs as examples of how to advance manufacturing. First, the AMGC will provide co-financing and management resources to support projects that apply the identified strategic priorities for the sector. The criteria for funding these projects will be based on the success factors for competitiveness outlined in the Plan, with a particular focus on value differentiation, and based on whether the projects will help to fill identified knowledge gaps. The projects will demonstrate best practice strategies to advance manufacturing in Australia and pave the way for other actors in the sector to model these practices with similar initiatives. These projects will also inform the evolving analysis of future Sector Competitiveness Plans. Projects could include:

- Investing in commercialised research collaboration between multiple actors (e.g. a global firm, Australian SMEs and domestic research institutions) and encouraging them to come together
- A partnership between Australian SMEs to build a more integrated product and/or service to deliver into global markets
- Enabling cross-industry technology transfer to capture export opportunities.

The AMGC recently announced project co-funding of $250,000 for the Advanced Fibre Cluster Geelong. This investment will kickstart projects among a consortium of advanced fibre and composite manufacturers located at the Carbon Nexus facility at Deakin University. The purpose of the project is to build on existing strength in carbon materials and encourage further innovation.

106 These metrics are available in the ABS's Expanded Analytical Business Longitudinal Database and other datasets.

Second, the AMGC will use hubs to support and demonstrate how firms can share resources and knowledge in pursuit of R&D priorities or shared technical leadership. The hubs will involve a mix of virtual and physical sites and institutions, and be located within different states and territories, and in different manufacturing sub-industries. The hubs will facilitate the sharing of resources, research outcomes, capabilities and skills between firms that have similar needs due to their location in the value chain, sub-industry or technology priority.

AMGC members will have priority access to these initiatives. Demonstration projects and collaboration hubs will be designed and selected with input from AMGC members. In addition, membership will be a requirement of participation in demonstration projects.

5.3.2 Near-term actions for the AMGC to demonstrate direction

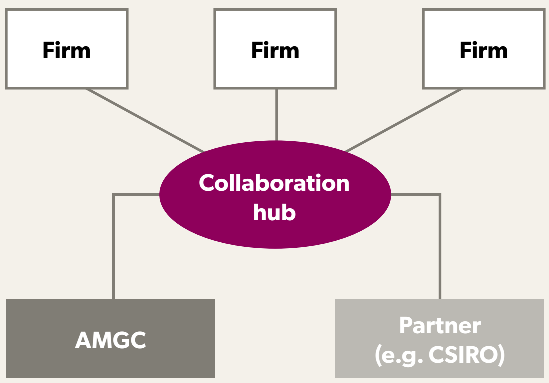
In addition to its current projects and hubs, the AMGC will identify further projects and hubs over the next 12 months in other states and content areas.

- The AMGC will keep an open dialogue with manufacturers, research institutions and industry associations and encourage strong prospects to apply and co-fund projects.
- The AMGC will work with leading research institutions and groups of companies to identify potential new hubs where there is an overlap with existing areas of comparative advantage, unmet technology needs for the sector or proximate companies that would like to collaborate further.

Exhibit 41 – The AMGC has begun identifying competitive technologies to accelerate through funding and as part of collaboration hubs

The AMGC will work to identify technology priorities and support these through collaboration hubs

- The AMGC has begun identifying technology priorities for research through its collaboration hubs. Further work is required to identify new areas where Australia has a distinctive competitive advantage, including existing world-leading industry or research strengths that can be leveraged.
- Collaboration hubs will facilitate the sharing of resources and research outcomes between firms that operate in the same geographical area and are part of comparable value chains.



Source: AMGC internal documents

Example: Advanced Fibre Cluster Geelong

- Announced in August 2016
- Joint initiatives with the CSIRO Manufacturing Division, Deakin University, Geelong Manufacturing Council and several firms
- Collaboration hub based in Geelong, where firms such as Carbon Revolution, Quickstep and Carbon Nexus are already established – this allows the AMGC to leverage pre-existing potential for collaborative gains
- $250,000 committed by the AMGC toward a Project Collaboration and Innovation Fund.

Source: CSIRO

5.4 PURSUING IMPACT BY WORKING WITH COMPANIES AND GOVERNMENTS

5.4.1 Overview of the role of pursuing impact

Australian manufacturing can only advance if companies lead the transition by focusing on competing on value. A comprehensive understanding of the requirements for shifting towards more advanced manufacturing is an essential enabler for progress. Accordingly, a key action area of the AMGC is to build this body of knowledge and share it among its constituency. The AMGC's members will have priority access to this body of knowledge, including consultations to provide more tailored insights from this knowledge.

Governments can accelerate businesses' transition to advanced manufacturing. As an industry-led but government-supported body, the AMGC is well positioned to ensure that government assistance is targeted to support the transition. Drawing on analysis and learnings, the AMGC will work with relevant government agencies to ensure that its policy, programs and regulations are better aligned to advance manufacturing.

5.4.2 Near-term actions for the AMGC to influence companies

Over the next 12 months, the AMGC will seek to influence companies by:

- Creating a tool for firms to benchmark themselves against key 'advanced' characteristics relating to such things as R&D intensity, capital intensity and wage levels. This will be delivered through an online tool created by the AMGC and distributed to constituents
- Communicating the characteristics associated with advancement among top-performing global manufacturing firms, the different 'ways to win' and the benefits of change to Australian manufacturers. This will be achieved through media outreach and the distribution of fact sheets via the AMGC website, major business organisations (e.g. CEDA), industry associations and the AMGC's mailing list
- Communicating the key findings of the Plan and the four key action areas that companies should pursue, via a series of roadshows and events. This will involve dissemination of both full and abridged versions of the Plan, a brochure, and targeted media and social media content
- Showcasing examples and case studies of firms that have successfully servitised, via the AMGC website, industry associations and the AMGC's mailing list. In the long run, the AMGC's projects will provide examples of companies that have successfully transitioned to 'more advanced' manufacturing
- Using online job ad data from manufacturers, demonstrating to manufacturers which parts of the sector are taking advantage of Australia's cost advantage in higher-skilled workers and which are not making the transition (including by sub-industry and geography); demonstrating which parts of manufacturing are making the shift to servitisation; and, identifying the skills of the future.

Over the next 12 months, the AMGC will evaluate which of these channels for impacting company behaviour are most effective, and will iterate accordingly.

5.4.3 Near-term actions for the AMGC to drive action within government

This Sector Competitiveness Plan identifies priorities for government action in R&D, smarter procurement, smarter programs and changes in sector measurement:

- **Change the lens on manufacturing:** This will involve encouraging governments to reframe the image of manufacturing and help shift public perception towards a 'more advanced' and less production-centric manufacturing industry.
- **Support business-led R&D:** The AMGC will publically support a number of the recommendations outlined in the recent Review of the R&D Tax Incentive by Finkel, Ferris and Fraser, and recommend that governments consider shifting the mix of support for business-led R&D towards more direct instruments. Further consideration of shifting the type of support for business-led R&D could form part of Innovation and Science Australia's 2030 strategic plan.
- **Encourage smarter civil procurement:** Working with the Department of Finance and communities of procurement practice across government, the AMGC will help to inform procurement officers about the key levers of competitiveness in manufacturing and help to shape how procurement opportunities can build firm capability in innovation, collaboration and links to global value chains.

- **Encourage smarter defence procurement:** The planned defence procurement program over the next decade is an historic opportunity for Australian manufacturing. It is essential that Australia leverages this opportunity to accelerate the growth and transformation of Australian manufacturing, both as a source of national advancement and as an essential support for a robust defence industry for the future. The AMGC will work with the Department of Defence to ensure strong industry policy objectives are achieved as part of upcoming strategic capability acquisitions and procurement, including the recently announced strategic submarine acquisitions. The AMGC will support the Department of Defence by mapping capability among Australian manufacturers to support work in upcoming procurement activities and to understand best practice in designing defence procurement to maximise industry policy objectives such as building capability in innovation, collaboration and export-readiness.
- **Identify under-served export markets:** The AMGC will encourage Austrade to map under-served export markets (including for intermediate goods) by manufacturing sub-industry. This Plan provides examples for medical technology and aerospace of the first steps in potential analysis that could be conducted.
- **Optimise assistance:** In cooperation with the Department of Industry, Innovation and Science, the AMGC will advocate for evaluation criteria for relevant funding and incentive programs being aligned with the characteristics associated with 'more advanced' manufacturing, such as advanced knowledge, advanced processes and advanced business models. This could include informing the CRCs, CRC-Ps, ARC Industry Transformation Research Programme and R&D incentive programs.
- **Optimise capability-building:** In cooperation with the Department of Industry, Innovation and Science and relevant state government departments, the AMGC will advocate for programs that offer capability-building for SMEs and other manufacturing firms to target the development of characteristics associated with more advanced manufacturing, such as advanced knowledge, advanced processes and advanced business models (niche market targeting and service offering). For example, the AMGC is currently working with the Entrepreneurs' Programme to inform program leaders and business advisers about the ingredients required to advance the sector, including through the Committee, Programme Leadership meeting, Annual Forum and quarterly Advisers meetings.
- **Measure manufacturing:** More work will be done in collaboration with the Department of Industry, Innovation and Science to embed changes in the way manufacturing is measured. As outlined in Section 3, the AMGC has been working with the department to establish a new definition of 'manufacturing' that is not linked to a set of ANZSIC codes but relates more to a continuum of advancement against the key characteristics of advanced knowledge, advanced processes and advanced business models. The department is currently working through the implications of this redefinition for measurement and evaluation purposes. The AMGC will work further with the department to embed processes that will track sector advances by prevalence of characteristics associated with being more advanced. As a first step towards this, the AMGC is currently working with the department to test whether the characteristics associated with advancement among top-performing global manufacturing firms are present in successful Australian firms and how Australian firms currently perform against key 'advanced' characteristics.

The analysis and actions contained in this report will help advance the Australian manufacturing sector. The AMGC will work with companies, governments and other stakeholders to implement this Plan and harness the under-utilised potential of Australian manufacturing.

A ANNEX A – GROWTH CENTRES INITIATIVE

BACKGROUND ON GROWTH CENTRE INITIATIVE

The Advanced Manufacturing Growth Centre (AMGC) is one of six bodies established by the Growth Centres Initiative, with each body corresponding to a key sector of the Australian economy[107] (Exhibit A.1). This industry-led initiative is designed to '*focus on areas of competitive strength and strategic priority to drive innovation, productivity and competitiveness*'.[108] Each Growth Centre is established as a not-for-profit company with a board comprised of industry experts. The initiative is a key part of the Australian Government's National Innovation and Science Agenda (NISA) but is not a delivery mechanism for other government programs.

The activities of each centre will be industry-led and structured around a mandate to:

- Improve access to international markets and participation in global supply chains
- Improve management capabilities and workforce skills
- Enhance industry–research collaboration and commercialisation
- Identify opportunities for regulatory reform.[109]

Exhibit A.1 – Industry Growth Centres have been established to drive industry-led activity in key sectors

The Industry Growth Centres Initiative is an industry-led approach driving innovation, productivity and competitiveness by focusing on areas of competitive strength and strategic priority. This will help Australia transition into smart, high-value and export-focused industries.

Six Centres have been established...

- **Advanced Manufacturing**
- **Medical Technologies and Pharmaceuticals**
- **Cyber Security**
- **Food and Agribusiness**
- **Mining Equipment, Technology and Services**
- **Oil, Gas and Energy Resources**

and have been broadly tasked with...

1. **Improve engagement with international markets and access to global supply chains**
2. **Improve managerial and workplace skills**
3. **Increase engagement between research and industry, and within industry, to achieve commercialisation outcomes**
4. **Remove unnecessary and over burdensome regulations**

107 The other five Growth Centres are Cyber Security; Food and Agribusiness; Medical Technologies and Pharmaceuticals; Mining Equipment Technology and Services; and Oil Gas and Energy Resources.

108 Department of Industry, Innovation and Science (2016), 'Industry Growth Centres Initiative Booklet', p 2.

109 Minister for Industry, Innovation and Science (21 April 2016), *Industry Growth Centres Initiative Programme Guidelines*, p 6. Available at: www.industry.gov.au/industry/Industry-Growth-Centres/Documents/Industry-growth-centres-initiative-programme-guidelines.pdf

CONSISTENCY WITH PROGRAM OUTLINES

As part of the Industry Growth Centres Initiative – and in identifying actions that will improve the sector's competitive strength, productivity and innovative capacity – the AMGC is tasked with addressing specific objectives. The following section maps the actions identified in this report against each of these objectives.

Objective: Improving the capability of the key sectors to engage with international markets and access global supply chains

This section outlines how the actions recommended in Section 4 map to the objective in the Growth Centre program.

- **Company action:** Collaborate to 'play bigger' – Reduce the cost disadvantage for small-scale companies by collaborating with other companies, allowing them to be more competitive in global supply chains (Section 4.2.5).
- **Company action:** Develop compelling service offerings – Accelerate the trend towards servitisation, which complements Australia's comparative advantages (Section 4.2.3).
- **Company action:** Reach untapped markets and segments – Grow exports in non-traditional markets, including by targeting niche or under-served export markets (Section 4.2.4).
- **Company action:** Increase business expenditure on R&D – Lift Australia's business-led R&D into the top half of OECD nations to drive technical leadership (Section 4.2.2).
- **Company action:** Collaborate with research institutions – Significantly improve Australia's weak record of industry–research collaboration to drive technical leadership (sections 4.2.2).
- **Company action:** Integrate into global value chains – Significantly improve on Australian manufacturing's current poor links into global value chains, with one of the lowest levels in the OECD on backward linkages (Section 4.2.4).
- **Knowledge Priority:** Understand the research and development Knowledge Priorities in areas of comparative advantage (Section 4.4.2).
- **Knowledge Priority:** Understand business improvement Knowledge Priorities (Section 4.4.3), including building better international linkages, leveraging government procurement and closing the management capability gap.

A ANNEX A – GROWTH CENTRES INITIATIVE

Objective: Improving management and workforce skills

This section outlines how the actions recommended in Section 4 map to the objective for the Growth Centre program.

- **Company action:** Lift the skill intensity of the manufacturing workforce – Capitalise on Australia's c.40% cost advantage in high-skilled labour to drive technical leadership (Section 4.2.1).
- **Company action:** Lift management capabilities – Close the deficit in management quality to improve productivity and reduce costs (Section 4.2.4).
- **Company action:** Increase business expenditure on R&D – Lift Australia's business-led R&D into the top half of OECD nations to drive technical leadership (Section 4.2.1).
- **Company action:** Collaborate with research institutions – Significantly improve Australia's weak record of industry–research collaboration to drive technical leadership (sections 4.2.1 and 4.2.3).
- **Knowledge Priority:** Understand business improvement Knowledge Priorities (Section 4.4.3), including closing the management capability gap and understanding current and future workforce skills requirements.

Objective: Improve engagement between research and industry, and within industry, to achieve stronger research coordination and collaboration, and stronger commercialisation outcomes

This section outlines how the actions recommended in Section 4 map to the objective for the Growth Centre program.

- **Government action:** Encourage greater collaboration between research and industry (Section 4.3.1).
- **Government action:** Improve the design of government support for business-led R&D
- **Company action:** Increase business expenditure on R&D – Lift Australia's business-led R&D into the top half of OECD nations to drive technical leadership (Section 4.2.1).
- **Company action:** Collaborate with research institutions – Significantly improve Australia's weak record of industry–research collaboration to drive technical leadership (sections 4.2.1 and 4.2.3).
- **Knowledge Priority:** Understand the research and development Knowledge Priorities (Section 4.4.2) in the areas of robotics and production processes; advanced materials and composites; digital design and rapid prototyping; sustainable manufacturing; additive manufacturing; sensors and data analysis; materials resilience and repair; bio manufacturing; precision manufacturing; and augmented or virtual reality systems.
- **Knowledge Priority:** Understand business improvement Knowledge Priorities (Section 4.4.3).

Objective: Identify regulations that are unnecessary or over-burdensome for the manufacturing sector and its ability to grow, and suggest possible reforms

This section outlines how the actions recommended in Section 4 map to the objective for the Growth Centre program.

- **Government action:** Adopt an amended methodology to define and measure the success of the manufacturing sector and capture the wider impact of manufacturing (Section 4.3.1).
- **Government action:** Use smarter procurement programs that enable innovation, collaboration and links into global supply chains (Section 4.3.2).
- **Government action:** Improve government support for business-led R&D and encourage industry–research collaboration (Section 4.3.1).
- **Knowledge Priority:** Understand business improvement Knowledge Priorities (Section 4.4.3).

B ANNEX B – METHODOLOGY

DETAILED METHODOLOGY: PRODUCT COST

Method

This study modelled a hypothetical firm's profit and loss (P&L) statement and solved for price to generate a fixed return on invested capital.

The price solved to generate Earnings Before Interest and Taxes (EBIT) was equivalent to Return On Invested Capital (ROIC). This approach has the benefit of factoring in both cost/operating profit margin and differences in capital intensity.

The model assumes 10% cost of capital.

The relative weight of each cost category for aerospace and medical technology companies was estimated using detailed data from the 2014 US Census of Manufacturers (Table 1).

The US Census of Manufacturers contains detailed information on financial metrics for US industries at the 6-digit level (e.g., aircraft and aircraft engines are listed as separate industries). Metrics include figures such as the number of employees, employee costs, production labour costs, electricity costs, materials costs and capital expenditure.

This detailed sub-sector-level financial information was used to develop a reference P&L for a hypothetical manufacturing firm in each sector (aerospace or medical technology), as shown below.

Transport costs were calculated separately as product shipping data was not available in the Census of Manufacturers, and is detailed in the following section.

For each cost category, industry-specific benchmarks were used to identify the relative cost (higher or lower) for Australian firms, resulting in an overall product cost impact, which is detailed in the following section.

Table 1

Breakdown of costs	Aerospace (%)	Medical technology (%)
Employee costs	24.40	30.90
Energy costs	0.70	0.60
Materials costs	61.20	49.20
Capital costs (excluding rental/lease)	2.20	3.30
Overheads (including rental/lease)	11.20	16.03

Definitions

Productivity-adjusted labour: The total amount spent on labour as an input, factoring in both changes in wages (price per hour of labour) and labour productivity (hours of labour per unit of output).

Inputs: The total cost of materials, including both raw materials and sub-assemblies.

Energy: The cost of electricity and gas used in both production and general operations.

Transport: The cost of delivering a typical product to a major overseas market, including local transport, port fees and customs.

Tax: Corporate tax rates payable in the respective countries.

Capital: Capital employed in the business, inferred from depreciation spend at 10%.

Overheads: Sales and general and administrative expenses, including rent.

Relative cost estimates

The comparable Australian cost was calculated by estimating the differential in each component separately against an international benchmark.

Productivity-adjusted labour: Differences in industry hourly wages and differences in labour productivity were compared to compute the *total* cost difference of producing a similar product in different countries. Two methods for each component were averaged, given challenges with cross-country labour productivity comparisons. See Exhibit B.1.

For labour productivity, comparisons were made using: 1) ABS Series 8155.0 and US Census of Manufacturing 2014 data by dividing FY14 industry value added by employment, correcting for hours worked and typical number of weeks leave and using the FY14 exchange rate; and 2) the EU KLEMS data set, a cross-country data set designed for these types of comparisons; however, it is only available up to 2005. Values after 2005 were projected using productivity indices for each country (at sub-industry level for US productivity and at the 1-digit level for Australia).

For wages, comparisons were made using: 1) ABS and US census data; and 2) KMPG/Mercer data on wages from the 2016 *Competitive Alternatives* report. The ABS/census data was corrected for typical hours worked and average number of weeks leave. Method one involved the following calculations:

- Occupation data from Australia (ABS Census) for both medical technology and aerospace manufacturing was used to estimate the mix of occupations in each industry.
- Wages data by occupation was obtained for Australia (Employee Earnings and Hours, ABS 6306.0) and matched to the industry occupation mix to estimate average wages for high-skill (defined as 'professional' and 'managerial') and lower-skill workers in each industry.
- Wages data by worker skill level, defined by production versus non-production workers, was calculated directly for each industry in the US (Census of Manufacturing data).

Inputs: The share of imported inputs was calculated for each sub-industry using the ABS's input–output tables (aerospace was 44% and medical technology was 55%). A markup due to transport costs was assumed for the imported input components, and was based on the calculated figure for transport as a percentage of costs overall.

Energy: A direct comparison of electricity unit costs were drawn from the BCG Global Manufacturing Cost-Competitiveness Index.

Transport: Differences in transport costs to end users were calculated using two approaches. The first involved using comparison values by country from a KPMG *Competitive Alternatives* report, which infers a typical demand distribution for each industry. The second approach was to build up freight costs from unit estimates, considering the proportion of air freight versus sea freight, and using estimates of cost from factory to port, cost to export (World Bank data), cost to ship (per container for sea freight and per kilogram for airmail) and, finally, tariffs in destination markets. In each case, this was based on shipping from Australia or the US to Western Europe (Germany) as the second-largest market for medical technology and aerospace components.

Tax: The corporate tax rates payable in the respective countries were compared with the OECD average.

Overheads: The model assumes a scale-efficiency function with a power of 0.75. This is applied to an inferred measure of average firm size, based on OECD STAN firm size data by sub-industry.

Capital: The model assumes a fixed capital to labour ratio (K/L).

ANNEX B – METHODOLOGY

Exhibit B.1 – Appendix: Labour cost was calculated using averages of different methods for assessing both wage and labour productivity

Labour cost differential

Contribution in percentage points

Method		Aero	Med
A	1	10.4	9.0
A	2	1.7	9.7
B	1	6.5	-2.2
B	2	5.0	-1.5
Average values:		9.1	3.0

Labour productivity

AUS as % of US

Method		Aero	Med
A	ABS/ Census	64	53
B	KLEMS	55	77
Average:		60	65

Method notes:
- FY14 data, $0.92 AUD/USD, sub-industry average
- $VA/hr (37 vs 41.2hrs, 47 vs 48 weeks)[1]
- Consistent PPP US/Aus data, 2005, projected
- BLS index for aerospace, ABS for mfg overall

Wages

AUS as % of US

Method		Aero	Med
A	ABS/ Census	108	71
B	KPMG	69	73
Average:		89	72

Method notes:
- FY14 data, $0.92 AUD/USD, sub-industry average
- $Wages/hr (37 vs 41.2hrs, 46 vs 47 weeks)
- 2016 data on 42 roles by country
- Assumed role distribution for theoretical firm

Values used in model

Source: Product cost competitiveness model; ABS; BLS; KPMG Competitiveness Database; RBA; EU KLEMS

DETAILED METHODOLOGY: SIZE OF THE PRIZE

Method

The potential impact of different improvement measures was triangulated using top-down and bottom-up estimates. This is framed in terms of the difference in value between a base case and a growth scenario in full year 2026, where value is defined as the total value added from advanced manufacturing sub-industries. For the purposes of this estimate, advanced manufacturing was defined according to the current ABS method, with ANZSIC sub-divisions 18 (basic chemical and chemical product manufacturing), 23 (transport equipment manufacturing) and 24 (machinery and equipment manufacturing).[110]

Top down, the overall size of the prize was estimated as a 33% uplift by projecting forward at historic high growth rates. Bottom up, a series of estimates were made for each area of improvement (reduce costs, improve differential value and shift market focus) and averaged to produce a total estimate of 34%.

110 ABS series 8170.0 (2015), 'Characteristics of businesses in selected growth sectors, Australia, 2013–14'.

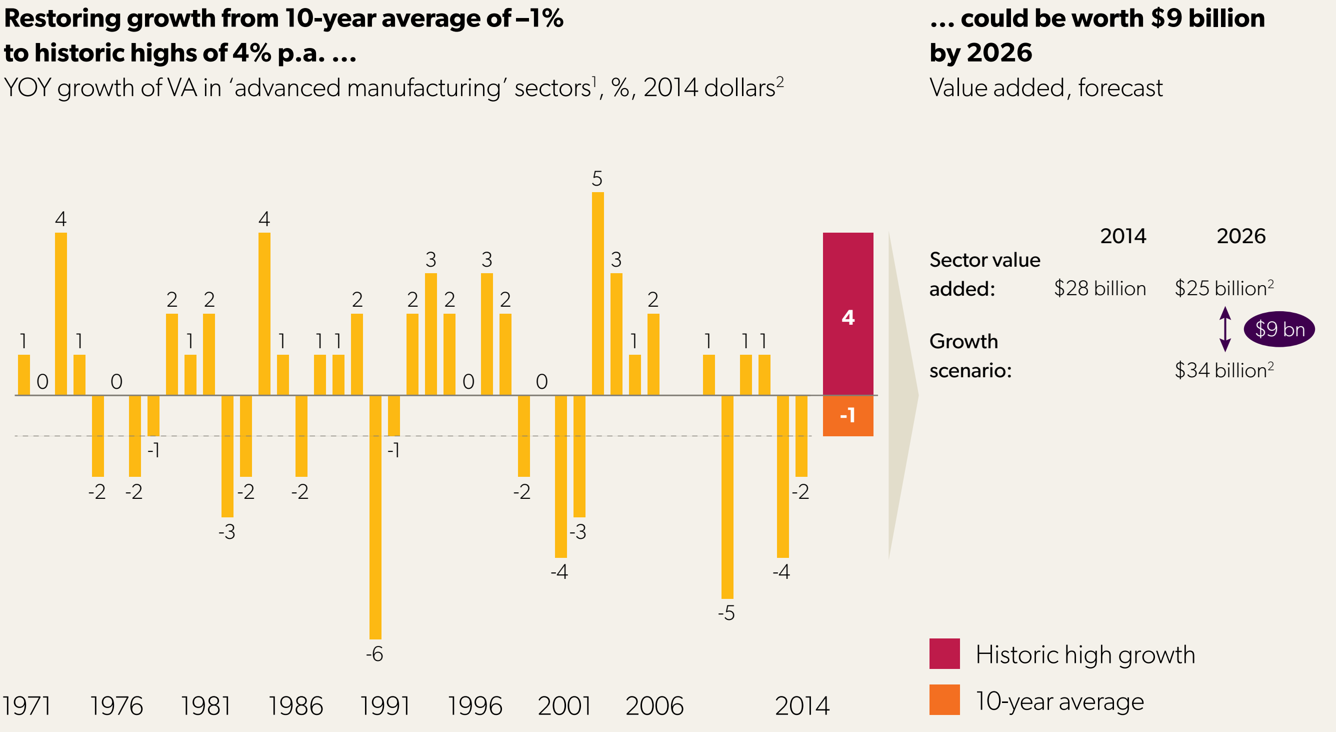
Top-down estimate

Base case growth for the sector was calculated to be -0.9% (real) and +1% (nominal) and projected to 2026 as follows:

- Value added data for advanced manufacturing sub-divisions was drawn from 2006–14 ABS series 8155.0. Historic data (1970–2005) was drawn from the OECD STAN database.[111]
- The annual values were converted to real (inflation-adjusted) dollars using the RBA's inflation calculator tool.[112]
- The year-on-year growth rates were calculated as a percentage change in value from the prior year.
- The base case growth was projected using 2006–14 CAGR as the average annual growth rate through to 2026. The growth scenario was projected by ramping growth (in current dollars) to historic highs of 4% per annum and projecting growth to 2026 accordingly.
- Growth (in current dollars) was ramped from -0.9% to historic highs of 4% per annum over the 10-year period, in linear increments.

We calculate the difference between base-case projections (projections at 2006–14 CAGR) and estimates (a historic high rate of 4% p.a.). The net result of this is a top-down estimate of A$9.3 billion in increased value added in 2026 (with a base case of A$25.3 billion and an upside case of A$34.6 billion, both in 2016 dollars), as shown in Exhibit B.2.

Exhibit B.2 – Top-down estimate: Restoring growth from 10-year average of –1% to historic highs of 4% p.a. could be worth $9 billion in value add by 2026



1 For 2007 onwards, ANASIC sub-divisions 18, 23 and 24 as per ABS definition of advanced manufacturing sector; for 1970–2006, ISIC rev 3 C23T25 Chemical, rubber, plastics and fuel products, C29T33 Machinery and equipment and C34T35 transport equipment

2 2014 real dollars; deflated using RBA calculator

3 Base case projects – 1% growth compounding over 10 years, growth scenario projects linear ramp up to 4% growth rate over period

Source: ABS Series 815540 'Australian Industry'; OECD STAN database; RBA calculator; AlphaBeta/McKinsey analysis

111 OECD STAN Database for Structural Analysis

112 RBA Inflation Calculator. Available at: www.rba.gov.au/calculator/annualDecimal.html

B ANNEX B – METHODOLOGY

Detailed bottom-up analysis

To calculate the bottom-up methodology, a series of estimates were made for each of the three areas of improvement (reduce costs, improve differential value and shift market focus) and averaged to produce a total estimate of 34%. For each area, three to five different measures were used to estimate the potential value at stake, as shown in Exhibit B.3.

For direct product cost, the first two estimates calculated the profit uplift for firms if they banked savings from closing the labour productivity gap by 50%. This was calculated as a total percentage uplift for both aerospace and medical technology, and then projected across the entire advanced manufacturing cost base. The third and fourth scenarios took the average uplift value and assumed that it was instead passed on as cost reduction to customers. Assuming demand elasticities of between 2 and 4 (the high and low range used for these two estimates), price reductions were translated into uplifts in value added.

For differential value, the first two estimates were based on lifting performance in export categories in each sub-industry (across the advanced manufacturing segments defined by the ABS) to either the highest level of Revealed Comparative Advantage (RCA) for aerospace or the average level for Medical Technology (a stronger performing export sector overall). The third approach looked at a sample of Australian medical technology firms for differences in profitability between the most innovative export successes and the average of the entire set, and projected this uplift across the entire sector. To estimate the value of shifting to the more service-based parts of the value chain, we lifted the proportion of high-skill research and design workers to US comparable levels. This was treated as an increase in employment, from which additional value added was calculated as the product of new roles and wages for high-skill roles. The total uplift was calculated for aerospace and medical technology separately and then projected as an average percentage uplift across the industry.

Finally, for market focus, each section was estimated separately.

To calculate the value of increased export market access, we based our estimates on average uplift for aerospace or medical technology in markets where Australia is underweight. For each, estimates were based on closing the gap between Australian exports for the category and Australia's average share of that category in each of the top 10 world import markets. This was done using 4-digit HS code data from UN Comtrade, which provides detailed breakdowns of Australian exports by country, and data on total imports by country for each category.

To estimate the value of drawing greater value added from higher-skill intense industries, we lifted Australia's proportion of value added derived from high-skill industries. The first method was based on lifting in sub-industries where Australian manufacturing has a skill deficiency relative to the US; the second approach focused on sub-industries that were the most skill-intense in the US. In each case, these sub-industries were lifted to the US share of the economy. However, sub-industries with poor definitional matches between Australia and the US (at the level of data available, given full concordance requires more detailed industry breakdowns to enable matching) were excluded, as were those where Australia had a small starting position (<$100 million in value added).

Detailed methodology: Defining advanced manufacturing

In developing the definition of advanced manufacturing, we followed a three-step process, seeking to identify 'more advanced' firms by both the characteristics they display and outcomes they achieve (see Exhibit B.3). First, we identified 'advanced characteristics', developing a long list based on expert interviews, workshops with the Department of Industry, Innovation and Science, and a literature review. This list was narrowed down based on measurability, including the use of proxies or inference. The shortlist of advanced characteristics comprised:

- **Advanced knowledge**, including R&D expenditure, ICT intensity, patent portfolio, collaboration with research institutions, collaboration with other firms, wage levels, employee qualifications and STEM skill intensity
- **Advanced processes**, including capital intensity, equipment age, level of automation, inventory management, energy intensity, water consumption and recycling rate

- **Advanced business models**, including product-value density, marketing spend, trade intensity, degree of backward linkages, geographical reach and share of services in total revenues.

Second, we ranked all firms by their success, defining 'success' by a number of outcome metrics including total factor productivity, gross margin, return on investment, EBIT margin and labour productivity.

Third, we determined the prevalence of these characteristics in more successful versus less successful firms to establish a shortlist of the most effective advanced characteristics.

To define success, we selected total factor productivity[113] as the primary measure and checked this against four other success metrics to observe whether similar firms demonstrated success on the other metrics. We selected total factor productivity as the primary metric as it is more comprehensive than labour productivity (including capital productivity) and represents a key driver of competitiveness in Australian firms. To analyse successful firms, we used a global database, Compustat, of 3,040 manufacturing firms with firm-level indicators.[114] For each of the success metrics, missing values and outliers were removed and the top quartile of performers were identified (Exhibit B.3).[115]

We found that firms that were top performers in gross margin, EBIT, ROI or labour productivity were also more likely to be top performers in total factor productivity (Exhibit B.4). This confirmed the utility of using total factor productivity as a primary success metric.

Exhibit B.3 – Success was defined by five metrics – total factor productivity, gross margin, ROI, EBIT and labour productivity

Total number of firms **3,040**[1]	**Total factor productivity metrics**	**Gross margin metrics**	**ROI metrics**	**EBIT% metrics**	**Labour productivity metrics**
1 **Removing missing values**	1,965	2,695	2,263	2,324	2,628
2 **Removing outliers**[2]	1,893	2,380	2,113	2,037	2,411
3 **Identifying top quartile**	**474** (A)	**474** (B)	**529**	**510**	**603**

3 approaches as to how we determine 'successful firms' (3)

A Assessing 'success' as top quartile TFP will give **474** firms

A Assessing 'success' as top quartile gross margin will give **595** firms

A Assessing 'success' as top quartile in at least two of TFP, GM, ROI or EBIT will give **574** firm

1 All firms in Compustat database that are primarily classified as manufacturers. Refer to appendix for details on calculation of success metrics

2 Outliers are selected and removed based on the criteria of being 3.5 times the median absolute deviation away from the median.

Source: Compustat, AlphaBeta/McKinsey analysis

113 Total factor productivity measures the joint productivity of capital and labour. It is not directly observable or measurable, and so was derived using the residual of the regression of gross value added against capital and labour.

114 We included all firms in the Compustat database that are primarily classified as manufacturers.

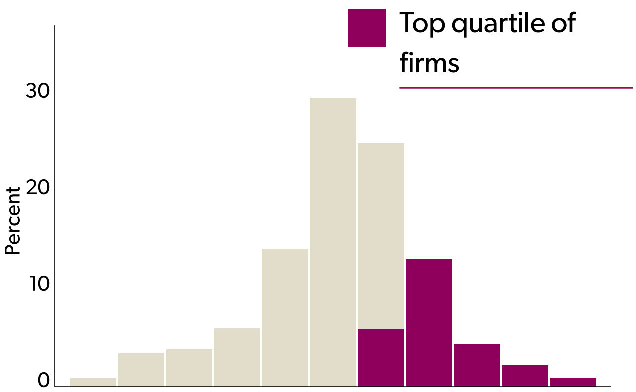
115 Outliers were selected and removed based on the criteria of being 3.5 times the absolute deviation away from the median.

Exhibit B.4 – Top-performing firms for gross margin, EBIT, ROI or labour productivity are also more likely to be a top performers in total factor productivity

Primary success metric

Total factor productivity (TFP)[1]

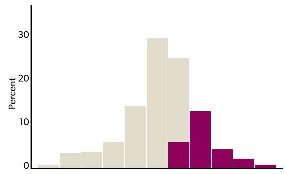
Total factor productivity was selected as the primary success metric as it is the key driver of competitiveness for Australian firms. It is more comprehensive than labour productivity, considering both labour and capital.



Secondary success metrics

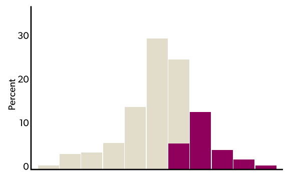
Gross margin

Firms in top quartile are **2 times** more likely to be in top quartile of TFP.



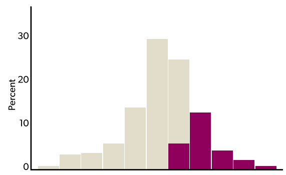
EBIT% (EBIT/total sales)

Firms in top quartile are **3.2 times** more likely to be in top quartile of TFP.



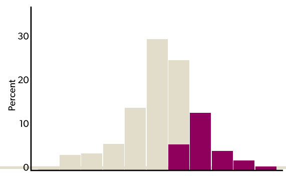
ROI (EBIT/average total investment)[2]

Firms in top quartile are **3.4 times** more likely to be in top quartile of TFP.



Labour productivity

Firms in top quartile are **3.7 times** more likely to be in top quartile of TFP.



1 Total factor productivity measures the joint productivity of capital and labour. It is not directly observable or measurable, and so was derived by the residual of the regression of gross value added against capital and labour.

2 Average total investment calculated by average capital expenditure over 2013–15.

Note:

All data has been adjusted to account for industry effects by calculating the mean at the 3-digit sub-industry level and subtracting it from the individual firm outcome.

Source: Compustat, AlphaBeta/McKinsey analysis

Cluster analysis demonstrates there are different strategies for advancement

Research and expert interviews conducted to support the revised definition and the AMGC's Sector Competitiveness Plan revealed multiple formulas for advancement. Thus, in revising the definition, we wanted to ensure it would reflect that firms pursue a number of different strategies to achieve success and advancement in manufacturing. We then used cluster analysis to quantitatively test this hypothesis.[116] Specifically, we performed a cluster analysis of five characteristics – R&D intensity, capital efficiency, automation, share of services and value density – to determine whether firms 'clustered' around particular intensities of characteristics (Exhibit B.5). We saw evidence of manufacturers pursuing different strategies for success and advancement.

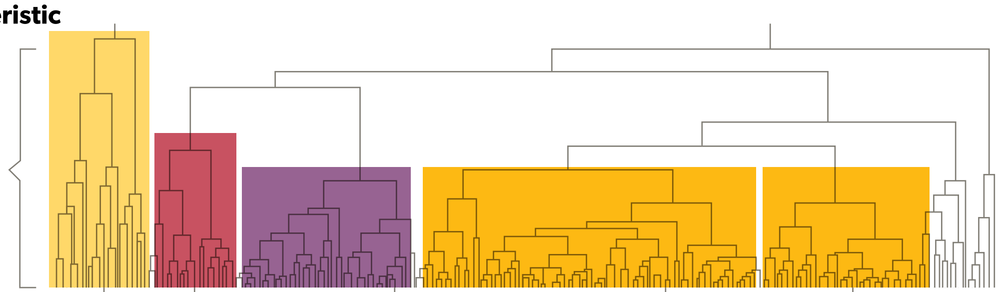
116 We developed hierarchical clustering by constructing a dissimilarity matrix, which contains dissimilarity scores for any pair of firms. The dissimilarity scores are based on the distances among the set of variables (R&D intensity, value density, share of services, and automation and labour productivity). For any pair of firms, the further these metrics are from each other the more dissimilar each firm is. We then created a dendrogram, where firms at the bottom have a smaller distance from each other (hence, they are less dissimilar), and firms further up have a greater distance (hence, they are more dissimilar). The different clusters were selected by cutting the dendrogram at select points.

- Firms exhibit different combinations of advanced characteristics to be successful, which are:
  - Knowledge differentiation: firms that use a high product value density (52% versus 25% in the median), capital efficiency and R&D intensity could be differentiating through product. Higher product value density would indicate superior product value or performance differentiation.
  - Process differentiation: firms that have high R&D intensity (26% versus 7% in the median), capital efficiency and high levels of automation could have sophisticated firm processes.
  - Business model differentiation: firms that differentiate based on a share of services that is significantly above the median (42% versus 6% in the median) could be winning by driving revenue uplift through service offering.
- Firms that appear to be successful using non-advanced factors (thus, less relevant to the definition), which are:
  - Low value density products: given that these firms are successful without ranking highly on any of the characteristics – and they hold a very low product value density – it is likely they represent industries that have an advantage through proximity of production to demand. For example, cement and bricks are usually locally produced due to their low value-to-weight ratio.
  - Non-advanced: a clear group is yet to emerge for these firms; however, it is possible this group represents a second set of less advanced firms that have an advantage through market regulation or other structural features.

Exhibit B.5 – Initial cluster analysis confirms that there are different strategies for successfully deploying more advanced characteristics

Median value by characteristic

Performing a cluster analysis of key characteristics, some clear groupings of firms formed[1]



	Overall					
R&D intensity	7.2%	**14.7%**	**8.7%**	**26.4%**	**1.2%**	7.3%
Capital efficiency	3.54	**2.76**	**3.99**	**3.73**	**2.76**	3.41
Automation	27%	25%	**33%**	**37%**	**20%**	26%
Share of services	5.7%	**42%**	**1.5%**	**1.1%**	**0.2%**	**0.6%**
Value density	25	**31**	**52**	23	**6**	21
Defining attribute/s		Business model	Knowledge	Process	Low value density	Unclear – less advanced?

There appears to be a number of successful firms exhibiting differing combinations of advanced characteristics

Likely firms that are **successful but through non-advanced factors** such as market structure or trade-protected industries

Below overall median

Above overall median

1 Hierarchical clustering developed by constructing a dissimilarity matrix, which contains dissimilarity scores for any pair of firms. The dissimilarity scores are based on the distances among the set of variables (R&D intensity, value density, share of services, and automation and labour productivity). For any pair of firms, the further these metrics are from each other the more dissimilar each firm is. We then created a dendrogram, where firms at the bottom have a smaller distance from each other (hence less dissimilar), and firms further up have a greater distance (hence more dissimilar). The different clusters were selected by cutting the dendrogram at select points.

Source: Compustat, AlphaBeta/McKinsey analysis

B ANNEX B – METHODOLOGY

DETAILED METHODOLOGY: IDENTIFYING KNOWLEDGE PRIORITIES

The Knowledge Priorities outlined below are the result of our competitiveness analysis of the Australian manufacturing sector, a review of the existing literature and industry engagement, including consultations and a Knowledge Priorities survey.

The priorities will be routinely updated according to industry need. The AMGC will conduct an annual literature review and survey to update the priorities.

Analysis of manufacturing sector

The AMGC carried out competitiveness analysis of Australian manufacturing to help identify challenges and opportunities for the sector. The AMGC's Sector Competitiveness Plan identified the importance of firms increasing technical excellence in their products and expanding their value-adding services. The Knowledge Priorities for both R&D and business improvement are targeted towards helping firms compete on value.

Literature review

We added to our original analysis by consulting a wide variety of existing literature on the future of advanced manufacturing here and in international markets. Studies by the CSIRO, industry associations, universities and private firms were all consulted.[117] We also looked to the National Science and Research Priorities and Practical Research Challenges endorsed by the Commonwealth Science Council. Key international sources, including foreign governments, industry associations and organisations such as the OECD, supplemented the domestic analysis.

Industry engagement and survey

The AMGC has regularly consulted industry associations, manufacturing firms, and government and research organisations over the past year.

We also carried out an industry survey across firms, industry associations, research institutions and government agencies, which sought input on our proposed list of Knowledge Priorities. Participants were asked to evaluate the relevance of the proposed priorities, identify additional priorities and offer further comment on R&D and business improvement issues most affecting the industry. More than 50 organisations and companies responded to the survey.

117 CSIRO (draft, October 2016), 'Future of the Australian Advanced Manufacturing Industry – An Industry Roadmap'; CEDA (April 2014), 'Advanced Manufacturing: Beyond the Production Line'; White House (April 2016), 'Advanced Manufacturing: A Snapshot of Priority Technology Areas Across the Federal Government'; US National Science Foundation (2002), 'Workshop on Nanomanufacturing & Processing: Summary Report'; M. A. White (2011), 'Physical Properties of Materials'; Princeton University Press, 'The Properties of Materials'; Industry Canada (2006), 'The Canadian Biopharmaceutical Industry Technology Roadmap'.

Learn more

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Contact us

enquiries@amgc.org.au

Australian Government
Department of Industry, Innovation and Science

Industry Growth Centres

GERMANY TRADE & INVEST

INDUSTRIE 4.0

Smart Manufacturing for the Future

Foreword

One of 10 “Future Projects” identified by the German government as part of its High-Tech Strategy 2020 Action Plan, the INDUSTRIE 4.0 project represents a major opportunity for Germany to establish itself as an integrated industry lead market and provider.

At Germany Trade & Invest we have been monitoring developments in the intelligent manufacturing and production sector as part of our ongoing “GERMANY. SMART SOLUTIONS. SMARTER BUSINESS.” international marketing campaign. We are delighted to present in this brochure the first fruits of our own INDUSTRIE 4.0 labors as part of our commitment to helping establish Germany as a lead market and provider of INDUSTRIE 4.0 solutions and services. We would like to extend a heartfelt thank-you to our science and industry partners without whom this publication would not have been possible.

We now invite you to join us on a journey which will effectively reinvent industrial production as we know it; one in which value chains become value networks; and in which countless new markets and market opportunities are created. We now move into the age of integrated industry.

Dr. Benno Bunse
Chairman/CEO Germany Trade & Invest

Photo: DMG MORI AG (cover), Germany Trade & Invest, acatech/D.Ausserhofer, Jim Rakete (left to right)

INDUSTRIE 4.0 is the German strategic initiative to take up a pioneering role in industrial IT which is currently revolutionizing the manufacturing engineering sector. INDUSTRIE 4.0's strategy will allow Germany to stay a globally competitive high-wage economy. Hence, cyber-physical systems (CPS) improve resource productivity and efficiency and enable more flexible models of work organization. Companies that use CPS will have a clear advantage when it comes to recruiting the best employees, since they can offer a better work-life balance. Germany has the potential to develop its position as a leading supplier and to become the leading market for INDUSTRIE 4.0 solutions - thereby strengthening the German economy, intensifying international cooperation and creating new, internet-based markets.

Professor Henning Kagermann
President acatech –
National Academy of Science and Engineering

Spokesperson of the Communication Promoters Group of the Industry-Science Research Alliance and Co-Chair of the INDUSTRIE 4.0 Working Group

The Internet of Things is finding its way into production. Semantic machine-to-machine communication revolutionizes factories by decentralized control. Embedded digital product memories guide the flexible work piece flow through smart factories, so that low-volume, high-mix production is realized in a cost-efficient way. A new generation of industrial assistant systems using augmented reality and multimodal interaction will help factory workers to deal with the complexity of cyber-physical production and enable new forms of collaboration by digital social media. Since on-demand production of highly individualized products like cars or kitchens requires short logistic chains in the markets where they are used, production is guaranteed to remain the backbone of Germany's economic performance.

Professor Wolfgang Wahlster
CEO and Scientific Director of DFKI
(German Research Center for Artificial Intelligence)

Member of the Industry-Science Research Alliance and Chair of the INDUSTRIE 4.0 Working Group on Human Factors

Industry: Where we have been, where we are going

The world as we know and experience it today has been shaped by three major technological revolutions. The first Industrial Revolution, beginning in Great Britain at the tail end of the 18th century and ending in the mid-19th century, represented a radical shift away from an agrarian economy to one defined by the introduction of mechanical production methods.

The second period of radical transformation – with the advent of industrial production and the birth of the factory at the start of the 20th century – was no less precipitous; ushering in as it did an age of affordable consumer products for mass consumption. In the late 1960s the use of electronics and IT in industrial processes opened the door to a new age of optimized and automated production.

Today we stand on the cusp of a fourth industrial revolution; one which promises to marry the worlds of production and network connectivity in an "Internet of Things" which makes "INDUSTRIE 4.0" a reality. "Smart production" becomes the norm in a world where intelligent ICT-based machines, systems and networks are capable of independently exchanging and responding to information to manage industrial production processes.

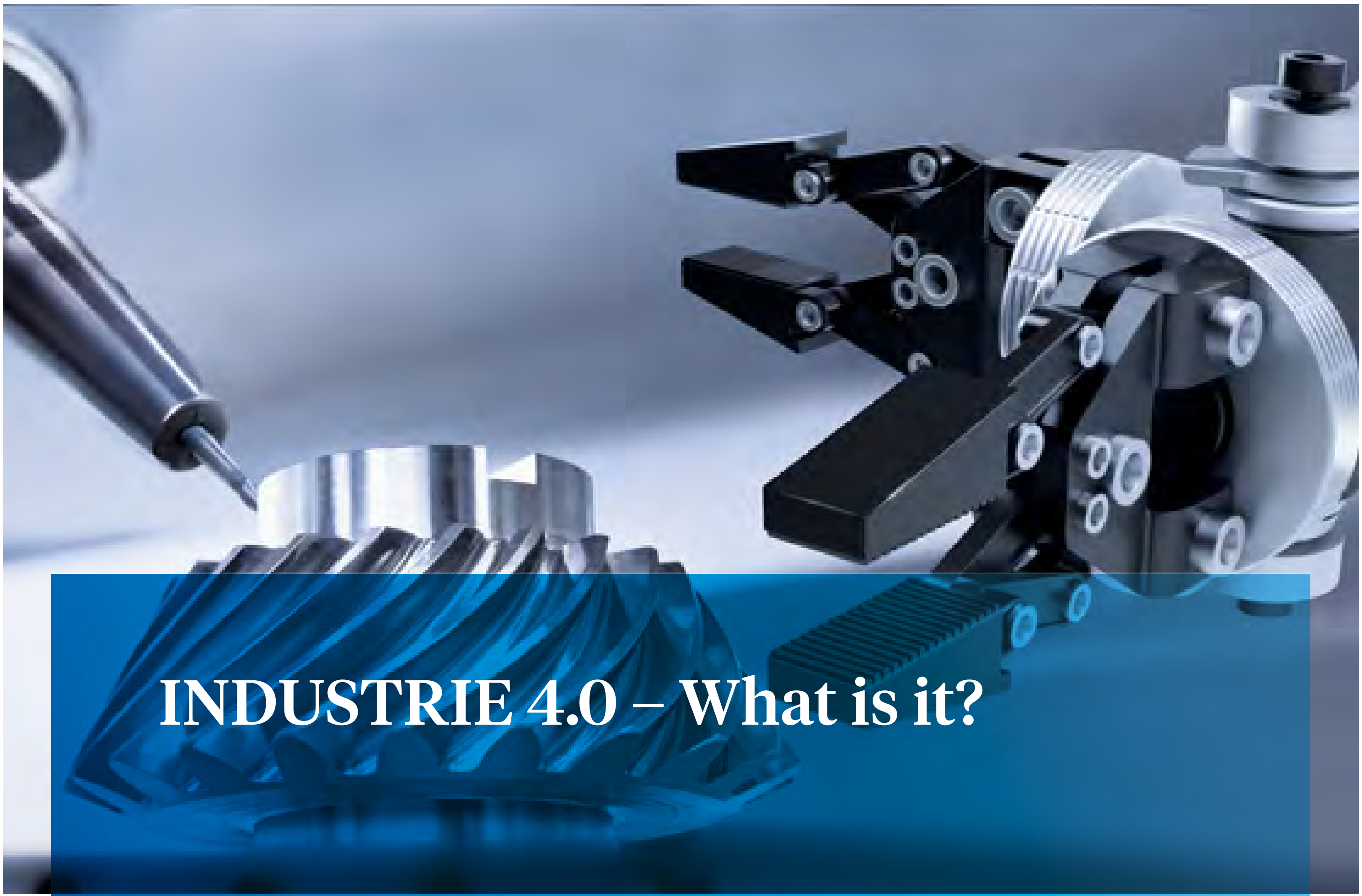
The conditions which make the fourth industrial revolution or INDUSTRIE 4.0 possible are unique to Germany. It is no idle boast to claim that nowhere else in the world do the required conditions necessary for the fourth industrial revolution exist. This brave new world of decentralized, autonomous real-time production being pioneered in Germany has its basis in two things: Germany's continued role as one of the world's most competitive and innovative manufacturing industry sectors; and the country's technological leadership in industrial production research and development.

Germany's position as an embedded systems technology leader gives birth to enabling cyber-physical system (CPS) technologies which ingeniously marry the digital virtual world with the real world. Cyber-physical production systems (CPPS) made up of smart machines, logistics systems and production facilities allow peerless ICT-based integration for vertically integrated and networked manufacturing.

One of 10 "Future Projects" identified by the German government as part of its High-Tech Strategy 2020 Action Plan to pursue innovation objectives over a 10 to 15-year period, INDUSTRIE 4.0 represents a major opportunity for Germany to secure its technological leadership role and establish itself as an INDUSTRIE 4.0 lead market and provider.

Germany has the ideal conditions to become a global leader in innovative, internet-based production technology and service provision. Technological leadership and vision in the fields of manufacturing, automation and software-based embedded systems, as well as historically strong industrial networks, lay the cornerstone for the long-term success of the INDUSTRIE 4.0 project.

Content



INDUSTRIE 4.0 – What is it?

INDUSTRIE 4.0 connects embedded system production technologies and smart production processes to pave the way to a new technological age.

What is smart industry and what does "INDUSTRIE 4.0" mean exactly? Smart industry or "INDUSTRIE 4.0" refers to the technological evolution from embedded systems to cyber-physical systems. Put simply, INDUSTRIE 4.0 represents the coming fourth industrial revolution on the way to an Internet of Things, Data and Services. Decentralized intelligence helps create intelligent object networking and independent process management, with the interaction of the real and virtual worlds representing a crucial new aspect of the manufacturing and production process. INDUSTRIE 4.0 represents a paradigm shift from "centralized" to "decentralized" production – made possible by technological advances which constitute a reversal of conventional production process logic. Simply put, this means that industrial production machinery no longer simply "processes" the product, but that the product communicates with the machinery to tell it exactly what to do.

INDUSTRIE 4.0 connects embedded system production technologies and smart production processes to pave the way to a new technological age which will radically transform industry and production value chains and business models (e.g. "smart factory").

Technological Background: Embedded Systems and Networks

Information and communication technologies (ICT) form the bedrock upon which tomorrow's innovative solutions are built. Embedded systems and global networks – like the internet and the data and services found there – are two major ICT motors driving technological progress. Embedded systems already play a central – if almost hidden – role in all of our lives.

More than 98 percent of all processors produced worldwide are deployed in regulator, control, and monitor functions in devices for all facets of daily life. For instance, they are there in everything from vehicle ABS and ESP systems, smart phone communication and information services and ordinary domestic household devices to industrial production plant systems. Embedded systems are the intelligent central control units at work in most modern technological products and devices. They typically operate as information-processing systems "embedded" within an "enclosing" product for a set range of device-specific applications. These "connect" with the outside world using sensors and actuators; allowing embedded systems to be increasingly interconnected with each other and the online world.

From Industry 1.0 to INDUSTRIE 4.0

First Industrial Revolution
Introduction of mechanical production facilities with the help of water and steam power

Second Industrial Revolution
Introduction of division of labor and mass production with the help of electrical energy

Third Industrial Revolution
Use of electronic and IT systems that further automate production

Fourth Industrial Revolution
Use of cyber-physical systems

Source: DFKI 2011

Germany – Embedded Systems Leader

Germany is an international leader in embedded systems and also enjoys a leading position in security solutions and business enterprise software. Germany also boasts an enviable engineering reputation in matters system solutions-related and can call upon considerable semantic technologies and embedded systems know-how.

Germany's embedded system market currently generates around EUR 20 billion annually, a figure which is forecast to rise to more than EUR 40 billion by 2020. The applications sector alone generates annual turnover in the region of EUR 4 billion, with an estimated value added factor of approximately EUR 15 billion. As such, Germany's embedded systems market is the third biggest in the world behind the USA and Japan.

National Roadmap Embedded Systems

In 2009 a group of more than 40 decision makers from important companies, research institutes and relevant industry associations came together to create the National Roadmap Embedded Systems for the further development of embedded systems technology.

Representatives from a number of industry sectors – including auto construction, automation technology, and machine and plant manufacturing – will spend more than EUR 2.5 billion in six research areas over the ten-year lifetime of the project.

Photo: DMG MORI AG

Cyber-Physical Systems

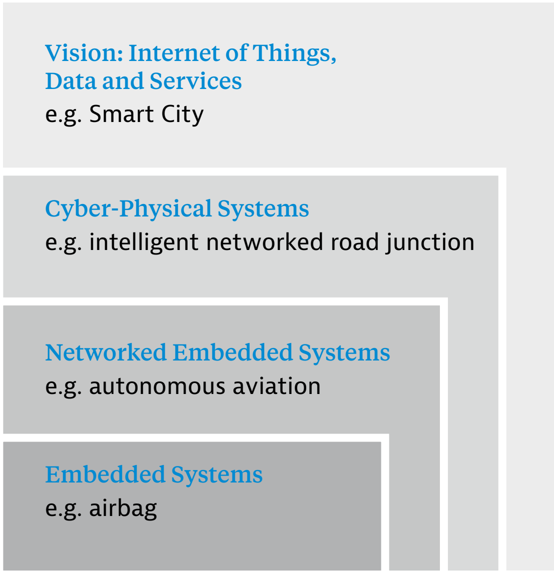
Cyber-physical systems (CPS) are enabling technologies which bring the virtual and physical worlds together to create a truly networked world in which intelligent objects communicate and interact with each other. Cyber-physical systems represent the next evolutionary step from existing embedded systems. Together with the internet and the data and services available online, embedded systems join to form cyber-physical systems.

Cyber-physical systems provide the basis for the creation of an Internet of Things, which combines with the Internet of Services to make INDUSTRIE 4.0 possible. They are "enabling technologies" which make multiple innovative applications and processes a reality as the boundaries between the real and virtual worlds disappear. As such, they promise to revolutionize our interactions with the physical world in much the same way that the internet has transformed personal communication and interaction.

The interplay between high performance software-based embedded systems and dedicated user interfaces which are integrated into digital networks creates a completely new world of system functionality. Modern mobile telephones are perhaps the most obvious example of this, offering as they do a complete bundle of applications and services which completely outstrip the device's original telephony function. Cyber-physical systems also represent a paradigm break from existing business and market models, as revolutionary new applications, service providers and value chains become possible.

Industry sectors including the automotive industry, the energy economy and, not least, production technology ("INDUSTRIE 4.0") for example, will in turn be transformed by these new value chain models. Global megatrends of globalization, urbanization, demographic change and energy transformation are the transformative forces driving the technological impulse to identify solutions for a world in flux. In the future, cyber-physical systems will make contributions to human security, efficiency, comfort and health in ways not previously imaginable. In doing so, they will play a central part in addressing the fundamental challenges posed by demographic change, scarcity of natural resources, sustainable mobility, and energy change.

The Evolution of Embedded Systems into the Internet of Things, Data and Services



Source: acatech 2011

Cyper-Physical Systems and the Internet of Things, Data and Services

The "The Evolution of Embedded Systems into the Internet of Things, Data and Services" illustration depicts the vision of a global "Internet of Things, Data and Services" through the evolutionary development of embedded system as a result of their being networked over the internet. Closed embedded systems (e.g. airbags) represent the starting point. Recommendations for the next step to locally networked embedded systems were already made in the National Roadmap Embedded Systems 2009. acatech's "Agenda CPS" study extended the spectrum to global networking (one example being the intelligent networked road junction that makes use of traffic jam information). Cyber-physical systems represent the next stage on the road to the creation of smart cities through the creation of an Internet of Things, Data and Services.

What does INDUSTRIE 4.0 mean for the software sector – ERP or MES?
INDUSTRIE 4.0 has sparked a debate within the German software industry as to whether enterprise resource planning (ERP) or manufacturing execution systems (MES) will establish themselves as the dominant software system force in production environments. Some industry voices believe that ERP software will be directly linked to process control systems (PCS) at the production level, thereby eliminating the need for ERP software. Conversely, a significant contingent considers MES software to be excellently situated for the implementation of INDUSTRIE 4.0.

In reality, the answer is not as clear cut, as INDUSTRIE 4.0 will also cause significant transformation in the field of production management software. However, because both traditional ERP and MES functionalities remain indispensable to production management, it remains unlikely that one software system will replace the other.

A more likely scenario is the increasing convergence of the two systems, with the line dividing corporate IT and production IT becoming blurred. This scenario matches the essence of interdisciplinary integration and the different stages of the product cycle foreseen in INDUSTRIE 4.0 (e.g. idea, development, production, service, and phasing out). Software systems utilized in INDUSTRIE 4.0 will also have to address new challenges including, for example, data correlations, as a result of ever more semantic networks and learning applications and the need to manage ever larger and more complex amounts of data.

ICT as Innovation Motor for all Fields of Demand – Relevance of the Internet of the Future

The Internet of Services
Cross-sectional themes applicable to all application scenarios:
semantic technologies, cloud computing, operator platforms for services

Industry	Energy	Mobility	Health	...
CPS Smart Factory Scenario	CPS Smart Grid Scenario	CPS Smart Mobility Scenario	CPS Smart Health Scenario	CPS ... Scenario ...

The Internet of Things
CPS cross-sectional themes applicable to all application scenarios:
security, long-term operations, engineering, training and advanced training,
standards and norms, reference architecture

Source: Germany Trade & Invest 2013 (based on “IKT als Innovationsmotor für alle Bedarfsfelder – die Relevanz des Internets der Zukunft” in “Bericht der Promotorengruppe Kommunikation – Im Fokus: das Zukunftsprojekt Industrie 4.0, Handlungsempfehlungen zur Umsetzung”, Forschungsunion 2012)

The Smart Factory – The Future of Automated Manufacturing

The merging of the virtual and the physical worlds through cyber-physical systems and the resulting fusion of technical processes and business processes are leading the way to a new industrial age best defined by the INDUSTRIE 4.0 project's "smart factory" concept.

The deployment of cyber-physical systems in production systems gives birth to the "smart factory." Smart factory products, resources and processes are characterized by cyber-physical systems; providing significant real-time quality, time, resource, and cost advantages in comparison with classic production systems. The smart factory is designed according to sustainable and service-oriented business practices. These insist upon adaptability, flexibility, self-adaptability and learning characteristics, fault tolerance, and risk management.

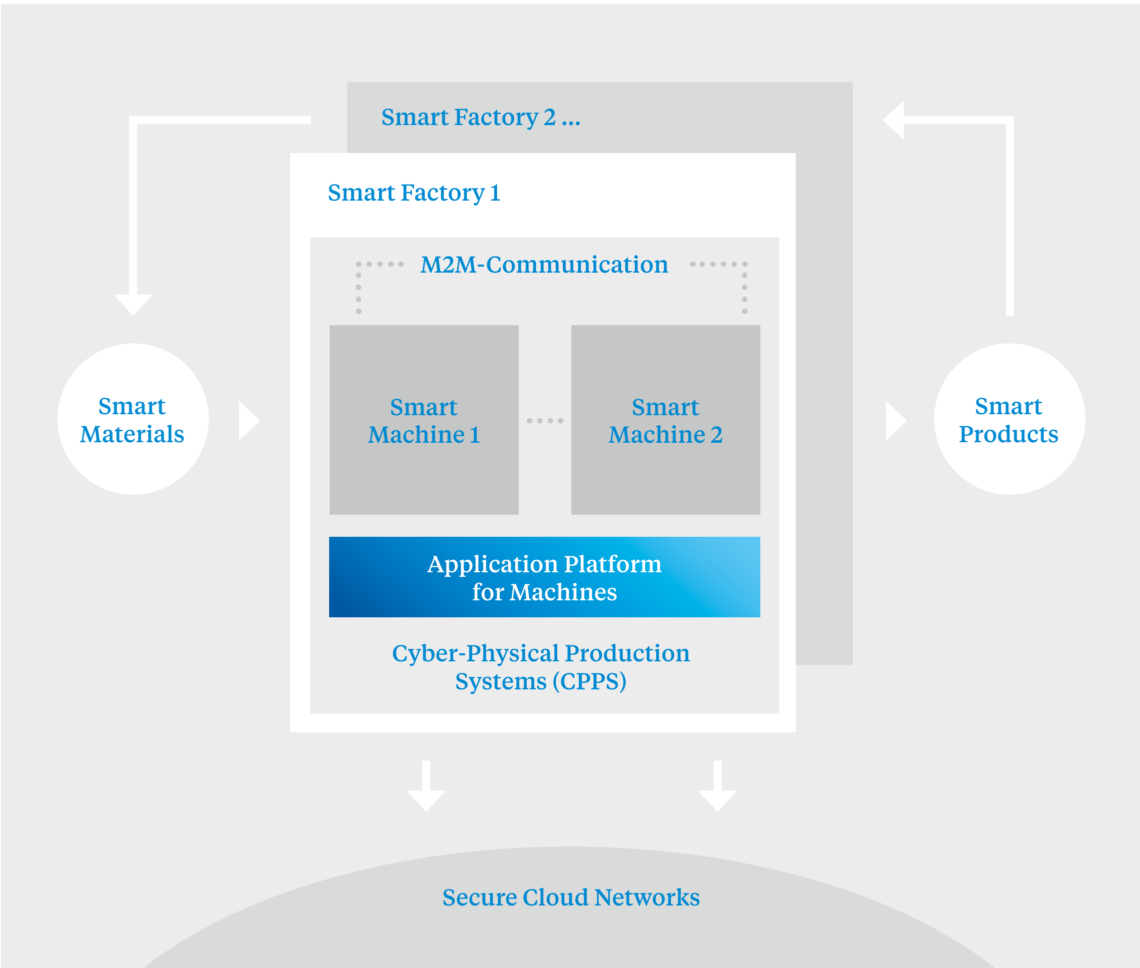
High levels of automation come as standard in the smart factory: this being made possible by a flexible network of cyber-physical system-based production systems which, to a large extent, automatically oversee production processes. Flexible production systems which are able to respond in almost real-time conditions allow in-house production processes to be radically optimized. Production advantages are not limited solely to one-off production conditions, but can also be optimized according to a global network of adaptive and self-organizing production units belonging to more than one operator.

This represents a production revolution in terms of both innovation and cost and time savings and the creation of a "bottom-up" production value creation model whose networking capacity creates new and more market opportunities. Smart factory production brings with it numerous advantages over conventional manufacture and production.

These include:

- CPS-optimized production processes: smart factory "units" are able to determine and identify their field(s) of activity, configuration options and production conditions as well as communicate independently and wirelessly with other units;
- Optimized individual customer product manufacturing via intelligent compilation of ideal production system which factors account product properties, costs, logistics, security, reliability, time, and sustainability considerations;
- Resource efficient production;
- Tailored adjustments to the human workforce so that the machine adapts to the human work cycle.

INDUSTRIE 4.0 Smart Factory Pipeline (cloud-based secure networks)



Source: DFKI 2012

Photo: Fotolia/Nataliya Hora

Policy Framework and Programs

A comprehensive package of complementary policy and funding programs and activities has been put in place in order to establish Germany as a lead market and provider of cyber-physical systems by 2020.

The High-Tech Strategy

Launched in August 2006, the "High-Tech Strategy" represents the first national concept to bring key innovation and technology stakeholders together in a common purpose of advancing new technologies.

The initiative combines the resources of all government ministries, setting billions of euros aside annually for the development of cutting-edge technologies (R&D projects can also count on generous financial support in the form of R&D grants).

High-Tech Strategy 2020

The objectives set out in the High-Tech Strategy were continued and extended within the framework of the "High-Tech Strategy 2020" launched in July 2010. Building on the initial successes of the High-Tech Strategy, this successor initiative intends to create lead markets, further intensify partnership between science and industry, and continue to improve the general conditions for innovation. The High-Tech Strategy 2020 exists to establish Germany as a lead provider of science and technology-based solutions in the fields of:

- Climate/Energy
- Health/Nutrition
- Mobility
- Security
- Communication

High-Tech Strategy 2020 Action Plan

The German government passed the High-Tech Strategy Action Plan in March 2012 for the further implementation of the High-Tech Strategy. The Action Plan identifies 10 "Future Projects" – including INDUSTRIE 4.0 – which are considered as being critical to addressing and realizing current innovation policy objectives as the focus of research and innovation activity. Within these lighthouse projects, specific innovation objectives will be pursued over a 10 to 15 year time frame. The INDUSTRIE 4.0 project has been allocated funding of up to EUR 200 million within the High-Tech Strategy 2020 Action Plan. The coalition agreement for the 18th legislative period signed by the newly constituted CDU-CSU-SPD coalition government of December 14, 2013, identifies the INDUSTRIE 4.0 future project as an important measure in consolidating Germany's technological leadership in the mechanical engineering sector. The coalition government plans to push ahead with the digitalization of traditional industry with expansion into the area of "Smart Services" foreseen, as well as the strengthening of projects and activities in the "Green IT" sector.

Germany – Lead Market for Cyber-Physical Systems 2020

As part of the country's INDUSTRIE 4.0 project, Germany aims to be the lead provider of cyber-physical systems by 2020. In marked contrast to many other industrialized nations, Germany has maintained a stable manufacturing labor force while integrating new technological developments into industrial products and processes at an early stage. A bridge between the real and virtual worlds is being created with the digital refining of everything from production facilities and industrial products to everyday products with integrated storage and communication capabilities, radio sensors and intelligent software systems. Boundaries between the real and virtual worlds are collapsing to create an Internet of Things. Germany's superior embedded system and cyber-physical systems know-how represents a major opportunity for industry in Germany to help shape the fourth industrial revolution (INDUSTRIE 4.0).

Agenda CPS

The objective of the Agenda CPS project led by the German National Academy of Science and Engineering (acatech) on behalf of the Federal Ministry of Education and Research (BMBF) is to establish an integrated CPS research agenda that allows Germany to shape this technological revolution as a lead market and provider in competition with other industrial and technological players.

Agenda CPS has identified four major fields of application up to the year 2025. These are "Energy" (cyber-physical systems for the smart grid); "Mobility" (cyber-physical systems for networked mobility); "Health" (cyber-physical systems for telemedicine and remote diagnosis); and, of course, "Industry" (cyber-physical systems for industry and automated production).

ICT 2020: Research for Innovations – IT Systems for INDUSTRIE 4.0

Innovative ICT research (including IT systems for INDUSTRIE 4.0) is provided by the Federal Ministry of Education and Research (BMBF) in its "ICT 2020 – Research for Innovations" program within the framework of the High-Tech Strategy 2020 and the federal government's "Digital Germany 2015" ICT strategy. Particular ICT research focus is concentrated in the area of ICT in complex systems (e.g. embedded systems), new business processes and production methods as well as the Internet of Things and Services. Research activities conducted in the area of IT systems for cyber-physical systems, the Internet of Things and Services, and INDUSTRIE 4.0 are all eligible for funding.

Software systems and knowledge processing research funding is divided into three specific categories:

- Embedded systems focusing in particular on software-intensive embedded systems with links to electronics, communication technology and microsystems technology;
- Simulated reality for grid applications and infrastructure, virtual/augmented reality and ambient intelligence, simulation, information logistics and software development for high-performance computing;
- Human/machine interaction with language and media technologies, bioanalogous information processing, service robotics and usability.

The three category research areas are complemented by the cross-sectional technologies of software engineering, reliability and security due to their specific focus on the strategic priorities of software-intensive embedded systems, grid applications and infrastructure as well as virtual/augmented reality. Applicant projects should be business-oriented and include cooperation with either university or non-university research institutions. Calls for applications are published on a case-by-case basis.

Autonomics for INDUSTRIE 4.0

The AUTONOMIK für INDUSTRIE 4.0 – Produktion, Produkte, Dienste im multidimensionalen Internet der Zukunft ("AUTONOMICS for INDUSTRIE 4.0 – Production, Products, Services in the Multidimensional Internet of the Future") technology program contributes to the implementation of the goals set out in the High-Tech Strategy 2020.

Priority areas include developing the next evolutionary steps for machines, service robots and other systems able to deal with complex tasks autonomously as the transition from ICT-based control mechanisms to autonomously acting components and systems ushers in a new age in which efficiency, cost effectiveness, and quality increase in new and flexible production infrastructures.

The technological development of the Internet of Things has already been covered in the Federal Ministry for Economic Affairs and Energy (BMWi) next generation media (new technologies and ubiquitous computing) and AUTONOMIK (autonomous, simulation-based systems for small and medium-sized enterprises) precursor projects which provided significant impulse to new products, services and business models in different application scenarios. Important developments in the field of semantic technologies applicable in the Internet of Applications and Services were also established in the BMWi THESEUS R&D funding project. The successor AUTONOMICS for INDUSTRIE 4.0 project has made EUR 40 million in funding available to companies and research institutions in order to advance intelligent interacting between ICT and industrial production in the areas of future-oriented production systems and production logic; future-oriented premium products (including service robots); and future-oriented, knowledge-intensive electronic services.

CyProS (Cyber-Physical Production Systems)

The CyPros (Cyber-Physical Production Systems) research project consisting of a consortium of actors from science and industry led by Wittenstein AG was initiated in 2012 in order to research and develop a representative spectrum of cyber-physical system modules for production and logistics systems for industrial use. Together with the underlying reference architecture, also to be developed during the course of the three-year project, these system modules will allow the manufacturing industry to realize a significant increase in productivity and flexibility which will also equip Germany to become the lead user and provider of such systems. This will allow the complexity of increasing competition to be controlled, but also lead to a sustainable and significant increase in productivity and flexibility of manufacturing companies through the development and introduction of cyber-physical production systems (CPPS). The resulting CPPS technologies will allow Germany to increase its competitiveness as an international production location as a result of improved productivity and flexibility, while simultaneously allowing CPPS to be introduced to the market as marketable products, thereby establishing the country as a lead CPPS provider.

CyPros follows three separate goal stages:

- Development of a reference architecture and a representative spectrum of cyber-physical system modules for production and logistics systems;
- Provision of universal practices, support tools and platforms for the introduction of cyber-physical production systems;
- Technical and methodological basis for the commercial operation of cyber-physical production systems and their implementation in the real production environment of a showcase factory.

RES-COM

Launched in June 2011 and funded by the Federal Ministry of Education and Research, the RES-COM project addresses automatized conservation of resources through highly interconnected and integrated sensor-actuator systems in an INDUSTRIE 4.0 context. Prototype scenarios for context-activated resource efficiency are being implemented. RES-COM adopts a completely new type of core technology based on active digital product memory and software service agents with embedded sensors and actuators. The project is overseen by the German Research Center for Artificial Intelligence (DFKI) in partnership with partners including SAP, Siemens, IS Predict, and 7x4 Pharma.

Actors and Institutions: A Selection

A number of important research and trade actors and institutions are working closely together to realize Germany's INDUSTRIE 4.0 vision.

Industry-Science Research Alliance

Initiated by the Federal Ministry of Education and Research (BMBF) in 2006, the Industry-Science Research Alliance is an advisory group which brings together 19 leading representatives from science and industry to accompany the High-Tech Strategy of interministerial innovation policy initiatives.

In January 2011, INDUSTRIE 4.0 was initiated as a "Future Project" of the German Federal Government by the Communication Promoters Group of the Industry-Science Research Alliance. The Industry-Science Research Alliance, in partnership with acatech – National Academy of Science and Engineering, established the INDUSTRIE 4.0 Working Group co-chaired by Dr. Siegfried Dais (Robert Bosch GmbH) and Professor Henning Kagermann (acatech president and spokesperson of the Promoters Group).

The Communication Promoters Group of the Industry-Science Research Alliance (Prof. Dr. Henning Kagermann, acatech; Prof. Dr. Wolfgang Wahlster, German Research Center for Artificial Intelligence – DFKI; and Dr. Johannes Helbig, Deutsche Post AG) in cooperation with acatech published the "Securing the future of German manufacturing industry: Recommendations for implementing the strategic initiative INDUSTRIE 4.0 – Final report of the INDUSTRIE 4.0 Working Group" report supported by the BMBF in April 2013.

acatech
NATIONAL ACADEMY OF SCIENCE AND ENGINEERING

acatech – National Academy of Science and Engineering

acatech – the National Academy of Science and Engineering – represents the interests of the German scientific and technological communities, at home and abroad. It is autonomous, independent and a non-profit organization. As a working academy, acatech supports policy-makers and society, providing qualified technical evaluations and forward looking recommendations. Moreover, acatech is determined to support knowledge transfer between science and industry, and encourage the next generation of engineers. acatech works to promote sustainable growth through innovation. Its work focuses on four core areas. Scientific recommendations: acatech advises policy-makers and the public on future technology issues based on best-in-breed research. Transfer of expertise: acatech provides a platform for exchanging excellence between the sciences and business. Promotion of young scientists and engineers: acatech is involved in the promotion of young scientists and engineers. A voice for science and engineering: acatech represents the interests of scientists and engineers at national and international levels.

www.acatech.de/uk

What role does your organization play in Germany's INDUSTRIE 4.0 project?

acatech – the National Academy of Science and Engineering – supports policy-makers and society by providing qualified technical evaluations and forward-looking recommendations. In 2010, acatech initiated a research project on cyber-physical systems – the technical core of INDUSTRIE 4.0. Initial implementation recommendations were formulated by the INDUSTRIE 4.0 Working Group between January and October 2012 under the coordination of acatech.

How does the INDUSTRIE 4.0 project contribute to the attractiveness of Germany as a location?

INDUSTRIE 4.0 marks a fundamental paradigm shift towards decentralized and individualized production cycles which will enable new, internet-based services and business models. INDUSTRIE 4.0 offers Germany the chance to further strengthen its position as a manufacturing location, manufacturing equipment supplier and IT business solutions supplier. All the stakeholders in Germany are now closely cooperating through the Plattform INDUSTRIE 4.0 in order to push implementation. Germany is well placed to become a global pacesetter in the area of INDUSTRIE 4.0.

What advantages does INDUSTRIE 4.0 have for small and medium-sized companies?

Germany's global market leaders include numerous "hidden champions" who provide specialized solutions – 22 of Germany's top 100 small and medium-sized enterprises (SMEs) are machinery and plant manufacturers, with three of them featuring in the world's top ten. INDUSTRIE 4.0 will also result in new ways of creating value and novel business models. In particular, it will provide start-ups and small businesses with the opportunity to develop and provide downstream services.

What impact will INDUSTRIE 4.0 have beyond Germany?

The fourth industrial revolution is a global trend. Many of Germany's competitors have also recognized this trend of using the Internet of Things in the manufacturing environment and are promoting it through a range of institutional and financial measures.

How can international companies profit from INDUSTRIE 4.0?

First, INDUSTRIE 4.0 will involve increased networking and cooperation between several different partners in international networks of value creation. To realize INDUSTRIE 4.0, a close international network between science, industry and universities is needed. INDUSTRIE 4.0 will address and solve some of the challenges the world is facing today such as resource and energy efficiency, urban production and demographic change.

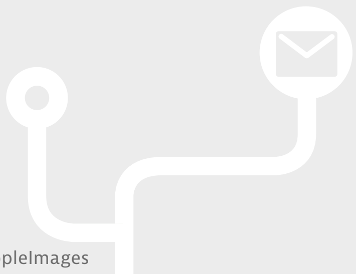


Photo: iStock/PeopleImages

German Research Center for Artificial Intelligence – DFKI

The German Research Center for Artificial Intelligence (DFKI) was founded in 1988 and has research facilities in Kaiserslautern, Saarbrücken, Bremen and a project office in Berlin. In the field of innovative commercial software technology using artificial intelligence, DFKI is the leading research center in Germany.

Based on application-oriented basic research DFKI develops product functions, prototypes and patentable solutions in the field of information and communication technology. Research and development projects are conducted in fourteen research departments and research groups, ten competence centers and five living labs. Funding is received from government agencies like the European Union, the Federal Ministry of Education and Research (BMBF), the Federal Ministry for Economic Affairs and Energy (BMWi), the German Federal States and the German Research Foundation (DFG) as well as from cooperation with industrial partners.

Apart from the state governments of Rheinland-Pfalz, Saarland and Bremen, numerous renowned German and international high-tech companies are represented on the DFKI supervisory board. The DFKI model of a non-profit public-private partnership (ppp) is nationally and internationally considered a blueprint for corporate structure in the field of top-level research.

DFKI is actively involved in numerous organizations representing and continuously advancing Germany as an excellent location for cutting-edge research and technology. Far beyond the country's borders DFKI enjoys an excellent reputation for its academic training of young scientists. At present, 413 highly qualified researchers and 272 graduate students from more than 60 countries are contributing to more than 232 DFKI research projects. Over the years, more than 60 staff members have been appointed professors at universities in Germany and abroad.

DFKI is on the forefront of INDUSTRIE 4.0 research. The SmartFactory Living Lab performs operation and testing of the latest technologies in process engineering and piece goods under industrial conditions. The project "RES-COM" examines the vision of an automatized conservation of resources through highly interconnected and integrated sensor-actuator systems.

"SmartF-IT" is looking at cyber-physical IT systems to master complexness of a new generation of multi-adaptive factories due to the intensive use of high-networked sensors and actuators, overcoming traditional production hierarchies of central control towards decentralized self-organization. Both projects are funded by the BMBF establishing Germany as one of the leading pioneers in the field of the Internet of Things.

www.dfki.de
www.facebook.com/DFKI.GmbH
www.smartf-it-projekt.de
www.res-com-projekt.de

How does the INDUSTRIE 4.0 project contribute to the attractiveness of Germany as a location? What impact will INDUSTRIE 4.0 have beyond Germany?

The Internet of Things is finding its way into production and revolutionizing existing manufacturing logic through high-resolution networking and extreme flexibility in the value chain. German mechanical engineering and plant manufacturers, who are international leaders, will profit from INDUSTRIE 4.0 as providers, as of course will the IT sector which is tasked with making production and business processes in real-time capable enterprise software solutions. On the INDUSTRIE 4.0 user side we primarily see auto manufacturers and suppliers as well as manufacturers of agricultural equipment, the packaging industry, and companies from the logistics sector. There will be no stand-alone solutions in the globally networked economy, but instead opportunities for global business innovation – with Germany preparing the path ahead.

What role does your organization play in Germany's INDUSTRIE 4.0 project?

The DFKI has already worked on the initial concepts for INDUSTRIE 4.0 as part of the Industry-Science Research Alliance advisory group. The partners work with policy makers on an equal footing in order to design and practically implement joint project of real societal importance. For several years the DFKI has, together with leading plant manufacturers, been operating the world's first so-called "smart factory" as a living lab which serves as a reference architecture for INDUSTRIE 4.0.

What advantages does INDUSTRIE 4.0 have for small and medium-sized companies?

INDUSTRIE 4.0 will be of paramount importance to small and medium-sized enterprises (SMEs). Flexible value chains will transcend departmental, business and company boundaries. As a result, SMEs can become temporary production networks with precisely calculated value added contributions. Continuous networking of course presents a challenge for security technology, but INDUSTRIE 4.0 allows client series and personalized products to be produced at unit costs previously only possible in mass production.

How can international companies profit from INDUSTRIE 4.0?

INDUSTRIE 4.0 is an industrial not a political revolution. That is to say, there will be no single defining event that takes place, but rather a period of dynamic development. New resource-efficiency optimization processes make environmentally friendly and urban production at acceptable costs possible in the near future – not only in Germany but across the world. INDUSTRIE 4.0 will therefore make a significant contribution to the biggest problems facing society; be it climate change, energy transformation or mega-city management.

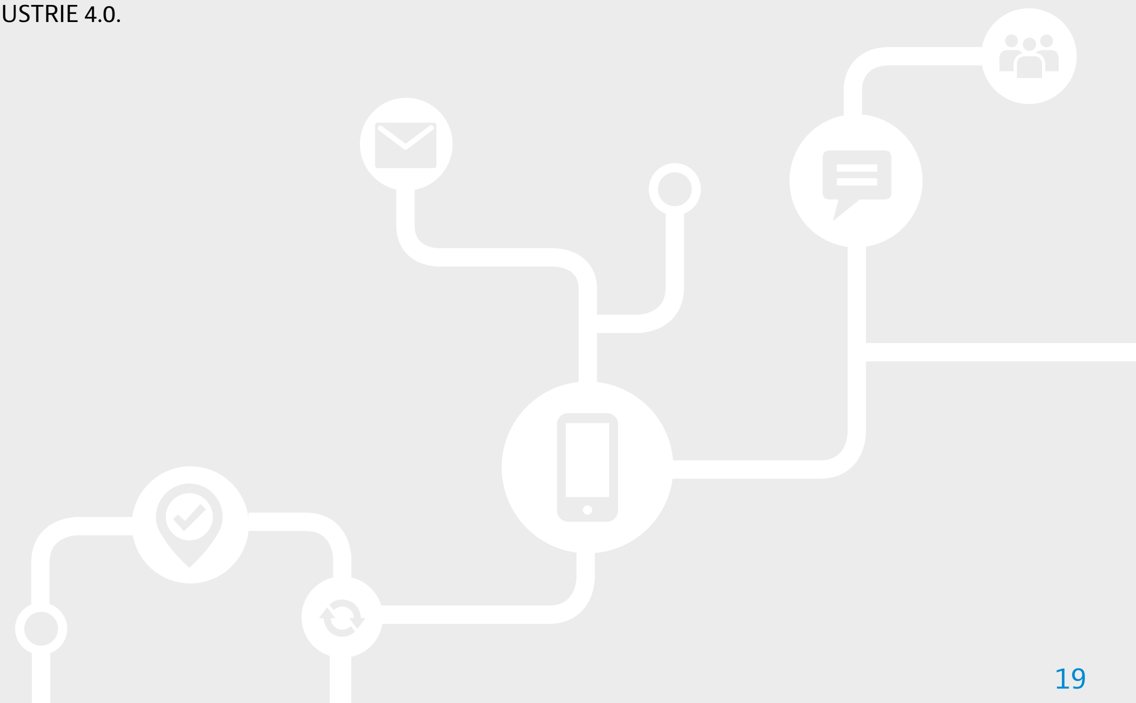


Photo: DFKI

Fraunhofer-Gesellschaft

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration.

At present, the Fraunhofer-Gesellschaft maintains 66 institutes and independent research units. The majority of the more than 22,000 staff are qualified scientists and engineers, who work with an annual research budget of EUR 1.9 billion. Of this sum, more than EUR 1.6 billion is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and federal state governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

Affiliated international research centers and representative offices provide contact with the regions of greatest importance to present and future scientific progress and economic development.

With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: Through their research and development work, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. They do so by promoting innovation, strengthening the technological base, improving the acceptance of new technologies, and helping to train the urgently needed future generation of scientists and engineers.

As an employer, the Fraunhofer-Gesellschaft offers its staff the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility within their institute, at universities, in industry and in society. Students who choose to work on projects at the Fraunhofer Institutes have excellent prospects of starting and developing a career in industry by virtue of the practical training and experience they have acquired.

The Fraunhofer-Gesellschaft is a recognized non-profit organization that takes its name from Joseph von Fraunhofer (1787–1826), the illustrious Munich researcher, inventor and entrepreneur.

www.fraunhofer.de

What role does your organization play in Germany's INDUSTRIE 4.0 project?
The Fraunhofer IAO* has been helping shape the INDUSTRIE 4.0 project since as early as 2011 as part of activities carried out by the Industry-Science Research Alliance. Since 2012 we have been working with industry partners in the area of highly flexible, self-organized capacity management as part of the publicly funded "KapaflexCy" (www.kapaflexcy.de/) INDUSTRIE 4.0 lead project. The current Produktionsarbeit der Zukunft – INDUSTRIE 4.0 ("Production of the Future – INDUSTRIE 4.0") pilot study lays the foundations for the Innovationsnetzwerk Produktionsarbeit 4.0 ("Innovation Network Production 4.0") in which Fraunhofer IAO is developing new applications and business models for INDUSTRIE 4.0 with industry and trade association partners.

How does the INDUSTRIE 4.0 project contribute to the attractiveness of Germany as a location?
With its innovative and leading mechanical engineering, automotive and electrical industries, Germany is a country with deep industrial roots that is already a world leader in embedded systems (the technological basis for INDUSTRIE 4.0). This provides the German manufacturing sector with the opportunity of following a dual strategy for the future. On the one hand, Germany can continue to build on its competitive position as a production country thanks to innovative factory concepts and INDUSTRIE 4.0 applications. On the other hand, Germany can become the global technology supplier for INDUSTRIE 4.0 factories.

What advantages does INDUSTRIE 4.0 have for small and medium-sized companies?
The German manufacturing environment is characterized by a large number of small and medium-sized enterprises (SMEs). These SMEs often produce highly innovative products for the rest of the world. New market segments will open up for these companies domestically and internationally with INDUSTRIE 4.0. Moreover, SMEs in particular stand to benefit from the standardized networking of their own production resources as many still work with proprietary systems. This will allow SMEs to drastically reduce production management efforts and respond in significantly faster fashion to market requirements.

What impact will INDUSTRIE 4.0 have beyond Germany?
INDUSTRIE 4.0 is not an issue that is limited just to Germany. There are similar approaches being carried out across the world which are being promoted under the names of "Internet of Things" and "Industrial Internet" for example. As well as manufacturing, these highlight many more everyday and routine fields of application for networked systems. However, the full potential of INDUSTRIE 4.0 can only be fully exploited through the global networking of production resources and the use of globally functioning applications. The identification and introduction of uniform standards is especially important in this respect.

How can international companies profit from INDUSTRIE 4.0?
Global sourcing and distributed processes are always associated with considerable coordination and management time and effort. INDUSTRIE 4.0 allows information to cover long distances in close to real time. International companies will therefore be able to quickly react to client requirements in globally distributed production systems as well as provide their customers with a current picture of production progress at all times.

What significance does INDUSTRIE 4.0 have for the future employment market? What impact will it have on the education and training of the workforce?
The operation of a factory according to the INDUSTRIE 4.0 principle requires workers with the relevant production and IT know-how. For the future it is important to create certified training courses in order to take interdisciplinarity to a new and highly innovative level. By means of just-in-time learning and just-in-time training, workers can be equipped for dealing with short-term, unplanned ad-hoc work activities with changing content on the job, thereby becoming qualified to solve problems as they are dealing with them.

* The Fraunhofer IAO is a member institution of the Fraunhofer-Gesellschaft. Fraunhofer IAO activities include applied research and development in the fields of engineering, IT, economics, and social sciences.

Photo: Fraunhofer IGD

it's OWL

In February 2012 the German Federal Ministry of Education and Research (BMBF) announced the "it's OWL" (Intelligent Technical Systems OstWestfalenLippe) high-tech strategy as one of the winners of its Leading-Edge Cluster competition.

it's OWL is a science and industry technology network which intends to set international standards in the field of intelligent technical systems. The cluster is helping pave the way to the fourth industrial revolution and makes a significant contribution to the competitiveness of manufacturing and production in Germany.

Tomorrow's technological systems will be intelligent and connected. This applies to the products of mechanical engineering sector and related industries such as the automotive industry, electrical engineering and medical as well as their corresponding production systems. Intelligent technical systems arise from the interplay of engineering and information technology. They interact with their environment and adapt to it autonomously. They also deal with unexpected situations in a dynamic environment and are able to anticipate the future effects of different influences thanks to experiential knowledge. Moreover, they also adapt to individual user behavior.

Within the it's OWL technology network, 174 companies – including world leaders such as Beckhoff, Claas, DMG MORI Aktiengesellschaft, Harting, Lenze, Miele, Phoenix Contact, WAGO, Weidmüller, and Wincor Nixdorf – and research institutions are carrying out pioneering work in this area. Intelligent products and production systems are being developed in 45 projects: from automation and drive solutions for machinery, automatons, vehicles and household devices to networked production facilities. Examples include self-correcting manufacturing processes, digitalization of work planning, energy efficient intralogistics for warehouses, resource-efficient industrial laundry as well as energy management in smartgrids.

The development, deployment, maintenance and life cycle management of products, machines and systems will be improved by it's OWL technologies and solutions. Their reliability, resource efficiency, and user friendliness will also be optimized, with individualized and adaptable production processes becoming reality.

www.its-owl.com

What role does your organization play in Germany's INDUSTRIE 4.0 project?
Mr. Roman Dumitrescu, chief executive it's OWL: The it's OWL (Intelligent Technical Systems Ost-WestfalenLippe) leading-edge cluster is currently the largest INDUSTRIE 4.0 project. Our intelligent technical systems provide a strong boost to Germany's competitiveness as a production location and pave the way to the fourth industrial revolution. INDUSTRIE 4.0 solutions are being developed in 45 different projects with a budget of around EUR 100 million. We see our strengths as being in industrial automation, human-machine cooperation and the realization of so-called 'self-x capabilities' like, for example, self-optimizing production systems.

How does the INDUSTRIE 4.0 project contribute to the attractiveness of Germany as a location?
The project clearly strengthens machine engineering as well as the electronics industry; industries which are thankfully still very strongly represented in Germany. In recent times these industry sectors have been dismissed as "old economy," with countries like Great Britain fully focusing on the service sector – something we now know to be a mistake. I believe that with INDUSTRIE 4.0 we have a unique opportunity to combine and play off our strengths to become not only the lead provider for production in the future but also to remain an important production location.

What advantages does INDUSTRIE 4.0 have for small and medium-sized companies?
The current state of affairs is that the subject seems a little far off for SMEs. I say "seems" very deliberately, as there are also companies who are already very successfully active in the INDUSTRIE 4.0 area. For example, MSF Vathauer Antriebstechnik – an it's OWL cluster member – won the Industry 2013 prize for its decentralized drive solutions for INDUSTRIE 4.0 application. SMEs certainly play a key role in Germany. That's why we have set up a EUR 5 million technology transfer project specifically for these companies in order to pass on INDUSTRIE 4.0 solutions.

What impact will INDUSTRIE 4.0 have beyond Germany?
It has certainly not gone unnoticed by other countries that Germany has fared comparably well despite the financial and economic crises of recent times. The reason for this is that we are still a strong production location. For instance, even the European Institute for Innovation and Technology (EIT) will invite tenders for a Knowledge and Innovation Community (KIC) in the area of "Value Added in Production" in 2016. I don't think this would have been the case without Germany's INDUSTRIE 4.0 initiative.

How can international companies profit from INDUSTRIE 4.0?
Quite simply: by buying our solutions. Because here they can access all of the components for future-proof production. International companies can of course also profit from these innovations. We should not forget that Germany has invested enormously in research and development for this success. That is the only reason why we now stand on the threshold of a fourth industrial revolution.

Photo: OstWestfalenLippe GmbH

Plattform
INDUSTRIE 4.0

Plattform INDUSTRIE 4.0

The Plattform INDUSTRIE 4.0 is a joint initiative of the industry organizations BITKOM (Federal Association for Information Technology, Telecommunications and New Media), VDMA (German Engineering Federation), and ZVEI (Electrical and Electronic Manufacturers' Association) and acts as a central point of contact for companies, employee representatives, politics and science in matters INDUSTRIE 4.0 related.

Officially launched at the Hannover Messe in April 2013, Plattform INDUSTRIE 4.0 will continue the work of the Federal Government's "Future Project INDUSTRIE 4.0" in order to strengthen Germany as an industry location. The main objective of the Plattform is the development of technologies, standards, business and organizational models and their practical implementation. The three industry organizations believe that INDUSTRIE 4.0 is of significant importance to the continued competitiveness of German industry.

The central office of the Plattform organizes and coordinates all Plattform INDUSTRIE 4.0 activities, informs on the progress made by the cooperation and serves as a main point of contact for business, politics and the media.

www.plattform-i40.de

What role does your organization play in Germany's INDUSTRIE 4.0 project?
Together, three leading industry associations are pushing the INDUSTRIE 4.0 theme forward. BITKOM, VDMA and ZVEI founded the Plattform INDUSTRIE 4.0 partnership which started operations in April of this year. The Plattform is based in Frankfurt am Main with a joint information portal and "virtual office" set up online. Plattform INDUSTRIE 4.0 will continue the work of the Federal Government's "Future Project INDUSTRIE 4.0" within the framework of the High-Tech Strategy. The main objective is the development and expansion of knowledge and understanding as well as the distribution of research results and their practical application in INDUSTRIE 4.0. The Plattform is intended as the central point of contact for all matters INDUSTRIE 4.0 related and, as such, will actively involve and/or participate with all relevant actors.

How does the INDUSTRIE 4.0 project contribute to the attractiveness of Germany as a location?
The INDUSTRIE 4.0 project builds bridges between manufacturing companies, providers, science, and politics. Cross-industry exchange of ideas and information help accelerate knowledge transfer for innovation in Germany. From the point of view of the three industry associations, INDUSTRIE 4.0 is of tremendous importance to the competitiveness of German industry. The term stands for networked – often with the internet over and beyond company borders – and connected industrial production. As a location we are strong in the development and application of production, automation, and embedded software-intensive IT and have longstanding and established industrial networks.

What advantages does INDUSTRIE 4.0 have for small and medium-sized companies?
From an overall economic perspective, SMEs in particular account for a significant share of employment and value creation in Germany and, as such, are of central importance to the economic structure. INDUSTRIE 4.0 is also of relevance to small and medium-sized enterprises: the next industrial revolution will be characterized by networking and the internet. Value chains become value networks. ICT, automation and production technologies will be more intertwined than ever before as a result of INDUSTRIE 4.0. The change process of INDUSTRIE 4.0 and the transformation it represents can be arranged with new opportunities. Examples already exist where INDUSTRIE 4.0 provides real added value to daily operations as well as strategic orientation for agile business behavior.

What impact will INDUSTRIE 4.0 have beyond Germany?
It is important to defend and expand the traditional core of German industry and its excellent international position with the advent of internet technologies. As an export nation, machines and plants are not only sold, maintained and operated worldwide, but also produced in branch factories and by licensees. The concepts at play in INDUSTRIE 4.0 do not observe national borders. The paradigm shift in industrial production and intelligent products creates the opportunity to increase productivity, flexibility and quality in many different economic regions.

How can international companies profit from INDUSTRIE 4.0?
Further improvements in the implementation of industrial processes in manufacturing, engineering, supply chain and life cycle management insist on new ideas, algorithms, technologies, reference architectures, standards, and business models. Germany has the ideal conditions to fulfill these tasks in order to play an internationally leading role in INDUSTRIE 4.0. Numerous standards, like the internet protocol, will be used internationally by foreign companies, thus allowing a swift entry for the Internet of Things and the Internet of Services into industrial production in Germany too.

Photo: Fotolia/industrieblick

smartFactory

SmartFactory KL

The SmartFactoryKL technology initiative, located at the German Research Center for Artificial Intelligence (DFKI) in Kaiserslautern, is the first European vendor independent demonstration factory for the industrial application of state-of-the-art information and communication technologies. The venture has the purpose of supporting the development, application and propagation of innovative automation technologies in different sectors as well as providing a basis for their extensive usage in science and industry.

Founded in 2005, the SmartFactoryKL initiative is a successful example of public-private-partnership; being a cooperative venture between vendors and users (manufacturers) of modern automation technologies as well as representatives of public interests. The common projects range from fundamental work on basic technologies to the development of marketable products. Members, sponsors and promoters create a living partnership in order to realize the vision of a future industrial landscape with modern and innovative means.

The mobile production plant of the SmartFactoryKL demonstrates the key aspects of INDUSTRIE 4.0: smart product, collaborative machine and augmented operator.

SmartFactoryKL works as a pioneer for the technology transfer of key aspects of INDUSTRIE 4.0 into practice. By operating several modular pilot plants, both state-of-the-art technologies and cutting-edge research results can be implemented and evaluated.

Within these plants, the key aspects of INDUSTRIE 4.0 are demonstrated in an intuitive and accessible way. The central research and demonstration platform of the SmartFactoryKL is its hybrid demonstration plant which can produce a customized product (soap bottles) in the batch size one to customer specification. Terms of requirements, structure and complexity of the laboratory system with industrial production in practice is absolutely comparable. Functional electrical components (i.e. controllers, sensors, actuators) from different vendors are flexibly networked. Communication systems operate wirelessly, both within the system as well as for overall control levels.

The mobile production line showcases the flexible production of an exemplary product whose components (i.e. case cover, case base, printed circuit board) are handled, mechanically machined, and assembled. The product is able to control its own production process as it has all of the necessary information available in its digital product memory stored on an RFID tag. The process is not controlled by a standard programmable logic controller (PLC), but by a service-oriented, decentralized control system consisting of distributed microcontrollers communicating using internet standards. Human workers are supported with innovative mobile device and augmented reality-based assistance systems.

www.smartfactory-kl.de

Photo left and right: SmartFactory KL

The hybrid soap production plant of the SmartFactoryKL can be used for demonstration, evaluation and field tests by its members.

Industry Voices: A Selection

A number of companies in Germany are already developing and implementing INDUSTRIE 4.0 technologies for use. A selection of companies provide their INDUSTRIE 4.0 perspective.

BOSCH
Invented for life

Robert Bosch GmbH

The Bosch Group is a leading global supplier of technology and services. In 2012, its roughly 306,000 associates generated sales of EUR 52.5 billion. Since the beginning of 2013, its operations have been divided into four business sectors: Automotive Technology, Industrial Technology, Consumer Goods, and Energy and Building Technology.

The Bosch Group comprises Robert Bosch GmbH and its roughly 360 subsidiaries and regional companies in some 50 countries. If its sales and service partners are included, then Bosch is represented in roughly 150 countries. This worldwide development, manufacturing, and sales network is the foundation for further growth. Bosch spent some EUR 4.8 billion for research and development in 2012, and applied for nearly 4,800 patents worldwide. The Bosch Group's products and services are designed to fascinate, and to improve the quality of life by providing solutions which are both innovative and beneficial. In this way, the company offers technology worldwide that is "Invented for life."

www.bosch.de

What role does your organization play in Germany's INDUSTRIE 4.0 project?
Bosch finds itself in a dual role on the way to networked and integrated industry ("INDUSTRIE 4.0"). The company itself deploys technologies and software in order to network its own manufacturing base. On top of this, the company also develops solutions in this area. Bosch Rexroth provides numerous solutions for the Factory 4.0. Bosch Packaging Technology is already building intelligent equipment for intelligent factories in the pharmaceuticals and foodstuff industries. A software suite developed by Bosch Software Innovations also optimizes the complete equipment maintenance process.

How does the INDUSTRIE 4.0 project contribute to the attractiveness of Germany as a location?
The advent of Web 3.0, i.e. the Internet of Things and Services, in industrial production provides Germany with enormous opportunities in two ways. On the one hand, German companies will develop, sell and export technologies and products for networked industry. On the other hand, the use of these technologies will improve the efficiency, and therefore competitiveness, of German industry.

What advantages does INDUSTRIE 4.0 have for small and medium-sized companies?
German companies are – notwithstanding the increasing competition from Asia – leaders in plant and mechanical engineering. German companies also have considerable know-how and a competent workforce in the fields of IT, embedded systems and automation technology. The framework for a concentrated implementation of networked production has been established with the creation of the BITKOM, VDMA, and ZVEI-funded "Plattform INDUSTRIE 4.0." German companies must actively shape the way to networked production and not lose sight of what is required.

What impact will INDUSTRIE 4.0 have beyond Germany?
The ideas behind INDUSTRIE 4.0 will change existing value chains – even across national borders. Value chains in which companies and business processes are horizontally integrated will emerge. This means that business processes – including their engineering – will be consistently designed across the whole value chain. Production systems are conceived in networks – from the supplier to the customer. These highly dynamic business networks provide potential for innovation and new business models. The same also applies to better data generation and evaluation.

How can international companies profit from INDUSTRIE 4.0?
Digitalization and networking help to optimize the value chains: customers are no longer obliged to choose from a fixed product spectrum set by the manufacturer, but instead are able to individually combine single functions and components. The range of variety will become profitable for companies. This can consequently increase the size of the market and turnover. At the same time, customer satisfaction increases as the internal operative costs sink as a result of increased value chain digitalization.

Photo: Bosch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FESTO

Festo AG & Co. KG

Festo is a leading international supplier of automation technology for factory and process automation. A globally oriented and independently run family business based in Esslingen, the company has established itself as a performance leader in the sector thanks to its innovations and problem-solving competence in the field of pneumatics. Today the company provides pneumatic and electric drive technologies for factory and process automation to more than 300,000 customers in 200 industry sectors across the world. Together with partners from science and industry, Festo is conducting research into new solutions for merging modern information and communication technologies with classical industrial production processes. The trend towards increasingly individualized products in smaller quantities and increased variety requires technologies that are able to continuously adapt to changing production conditions.

Festo recognizes intelligent components which organize themselves and process requests from higher level control systems as the basis for tomorrow's production systems. Festo is actively developing precision engineering and microsystem technologies in order to realize fully networked overall systems. Festo also conducts research into solutions which allow the human workforce to directly interact with new machine and robot technologies. To this end, the company is also extensively concerned with the proper provision of education and training for the next generation of workers in the new production world.

www.festo.com

What role does your organization play in Germany's INDUSTRIE 4.0 project?
Festo contributed to the recommendations made by the Industry-Science Research Alliance. Within this context, a "Resilient Factory" application case – with systems that are tolerant to disruptions – was introduced. These activities have subsequently been transferred to the Plattform INDUSTRIE 4.0 in which Festo is also very much actively involved.

How does the INDUSTRIE 4.0 project contribute to the attractiveness of Germany as a location?
From a European perspective it is important to ensure that production in high-wage countries, of which Germany is one, remains competitive in the long term. INDUSTRIE 4.0 activities will contribute to achieving this. The perspective merging of manufacturing technology with IT can be carried out in especially efficient manner in Germany in particular, as public funds are also in operation. This special situation allows the attractiveness of Germany to be significantly increased with INDUSTRIE 4.0.

What advantages does INDUSTRIE 4.0 have for small and medium-sized companies?
The creation of commonly defined standards with widespread effect is an important part of INDUSTRIE 4.0 activities. Continuous and open standard architectures are also clearly more advantageous for small and medium-sized enterprises (SMEs) than closed concepts from major concerns that shape the market themselves. It is therefore worthwhile for SMEs to force non-proprietary solutions within an INDUSTRIE 4.0 context.

What impact will INDUSTRIE 4.0 have beyond Germany?
Activities are being closely followed, for example, in Great Britain and the USA. Horizontal networking in value chain networks is not limited to just one company or country. Successful concepts which are developed will also be accepted internationally.

How can international companies profit from INDUSTRIE 4.0?
As already alluded to in the answer to the previous question, economic concepts are not applied nationally. International companies will be able to benefit just as much where technological and commercial advantages arise from the implementation of INDUSTRIE 4.0 concepts.

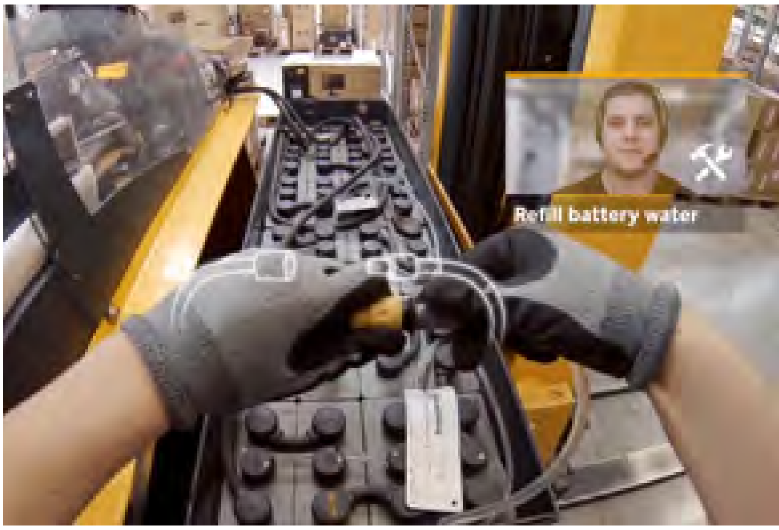
SAP AG

As market leader in enterprise application software, SAP helps companies of all sizes and industries run better. From back office to boardroom, warehouse to storefront, desktop to mobile device – SAP empowers people and organizations to work together more efficiently and use business insight more effectively to stay ahead of the competition.

As manufacturers face increased cost pressure and market volatility, product life cycles and test cycles are getting shorter. Products are becoming more complex and customized. Manufacturers find that moving production to emerging countries with cheap labor costs is no longer a path to success as they must balance customization with mass production. Production must increasingly be local, e.g. with 3D printers, to meet rapid changes in demand. Other factors also rise in importance – taking advantage of low energy costs as well as co-locating R&D and manufacturing to accelerate time-to-market.

Today, the manufacturing industries undertake a new and profound shift as business and technology trends converge in an unprecedented way. Manufacturers can now add sensors and microchips to tools, machines, vehicles, buildings, and even raw materials to make products "smarter."

These smart items will provide a wealth of data that can be used to better understand products and potential issues around them. The ongoing digitalization of products and services is also freeing manufacturers and their customers from fixed locations. In the future, spare parts might be produced at the locations where original parts fail, saving significant costs related to transportation and inventory. As technology fosters stronger vertical integration between shop floor and global business strategies (as well as greater horizontal integration across design, planning, production of products and service provision), manufacturers are increasingly more responsive and efficient than before. They also benefit from agile, self-organized business networks that allow local execution of global business plans.



Companies need to be aware of the current business and technology trends and prepare for the upcoming transformation. SAP offers a holistic framework to align business models, technology platforms and solutions on the way forward. To integrate the industrial value chain and product lifecycles, business IT must seamlessly integrate processes: from product design to supply chain management, production, aftermarket service, and training. SAP's "Idea to Performance" initiative helps manufacturers seize new business opportunities using Big Data, 3D Visualization, Cloud and Mobility solutions to create new insight and connect with partners and customers. SAP's "Idea to Performance" concept covers the following areas:

- Sustainable innovation
- Responsive manufacturing
- Operational excellence
- After-market service

Solutions within the "Idea to Performance" portfolio enable intelligent process execution, resourceful operations, and intuitive user experiences. They help customers become smarter, faster, and simpler.

www.sap.com

Smarter
Provide intellectual power and insightful decision support

Faster
Enable quicker time-to-market and improved brand recognition

Simpler
Improve adaptability, consumability, and flexibility

What role does your organization play in Germany's INDUSTRIE 4.0 project?

SAP has been engaged in several public research projects and initiatives in the context of INDUSTRIE 4.0 and contributed to the recommendation paper issued by acatech – the National Academy of Science and Engineering. SAP provides technologies and solutions that help companies to embrace the upcoming changes in the manufacturing industries. SAP follows a holistic approach called "Idea to Performance" enabling companies to develop new business models and a roadmap for implementing INDUSTRIE 4.0 scenarios.

How does the INDUSTRIE 4.0 project contribute to the attractiveness of Germany as a location?

For highly industrialized countries like Germany, INDUSTRIE 4.0 is a great opportunity to keep manufacturing jobs in the country and secure long-term growth and innovative strength. German manufacturers are often highly specialized global leaders in their field. With INDUSTRIE 4.0, they can further enhance their competitive advantage by becoming more efficient and responsive to market changes and introducing new service offerings based on a wealth of data from smart products and machines.

What advantages does INDUSTRIE 4.0 have for small and medium-sized companies?

With INDUSTRIE 4.0, supply chains will evolve into highly adaptive networks. Small and midsize companies will play an important role in such value-add networks. By integrating INDUSTRIE 4.0 concepts and technologies, they can provide individualized products and services and will be highly adaptive to demand changes. Sensors flexibly provide machine data that is captured and analyzed while the manufacturer is producing, delivering, assembling, and operating machines. Pro-active services for example trigger machine data anomalies.

What impact will INDUSTRIE 4.0 have beyond Germany?

Manufacturers all over the world face increased cost pressure and market volatility. Product life cycles are getting shorter and products are becoming more complex and customized. Manufacturers must find ways to balance customization with mass production. Production will increasingly be local to meet rapid changes in demand. Many countries are aware of this trend and launched programs similar to INDUSTRIE 4.0. In addition, INDUSTRIE 4.0 addresses some of today's biggest challenges such as resource and energy efficiency.

How can international companies profit from INDUSTRIE 4.0?

INDUSTRIE 4.0 is a global topic, encompassing fast-growing markets like China or India as well as traditional manufacturing countries such as Germany, US, Korea, or Japan. Wherever they are based, companies can use INDUSTRIE 4.0 scenarios to prepare for upcoming changes and lead this new industrial revolution. With SAP's holistic "Idea to Performance" approach, our customers can position themselves and start implementing INDUSTRIE 4.0 scenarios to work smarter, faster, and simpler.

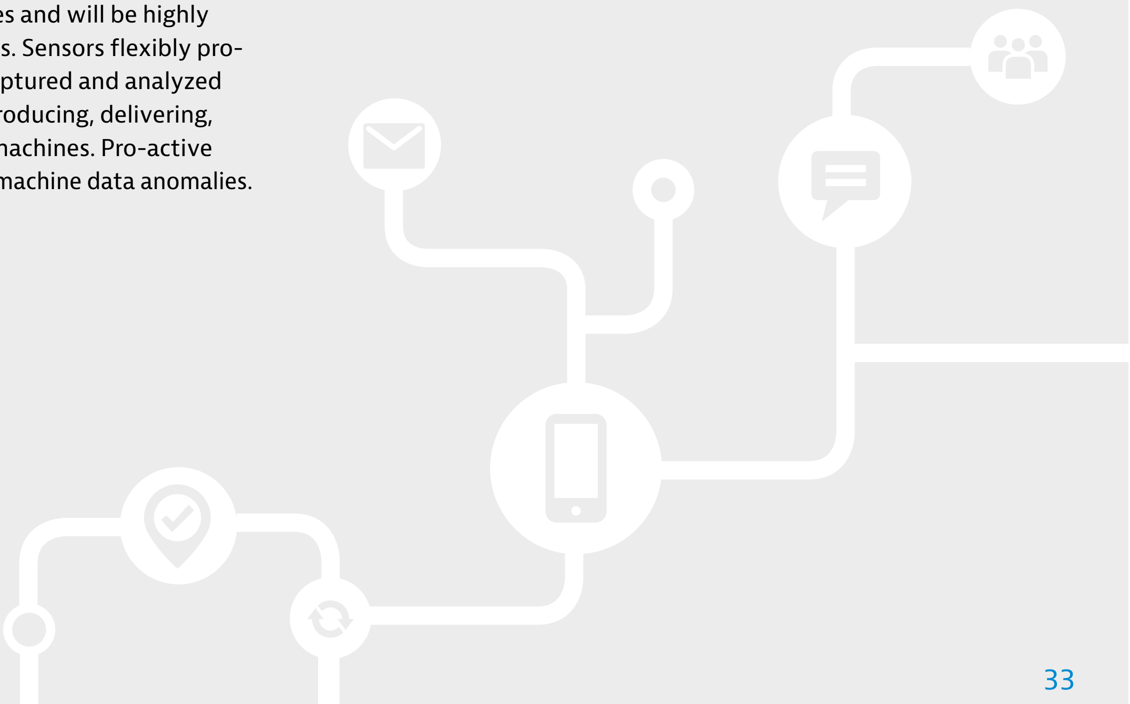
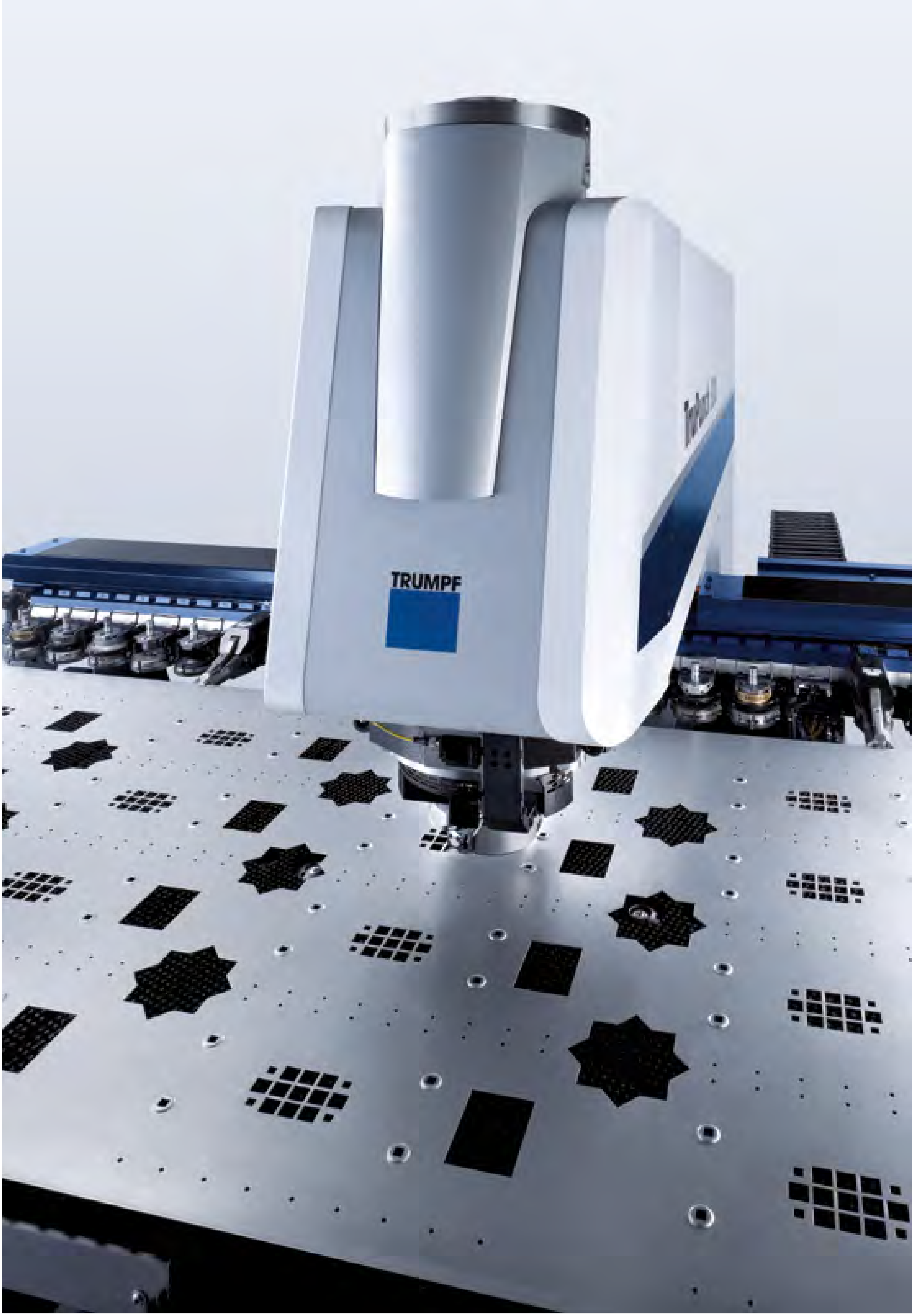


Photo: SAP AG


TRUMPF

TRUMPF GmbH & Co. KG

TRUMPF is a leading global technology company with machine tools, laser technology, electronics and medical technology as its business fields. Products manufactured with the company's technology can be found in almost every sector of industry. TRUMPF is the world technological and market leader for machine tools used in flexible sheet metal processing, and also for industrial lasers.

In 2012/13 the company – which has approximately 9,900 employees – achieved sales of EUR 2.34 billion. With more than 60 subsidiaries and branches, the TRUMPF Group is represented in almost all the countries of Europe, North and South America, and Asia. It has production facilities in Germany, China, France, Great Britain, Japan, Mexico, Austria, Poland, Switzerland, the Czech Republic and the USA.

www.trumpf.com

What role does your organization play in Germany's INDUSTRIE 4.0 project?

TRUMPF has been a member of the federal government initiated INDUSTRIE 4.0 Working Group since 2011 and has already provided a decisive contribution to the definition of the "smart factory." As well as this, TRUMPF is also active in the Plattform INDUSTRIE 4.0 management board and steering group set up by the VDMA, BITKOM and ZVEI industry associations. Alongside projects like CyProS – in which 20 partners are conducting research into the implementation of cyber-physical production systems – TRUMPF is also working to create solutions for more productive and efficient production processes.

How does the INDUSTRIE 4.0 project contribute to the attractiveness of Germany as a location?

The INDUSTRIE 4.0 vision is one of networked systems in which no capacity bottlenecks or available resources remain undetected. They are transparent, can react to variations flexibly and allow humans to intervene as intelligent decision makers according to the situation. These systems will allow individual products to be produced in an efficient and swift manner normally associated with mass production. The INDUSTRIE 4.0 project creates the conditions for the implementation of such production networks in Germany.

What advantages does INDUSTRIE 4.0 have for small and medium-sized companies?

Small and medium-sized companies in particular must react quickly to changes – for example short-term customer orders. The networked manufacturing foreseen in INDUSTRIE 4.0 allows all production processes to be transparent and easily influenced. INDUSTRIE 4.0 provides the companies with the flexibility which allows them to remain internationally competitive.

In your opinion what impact will INDUSTRIE 4.0 have beyond Germany?

The "Global Facility" is one of the five elements of the Smart Factory. Production systems are already often internationally networked – with INDUSTRIE 4.0 this networking will continue to increase. Moreover, the new technological opportunities are not only available in Germany. The advantages that the Internet of Things for example brings to manufacturing won't go unnoticed in other countries. The different elements of INDUSTRIE 4.0 will therefore also affect production in other countries.

How can international companies profit from INDUSTRIE 4.0?

Just as is the case for German companies, international companies will be able to more efficiently shape their own production according to the principles of INDUSTRIE 4.0. For this they can call upon the services of German machine builders who have long been occupied with the opportunities made possible by networking. TRUMPF provides its customers, whether domestic or international, with state-of-the-art technology. The company has already been deploying the first elements of INDUSTRIE 4.0 in its machine tools and lasers for years.

Photo: TRUMPF Gruppe

WITTENSTEIN AG

With an international workforce of around 1,700 and turnover of EUR 241 million in 2012/13, WITTENSTEIN AG stands for innovation, precision and excellence in the world of mechatronic drive technologies – both nationally and internationally. The group, with headquarters in southern Germany, covers eight innovative business fields with respective subsidiary operations: servo gearheads, servo drive systems, medicine technology, miniature servo units, innovative gearing technology, rotary and linear actuator systems, nanotechnology as well as electronic and software components for drive technology. With around 60 subsidiary and representative operations in approximately 40 countries, the company is represented in all important global technology and sales markets, WITTENSTEIN focuses on innovation – without limiting itself solely to technological innovations and products but also applying itself to new processes. The company intends to merge the terms "innovation" and "factory" in order to bring the new thinking to the fore: innovative products need innovative production. Together with partners from science and industry, WITTENSTEIN has set out on the path of making its own production INDUSTRIE 4.0 capable. INDUSTRIE 4.0 use cases will be carried out at the "Urban Production of the Future" showcase factory established in Fellbach near Stuttgart. A WITTENSTEIN innovation factory and production facility, which brings together development, sales and production of the different mechatronic company units together at one site, is currently being built at the company headquarters in Igersheim-Harthausen.

www.wittenstein.de

Future urban production at WITTENSTEIN's facility in Fellbach

What role does your organization play in Germany's INDUSTRIE 4.0 project?

Dr. Manfred Wittenstein, chairman of the WITTENSTEIN AG board, is certain: INDUSTRIE 4.0 will most likely only become a reality in the next decade. However, companies who want to internationally profit from the new technology wave must lay the proper foundations today. New answers are required in the world of production in order to master the challenges of the future. As one of the INDUSTRIE 4.0 driving forces, WITTENSTEIN, together with its partners, is seeking out the smart answers in order to meet future production requirements. This also has something to do with corporate responsibility in terms of society and the environment.

How does the INDUSTRIE 4.0 project contribute to the attractiveness of Germany as a location?

As a high-performance location, Germany is well equipped to meet global challenges. Should German industry set the pace for the fourth stage of the industrial revolution, then developments made in INDUSTRIE 4.0 will also help contribute to secure Germany's position. Important and necessary for success here is the integration of science and industry – the major location advantage of German mechanical engineering companies since time immemorial. German companies have a great opportunity to help shape new standards across the entire value chain in a pioneering role.

What advantages does INDUSTRIE 4.0 have for small and medium-sized companies?

Germany's Mittelstand is used to including and integrating new skills. In fact it is the structure of many small and often family-run businesses in the machinery and equipment sector that provides the ideal conditions for quickly and intelligently mastering the way to the merging of internet and production technology. The German mechanical engineering industry could be a pioneer with its manufacturing and technology.

What impact will INDUSTRIE 4.0 have beyond Germany?

"INDUSTRIE 4.0 will become the global language of production." Hartmut Rauen, VDMA (Verband Deutscher Maschinen- und Anlagenbau – German Engineering Federation)

How can international companies profit from INDUSTRIE 4.0?

INDUSTRIE 4.0 will yield a new generation of automation technology and production systems. The goal for German companies is to become the lead provider in the future market for such systems. For foreign companies, the opportunity exists to profit from the technological achievements of INDUSTRIE 4.0 as well the integration and application know-how of German providers of highly productive systems in this market.

Photo: WITTENSTEIN AG

Our Services

Germany Trade & Invest's teams of industry experts will assist you in setting up your operations in Germany. We support your project management activities from the earliest stages of your expansion strategy.

We provide you with all of the industry information you need – covering everything from key markets and related supply and application sectors to the R&D landscape. Foreign companies profit from our rich experience in identifying the business locations which best meet their specific investment criteria. We help turn your requirements into concrete investment site proposals; providing consulting services to ensure you make the right location decision. We coordinate site visits, meetings with potential partners, universities, and other institutes active in the industry.

Our team of consultants is at hand to provide you with the relevant background information on Germany's tax and legal system, industry regulations, and the domestic labor market. Germany Trade & Invest's experts help you create the appropriate financial package for your investment and put you in contact with suitable financial partners. Incentives specialists provide you with detailed information about available incentives, support you with the application process, and arrange contacts with local economic development corporations.

All of our investor-related services are treated with the utmost confidentiality and provided free of charge.

Our support services for your investment project

Strategy → Evaluation → Decision & Investment

Project management assistance

Business opportunity analysis and market research	Market entry strategy support	Project partner identification and contact	Joint project management with regional development agency	Coordination and support of negotiations with local authorities

Location consulting/Site evaluation

Identification of project-specific location factors	Cost factor analysis	Site preselection	Site visit organization	Final site decision support

Support services

Identification of relevant tax and legal issues	Project-related financing and incentives consulting	Organization of meetings with legal advisors and financial partners	Administrative affairs support	Accompanying incentives application and establishment formalities

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Germany Trade & Invest is the economic development agency of the Federal Republic of Germany. The company helps create and secure extra employment opportunities, strengthening Germany as a business location. With more than 50 offices in Germany and abroad and its network of partners throughout the world, Germany Trade & Invest supports German companies setting up in foreign markets, promotes Germany as a business location and assists foreign companies setting up in Germany.

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