ADAPTABILITY OF BIM TECHNOLOGY TO MITIGATE THE COST OVERRUNS IN DESIGN AND BUILD PROJECTS

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ABSTRACT

Purpose: Cost overrun is an inevitable issue in Design and Build (D&B) projects. In D&B projects, causes for cost overruns can be managed by adopting appropriate Building Information Modelling (BIM) functions. Since, there is a research gap of synergy between the use of BIM for mitigating cost overruns in D&B projects, this study aimed at evaluating the adaptability of BIM to manage cost overrun issues in them.

Design/ methodology/ approach: Research objectives were attained through quantitative research approach adopting to Delphi technique consisting of three rounds of questionnaire survey. Through statistical tools collected data were analysed.

Findings: This research revealed ten the most crucial causes for cost overruns in D&B projects where continuous changes in designs and drawings is the top most cause. Change and revision management, and interoperability are the most crucial BIM functions to address the aforementioned cause. Subsequently sixteen (16) enablers, twenty-six barriers (26) and nineteen (19) strategies to implement BIM to manage the identified significant causes of cost overruns were overviewed.

Originality / Value: The Research study addresses the literature gap pertaining to the cost overrun in D&B projects and application of BIM by studying the causes for cost overrun, suggesting BIM functions to mitigate the above cause. Moreover, this study assessed the probable barriers and enablers for BIM adoption in construction projects from D&B perspective.

Key words: *Building Information Modelling (BIM), Design and Build (D&B), Cost Overrun, Construction Industry, Delphi Study*

1 Introduction

The Design and Build (D&B) procurement method is an efficient integrated approach to project delivery which shifts major portion of risk to contractors by assigning them the design responsibility other than the construction responsibility of the project (Ruvinda and Bamunuachchige, 2020). According to the research findings of Pham *et al.* (2021) and Ramanathan *et al.* (2011), cost overrun is a prominent risk factor associated with D&B projects since the nature of D&B projects has created price certainty as an arduous task which demands for strict cost controlling strategies to deliver a high degree of cost certainty from the contractor's perspective. Moreover, Atapattu *et al.* (2023) revealed that primarily causes of cost overruns in D&B projects are centred around project performance issues, design and methodology related issue and management related obstacles. Accordingly, cost overrun has long been a major concern in D&B projects, which is still possible to be avoided by implementing modern technologies (Brahim *et al.*, 2018).

In response to above issue, expertise in the effective utilization of digital technologies such as Artificial Intelligence (AI), Internet of Things (IoT), Building Information Modelling (BIM), Digital Twins (DTs) and machine learning (Opoku *et al.*, 2022) is needed to improve the cost estimation process (Sepasgozar *et al.*, 2022). Advocating above, Igwe *et al.* (2022) concluded in his study emphasizing that aforementioned advanced technologies have been created and deployed to the site for the cost management in the era of digital construction. BIM as a collaborative platform for construction management (Muhammad *et al.*, 2019) allows all construction professionals to view, upload and access their most recent 3D models from anywhere at any time (Davies, 2020), contributing severely towards cost overrun negation (Sánchez *et al.*, 2022).

In D&B projects pricing risk is borne by the contractors needs to be properly managed to avoid financial losses to them in D&B projects (Global Arbitration Review [GAR], 2019). BIM and comparable tools like IoT and cloud computing have raised the awareness by offering a direction for the resolution of most of the conflicts that arise between architects and cost managers in D&B projects (Yusoff *et al.*, 2022). Thus, an effective approach to meet the industrial need for the procurement of D&B projects is the adaptability of BIM technology to mitigate the contractor's pricing risk in D&B projects. In addition, limited research exists on the use of BIM in D&B projects (Brahim *et al.*, 2018; Yusoff *et al.*, 2022), particularly, research

on investigating the use of BIM in D&B projects to manage pricing risk from the contractor's perspective is lacking. Accordingly, a theoretical research gap can be found for the amalgamation of the three elements namely "BIM", "D&B" and "contractor's pricing risk". It is so evident that research is needed to determine how adaptable BIM technology is in order to reduce contractor pricing risk in D&B projects, given the industrial requirement and research gap focused. Concerning the aforementioned facts, the study aims to evaluate the adaptability of BIM technology to manage the cost overrun issue in D&B projects with objectives namely: to investigate the most significant causes for cost overrun in D&B projects; to investigate the most suitable BIM functions to be used to manage the above identified significant causes; to identify the significant barriers and enablers to implement BIM to manage the above identified causes of cost overruns in D&B projects and to propose the most suitable strategies to control above identified barriers to implement BIM to manage the cost overruns in D&B projects**.** The scope of this research is limited to building construction projects which are executed through the D&B procurement method and the study is designed in the perspective of D&B contractors.

2 Literature Review

2.1 Pricing Risk in Design and Build (D&B) procurement method

Pricing risk of the D&B projects, which is resulted due to the higher price uncertainty nature in D&B method is called as cost overrun in D&B projects (Potty *et al.*, 2011). According to Ramanathan *et al.* (2011), contractors working on D&B projects have a high risk of cost overruns where they must pay close attention and carefully grasp the project's risks and risk management strategies before committing to the project. Table 1 summarizes the causes for cost overruns in D&B projects.

Having a clear understanding about the causes for cost overrun issue in D&B projects makes the D&B contractors to accurately allocate the contingencies for potential risk factors (Ramanathan and Narayanan, 2014). According to Yusoff *et al.* (2022), most of these causes can be effectively managed with the adoption of latest and innovative technologies in construction field.

<Insert Table 1>

2.1.1 BIM Functions in D&B Projects

According to Gholizadeh *et al.* (2018), the three main BIM functions that are most frequently used are 3D visualization, clash detection and constructability analysis, while code validation, material tracking, delivery, and management, facility management, and energy analysis are rarely used. Figure1 further condenses the functions of BIM technology; planning, scheduling, cost estimation, cloud computing, building simulation, design coordination, digitalized quantity take-off structural and engineering analysis, reviews and revision management, design coordination, safety analysis and clash detection (Gholizadeh *et al.*, 2018; Kang *et al.*, 2013; Ganbat *et al.*, 2020; Charehzehi *et al.*, 2017). This is further validated by Ganbat *et al.*, (2020) where they rank them as the top beneficial functionalities of BIM.

2.1.2 Barriers and enablers for adoption of BIM for cost management in construction projects

Despite the fact that the adoption of BIM has enormous potential to manage information, risk and complexity of construction projects, it is still restrained in most developing countries by its barriers of adoption (Vidalakis *et al.*, 2020). Most commonly discussed barriers are associated with high cost for technology implementation, software and hardware, training, lack of proficient workforce and shortage of resources (Sun *et al.*, 2015; Oesterreich and Teuteberg, 2019) as delineated in Figure 1 the theoretical framework. According to the previous research findings, “Lack of skilled professionals (lack of in-house expertise)” is the prominent obstacle in BIM adoption (Sun *et al.*, 2015; Won *et al.*, 2013;. Oesterreich and Teuteberg, 2019).

In contrast to the barriers, crucial influencing factors for the adoption and execution of BIM have been studied in many previous studies across variety of professionals and countries (Olanrewaju *et al.*, 2020; Sinoh *et al.*, 2020). Increased profitability, growing awareness for BIM in global practices, shortening of the project duration, enhanced visualization and improved coordination (Badi and Diamantidou, 2017; Shojaei *et al.*, 2022) are the most widely applicable driving factors for BIM implementation as detailed in Figure 1.

2.1.3 Strategies enhance use of BIM for cost management in construction projects

Through successful execution of strategies for BIM implementation, barriers of BIM adoption can be effectively managed (Olugboyega and Windapo, 2021). Accordingly, Figure 1 the

theoretical framework depicts the strategies for BIM implementation as revealed by past studies. As highlighted by Zhou *et al.* (2019), Besné *et al.* (2021), Manzoor *et al.* (2021) and Ullah *et al.* (2022) the most effective BIM implementation strategies include the growing awareness among construction stakeholders through systematic approaches like training programs, seminars, academic research, roadmaps and guidelines for BIM implementation.

<Insert Figure 1>

2.2 Necessity of the Research

The arduous obstacle for contractors in D&B in meeting project objectives is cost overrun (Chamikara *et al.*, 2023). This is mainly because simultaneous collaboration of design and construction works has led to cost uncertainties (Ogunsanmi *et al.*, 2011). Nevertheless, the majority of causes for cost overruns in D&B projects can be efficiently controlled by implementing the newest technologies, which facilitate collaborative work environments and improve data accuracy (Braglia *et al.*, 2022; Yusoff *et al.*, 2022). Capability of BIM to automate estimating (Hasan and Rasheed, 2019) and creation of open lines of communication between the design and construction teams (Yusoff *et al.*, 2022) have proven potential of BIM to establish a consistent price certainty for construction projects (Hasan and Rasheed, 2019). Therefore, addressing impediments, enablers and strategies to BIM implementation effectively offers effective management of D&B project cost overrun (Yusoff *et al.*, 2022). BIM enabled functionalities such as early identification of design clashes and issues, improved collaboration and communication (Zhou *et al.*, 2019) which helps to reduce misunderstandings, accurate cost estimation, improved construction scheduling and reduced rework are some of the drivers to encourage the implementation of BIM to mitigate cost overruns of D&B projects. Nevertheless, the construction industry has lagged behind in implementing BIM technologies for construction project management, which has resulted in budget overrun (Hasan and Rasheed, 2019)

In scrutinizing antecedent research on BIM, D&B, and cost overrun concepts; BIM has been investigated by Yusoff *et al.* (2022) as a communication channel in D&B projects, Sepasgozar *et al.* (2022) and Muhammad *et al.* (2019) concentrated on role BIM as a digital tool in construction cost management, whereas extensive number of research publications have been made discussing cost overrun in construction projects in multifaceted perspectives (Asiedu and Ameyaw, 2020; Ghazal and Hammad, 2020). However, neither research has explored employing of BIM technology to address the cost overrun issue in D&B projects.

Hence, it is imperative to explore the synergy between BIM adaptation and cost overrun mitigation of D&B projects. This research is aimed at fulfilling this gap of synergy between BIM, D&B and mitigation of cost overruns.

3 RESEARCH METHODOLOGY

Quantitative research approach seeks to find answers to queries such as how many, how much, and to what extent and reveals patterns in the research from larger population (Rasinger, 2013). Accordingly, For the validation and evaluation of literature findings, to assess the most crucial causes for cost overruns in D&B projects and to evaluate enablers, barriers and strategies in relation to adaptability of BIM in curbing project cost overrun quantitative approach was followed.

A comprehensive literature review was conducted highlighting causes for cost overrun in D&B projects, to explore BIM functions used in pricing, and understand barriers, enablers and strategies for BIM implementation in the construction sector. The study employed Delphi technique since it facilitates the collection of professional opinions on a particular subject (Mansour *et al.*, 2020; Moragane *et al.*, 2022). Xia and Chan (2012) stated that to reach a valid conclusion, three Delphi rounds are necessary. Thus, there were three rounds in the study. To achieve the defined objectives, it is imperative to consider the participants' discipline while selecting them for the Delphi round (Avella, 2016). Purposive sampling method is used in this study because it is based on the selection of respondents from a sample of specific qualities who can provide the best information to achieve the research objectives (Campbell *et al.*, 2020). Accordingly, the target respondents were determined by a selection criterion, who have at least more than 15 years of experience in the construction industry, involved in D&B projects and have participated in BIM projects as given in Table 2. The respondents for each Delphi round was selected under five categories; Quantity Surveyor, Architect, Engineer (Civil/MEP), Project Manager and Academic Researcher. Zahoor *et al.* (2017) recommends a minimum of 7 and a maximum of 50 respondents for the Delphi technique. Table 2 displays the quantity of responses collected in each survey round, aligning with these guidelines.

Data were gained from construction professionals through questionnaire survey due to its efficacy in yielding accurate data by providing reliable and cost-effective means of gathering information (Taherdoost, 2016). Moreover, the data collected through questionnaire surveys can be represented numerically, allowing statistical analysis (Weyant, 2022). Accordingly,

closed-ended questionnaires were employed in three rounds. Experts, contacted through phone or email, participated in the online distribution of the questionnaires.

<Insert Table 2>

<Insert Figure 2>

The collected data from round 01 were analysed and amended to round 02 questions. Rounds 02 and 03 were extended in-depth questions of round 01. Figure 2 presents the areas overviewed in each Delphi round. Quantitative data need to be analysed using mathematical techniques together with statistical concepts (Mehrad and Zangeneh, 2019). Therefore, quantitative data gathered through three rounds of questionnaire survey was analysed using weighted mean rating method and standard deviation.

Weighted mean rating of a particular item is derived as,

$$WMR = \frac{\sum_{i=1}^{5}(x_i \times f_i)}{n}$$

Where: WMR = Weighted Mean Rating

fi = Frequency of responses

n = Number of responses

Standard deviation, which denotes the spread of the data set is derived as,

$$SD = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n}}$$

Where: SD = Standard Deviation; $\bar{x}$= Mean of the data set; n= Number of respondents

4 FINDINGS AND ANALYSIS

4.1. The most significant causes for cost overrun in design and build projects. (R1Q1, R2Q1)

In the literature review, thirty (30) causes for cost overruns in D&B projects were identified. The round 1 question1 was utilized to filter those causes considering their relevancy for D&B projects and possibility of solving them through the use of BIM. At the end of the questionnaire

survey round 1, two number of initially identified literature findings of the causes for cost overruns modified, 9 were rejected and four (4) new causes were added to the list. Modified phrases in the causes are indicated in italics, whereas the newly added causes are in bold. Consequently, the findings of round 1 were refined to a finalized list of 25 causes.

Moreover, questionnaire survey round 2 was launched to identify the most significant causes for cost overruns in D&B projects. Respondents were asked to rank the level of significance of each listed cause. Accordingly, the level of significance of each cause towards cost overruns in D&B projects was evaluated through the weighted mean rating (WMR) method as summarized in Table 3.

<Insert Table 3>

As indicated in Table 3, out of the listed twenty-five (25) causes of cost overruns in D&B projects, ten (10) causes having more than WMR value of 4.0 were identified as the most significant causes for cost overruns in D&B projects.

According to Table 3, the most significant cause is "*continuous changes in design and drawings due to incomplete initial drawings prepared with insufficient design data at tendering stage".* It has the highest WMR value of 4.355 and the second lowest SD of 0.661 out of the entire data set. A primary cause of inaccurate project cost estimation in D&B projects is incomplete drawings with limited details during tendering.

The second most significant cause for cost overruns in D&B projects was identified as "*errors or omissions revealed during construction"* with a WMR of 4.290 and SD of 0.739. Insufficient details and supervision during the design stages, errors or omissions might occurred which may be revealed during the construction stages. Restricted data about the employer's requirements and poor identification of errors at early stages are the reasons for this cause as discussed by the interviewees.

"Inefficient planning and scheduling by contractor" was identified as the third most significant cause. As pointed by the interviewees in round 1, the main reason behind this cause is lack of familiarity of the contractors regarding the D&B procurement approach. When they fail to properly plan and schedule the design and construction phases with relevant overlaps, conflicts might arise causing an overall cost overrun in the entire project.

"*Inadequate constructability of the design"* and *"inappropriate construction methods followed by contractors*" represent the fourth and fifth rank of the list which are related with each other to a certain extent. Constructability of the design is expected to be high in design and build projects since contractors are responsible and they are more experienced about construction related matters and solutions. However, inefficient communication between the client and contractor leads to design the building with less constructability (Nolan & Gibson, 2022).

As a significant finding, two of the new causes identified during the round 2 had come to sixth and seventh rank of the list. As discussed under the survey round 2 findings, miscommunication and inefficient methods of extracting the client requirements is a major cause for cost overrun in D&B projects. Mostly in local practices, drafting of conditions of contract referring to standard conditions of D&B contracts is said to be at a primary level because of the less awareness about this procurement method.

4.2. The most suitable BIM functions that can be used to manage the most significant causes in D&B (R2Q2, R3Q1)

In round 2 question 2, using thirty-five (35) BIM functions identified via literature, interviewees were asked to comment on their awareness about these BIM functions as a "Yes/No" answer and were asked to raise any modifications to the listed items if required and add any new BIM function which is missing in the given list. None of the interviewee modified the existing functions and added new elements. Subsequently, thirty-five BIM functions were confirmed at the end of Delphi round 2.

In questionnaire survey round 3, respondents were asked to select the most suitable BIM functions out of the aforementioned 35 BIM functions which are best suited to manage the most significant causes for cost overruns in D&B projects. Accordingly, each respondent selected five most suitable BIM functions in a descending order considering their significance towards managing the particular significant cause for cost overruns in D&B projects. At the end of questionnaire survey round 2, the responses with WMR 3.00 and above were considered as responses with significant impact. Accordingly, Table 4 demonstrates the most suitable BIM functions that can be incorporated to manage the most significant causes for cost overruns in D&B projects.

<Insert Table 4>

According to the Table 4, the top two (2) BIM functions which are commonly selected for the management of causes are "*interoperability and exchange of information*" and "*clash detection*". As a pillar of BIM "*interoperability and exchange of information"* function facilitates exchange of more information about the project among stakeholders during designing and construction of the project. Adopting aforementioned BIM function could mitigate cost overruns in D&B projects resulting from continuous changes in designs due to incomplete drawings, errors and omissions revealed during construction, issues in conditions of contract in D&B projects, poor communications between design and construction teams and lack of clarity in employer's brief. BIM technology facilitates to detect clashes of the construction project at an early stage. Therefore, "*Clash detection*" BIM function can detect errors in designs, schedules, and planning aspects of the project at the early phase ensuring efficient project planning, scheduling, constructability of the design while ensuring. "*Digitalized quantity take-off*" function assists the construction practitioners to measure the quantities of the project automatically. Therefore, whenever the designs of the project vary, the quantities will vary accordingly without any errors within milliseconds. "*Cloud computing*" BIM function offers architects, engineers and practitioners to access the 3D model virtually from anywhere. Accordingly, the employer can improve the clarity of the brief, and architects and designers could make changes to the project through "cloud computing" function minimizing the risk of cost over run and time extensions. Unforeseen weather condition is another cause for cost and time overrun in D&B projects. Nevertheless, "*Safety Planning and Review*" and "*Occupational safety analysis*" functions prepare the respective practitioners in advance to take necessary actions to manage such situations ensuring the on-time completion of D&B projects.

4.3. The most significant enablers and barriers to implement BIM to manage the above identified causes of cost overruns in D&B projects (R2Q3, R3Q2)

In Delphi round 2, twenty (20) enablers identified through the literature review were listed, interviewees were asked to comment on their applicability to the BIM implementation. Following this round, two new enablers were added, and five existing enablers were modified, making a total of 22 BIM adoption enablers. Additionally, interviewees were asked to affirm the existing listed barriers and add new barriers when implementing BIM to manage the cost overrun issues in D&B projects. Consequently, five barriers were modified, six new barriers were added, and two were rejected, culminating in a total of thirty-one identified barriers to BIM implementation.

In round 3, respondents were subsequently asked to select the most significant enablers and barriers which can manage the most significant causes of cost overruns in D&B projects. Enablers and barriers with WMR of 3.00 and above were selected as the best suited enablers and barriers respectively with significant impacts. Modified phrases of existing barriers and enablers are given in bold letters whereas newly identified ones are denoted in bold and italic letters as showed in Table 5.

<Insert Table 5>

As a summary of Table 5, the most commonly used enabler of BIM implementation is "*real-time collaboration among all the project professionals and stakeholders*". It is used as an enabler to manage six different significant causes for cost overruns in D&B projects. Since design and construction are carried out in parallel in D&B projects, real-time collaboration among project professionals is crucial for adjusting planning, scheduling, material allocation, construction methods and techniques timely when design changes occur frequently. The next most common enabler is the "*improvement of the construction productivity*", identified as an enabler to implement BIM to manage five different significant causes. Frequent design changes, unforeseen weather conditions, improper geotechnical investigations, inefficient planning and scheduling and errors found lately directly contribute to time-consuming and costly redesigning and precautionary actions, resulting in reduced project productivity. In that sense, "*improvement of the construction productivity"* could draw the attention of project team members to apply BIM into D&B projects. Moreover, coordination among project members and documentation is paramount to ensuring efficient planning and scheduling, early detection of errors and mistakes and facilitating design changes in D&B projects. Accordingly, identified "*improving the coordination of construction documents*" would be another enabler of adopting BIM function to D&B projects. In addition to that, "*trend of using BIM for management of construction project information and the possibility of using such information for future projects*" has been selected as enablers to manage four different causes.

On the other hand, according to Table 5, the most commonly identified barriers to BIM implementation for managing the most significant causes for cost overruns in D&B projects are "*overall industry resistance to process change*" and "*belief that existing techniques are adequate and reluctance to put additional efforts to formulate BIM contracts*". They were identified as barriers for four different causes. In developing countries, practitioners in the construction industry are reluctant to automate the project procurement through applying BIM

functions. Simultaneously, the 11most senior practitioners believe that currently available methods are sufficient to carry out both design and building aspects in parallel. Therefore, those practitioners do not prefer to allocate their efforts to learn new technologies. Still there is lack of knowledge among construction professionals regarding the new employability opportunities with BIM, and most industry professionals do not have a clear idea of what kind exposures they can obtain by practicing BIM. Therefore, "*lack of industry awareness about BIM*" is another identified obstacle in applying BIM into D&B projects. In addition to above, there are several other common barriers namely *"high initial cost for software and hardware, lack of skilled professionals (lack of in-house expertise) and minimum support from construction industry related professional bodies*" which have been identified as barriers in applying BIM technology for D&B projects.

4.4. The most suitable strategies to manage the identified barriers to implement BIM to manage the cost overruns in D&B projects (R2Q4, R3Q3)

Fifteen (15) BIM implementation strategies identified from the literature were introduced to round 2 survey tailored them to suit for D&B project nature. These strategies were basically considered regarding their applicability to enhance the enablers and overcome the barriers of BIM implementation to construction industry. Following this round, five strategies were altered and five novel strategies were added. Concluding the Delphi round 2, twenty (20) strategies were carried out to Delphi round 3.

Based on the findings of round 2, in round 3 questionnaire, the respondents were asked to select the most significant strategies to control the barriers and enhance the enablers of implementing BIM to manage cost overruns in D&B projects. In the Table 6, strategies with WMR 3 and above were considered as strategies with significant impact. Modified phrases of the existing strategies are indicated in bold letters whereas newly identified strategies are in bold and italic letters.

<Insert Table 6>

Table 6 indicates how the most significant strategies are incorporated to enhance the enablers and control the barriers of implementing BIM to manage most significant causes of cost overruns in D&B projects. As demonstrated in Table 6, the most commonly highlighted strategy for BIM implementation in D&B projects is "*designing robust organisational structures for effective collaboration and communication*". When D&B project team members

working under collaborative environment, it could act as a means of sharing knowledge with others, and could influence other practitioners to employ BIM technology, thereby improving awareness about the benefits of incorporating BIM into D&B projects. The next most common strategies are "*conducting BIM based CPDs for existing staff*" and "*introducing BIM roadmaps and execution plans even for infrastructure projects*". Continuous Professional Development (CPD) programs are widely practiced strategies for enriching professionals in areas where they may lack expertise. Therefore, conducting CPDs promoting BIM applications in D&B would be a practical strategy. Furthermore, there are several other common strategies such as "*user friendly BIM software development, governmental subsidies for BIM projects, and encouraging the involvement of BIM managers for construction projects*". As a whole, all the strategies listed under each most significant cause contribute to enhance their enablers and overcome their barriers of implanting BIM to manage cost overrun issues.

4.5. Discussion

In recent years, the demand for BIM has significantly increased in the construction industry across the globe. It has been widely reported that developed countries are actively employing BIM for the construction projects (Ismail *et al.*, 2017). Nevertheless, in many developing countries including Malaysia, Vietnam, Myanmar, and Pakistan, BIM is still in its infancy as an alternative technology for construction management (Muhammad *et al.*, 2019; Ismail *et al.*, 2017). Particularly, in the Sri Lankan context, the adoption of BIM technology is quite low (Epasinghe *et al.*, 2018; Jayasena and Weddikkara, 2012). According Akram *et al.* (2022), a significant obstacle for any BIM-driven solution is the reduced dispersion of BIM's enabling environment as a fundamental decision support system. Due to poor economies, lack of collaboration between academic and industrial researchers and practitioners, lack of research studies and general lack of enthusiasm for adopting new technologies, Sri Lanka as a developing country faces a far greater challenges than developed countries (Akram *et al.*, 2022; Epasinghe *et al.* 2018). Nevertheless, this study thoroughly examined the adoptability of BIM technology for D&B projects in order to draw the attention of industry practitioners towards BIM application.

The framework named "BIM adaptability framework for mitigating cost overruns in D&B projects" as delineated in following Figure 3 showcases, the most significant causes (SC) which were identified in Delphi round 1 and round 2 are linked with the significant functions (SF) of BIM, and significant enablers (SE), significant barriers (SB) and significant strategies (SS) to

implement BIM to manage those causes as identified according to the Questionnaire Survey round 2. It denotes how the twenty-eight (28) BIM functions, sixteen (16) BIM enablers, twenty-six (26) barriers and nineteen (19) strategies to implement BIM to manage the most significant causes. All the BIM functions, enablers, barriers and strategies are sorted in descending order according to their frequency of occurrence.

For projects, the construction industry has used a variety of procurement techniques, including traditional method, design and build, project management, management contracting and partnering (Naoum and Egbu, 2015). According to Naoum and Egbu (2016), construction management and partnering project procurement methods are excel at high quality project delivering whereas, traditional procurement method is criticized by researchers for not achieving value for money. In D&B procurement method, detail design and construction are carried out in parallel and concurrently each other, allowing earlier commencement of the project (Suratkon *et al.*, 2020). Nevertheless, Morledge and Smith (2013) revealed that cost certainty in D&B procurement method is low due to lack of design and specification detailing at the tendering phase.

When a project's actual cost exceeds the initial budget or cost estimate, it is said to have experienced a cost overrun (Niazi and Painting, 2017). In other words, cost overruns occur when the overall cost of a construction project exceeds the original budget or projections. (Enrica *et al.*, 2021). According to El-Ahwal *et al.* (2016), some of the major factors for cost overruns are changes in project scope, design errors, inadequate planning, and delays occurred due to internal and external factors. Same causes were confirmed by expert interviewees regarding their applicability to D&B projects in particular. Accordingly, several the most significant causes for cost overruns in D&B projects as identified in Delphi round 2 were previously identified by past researchers as well. For instance, *continuous changes in design and drawings due to incomplete initial drawings prepared with insufficient design data at tendering stage* was identified by Chang *et al.* (2011) as a critical factor for cost overruns in D&B projects and it was ranked at the top most significant cause for cost overruns in D&B projects from the Delphi round 2. Furthermore, *errors or omissions revealed during construction and inefficient planning and scheduling by contractor* are some other most significant causes for cost overruns in D&B projects proved again from this research where they were previously established by Akinradewo *et al.* (2019). According to Johnson and Babu (2020), *errors or omissions revealed during construction and inadequate constructability of the design* were some critical factors for cost overruns in they were established as unique causes

of cost overruns in D&B projects by the expert interviewees. Other than that, two new causes for cost overruns in D&B projects were identified as the most significant causes namely *lack of clarity in employer's brief* and *issues relating to D&B being not properly addressed in the Conditions of Contract.* and, *poor communication between design and construction teams.*

< Insert Figure 3>

<Insert Figure 4>

Finding the specific BIM functions to mitigate the risk of cost overruns of D&B projects was seen as a research gap. Nevertheless, Delphi round 1 was unable to make additions, alternations or omissions to the initial list of BIM functions in literature section, Delphi round 2 and round 3 revealed several most crucial BIM functions in relation to cost management such as *interoperability and exchange of information* and *clash detection* and *digitalized quantity take-off, cloud computing* and *constructability reviews and building simulation,* those were previously found by Hamid and Abdelhaleem (2023) and Bello *et al.* (2021) respectively. Furthermore, *digitalized quantity take-off, cloud computing and constructability reviews and building simulation* are some other BIM functions previously identified by several authors such as Brahim *et al.* (2018), Bello *et al.* (2021) and Gholizadeh *et al.* (2018) and ranked by the respondents of Delphi round 3 phase 1 as significant BIM functions to manage the causes for cost overruns in D&B projects.

Initially identified generic barriers and enablers of implementing BIM for construction projects were fine-tuned towards the D&B projects during the round 1 survey through making additions and alterations to the existing barriers and enablers. When such barriers and enablers were narrowed down specifically to implement BIM for the management of most significant causes for cost overruns in D&B projects, some common barriers and enablers could be identified. Most common barriers of BIM implementation were identified as *overall industry resistance to process change* and *belief that existing techniques are adequate and reluctance to put additional efforts to formulate BIM contracts* which were also highlighted by Gardezi *et al.* (2014) and Zhou *et al.* (2019). Most commonly identified enabler of BIM implementation was *real time collaboration among all the project professionals and stakeholders* which complies with the opinion of Saghatforoush *et al.* (2021) where they insisted this BIM function as the essence of BIM implementation. Furthermore, *improvement of the construction productivity* is another significant enabler to implement BIM which was previously declared by Abbasnejad *et al.* (2021) and Shojaei *et al.* (2022).

Similar to enablers and barriers, strategies of BIM implementation were identified as generic strategies of BIM implementation. Over the questionnaire survey, they were modified and new strategies were formulated to the initial list. Accordingly, the most commonly identified strategy of BIM implementation was *designing robust organisational structures for effective collaboration and communication*. It was also outlined by Saghatforoush *et al.* (2021) as a key strategy to BIM execution in organisational level. A newly identified strategy of *conducting BIM based CPDs for existing staff* was within the common strategies of BIM implementation to manage causes of cost overruns in D&B projects. As stated by Smith (2014) *introducing BIM roadmaps and execution plans* was another key strategy of BIM implementation further proved from this research as well.

5 Conclusions and Recommendations

Cost overrun has been a huge burden to D&B projects. Accordingly, the research study revealed a modified list of 25 causes for cost overruns in D&B projects and ten (10) most significant causes for cost overruns in D&B projects were finalized where "c*ontinuous changes in design and drawings due to incomplete initial drawings prepared with insufficient design data at tendering stage"* is the top most cause. BIM can be identified as an effective mechanism to strengthen the price certainty of D&B projects and minimize the risk of cost overruns of the project. Accordingly, aforementioned ten most significant causes for cost overruns in D&B projects were considered to explore the adaptability of BIM technology to mitigate the cost overruns in D&B projects. Using BIM as a tool, the study investigated 'BIM functionalities thoroughly and proposed most suitable BIM functions to manage each most significant cause of cost overruns in D&B projects. Moreover, a list of twenty-two (22) enablers and twenty-nine (29) barriers of BIM implementation were depicted based on the findings of literature review and round 2 and 3 questionnaire surveys. Additionally, the most appropriate enablers and barriers for the outlined significant causes of cost overrun were proposed. Accordingly, "*Trend of using BIM for management of construction project information and the possibility of using such information for future projects*" and "*Lack of client demand and interest*" are the most crucial enabler and barrier respectively. Advocating above, as the achievement of final objective, it was suggested crucial strategies to overcome the revealed prioritized causes of overrun.

Concerning the overall findings of the research study, it is recommended to promote the formulation of BIM contracts with the help of standard documents like CIC BIM Protocol and Publicly Available Specifications (PAS) 1192-2:2013. By considering the prominent cost overrun issue and capability of BIM implementation, D&B projects can be greatly benefited with the incorporation of BIM technology to their project delivery path. Therefore, it can be ultimately recommended to implement BIM to manage the cost overruns in D&B projects. This research findings make contribution to the industry by, introducing appropriate BIM functions against the causes of cost overruns in order to minimize the risk of budget overrun in the construction projects. Additionally, the findings of BIM functions are applicable to ameliorate the efficiency in project delivery performance. The research study contributes to the theory by, amalgamating BIM, D&B and cost overruns through investigating the adaptability of BIM to mitigate cost overruns in D&B projects. Since BIM is a relatively new concept to a developing country like Sri Lanka, this research is limited to developing countries

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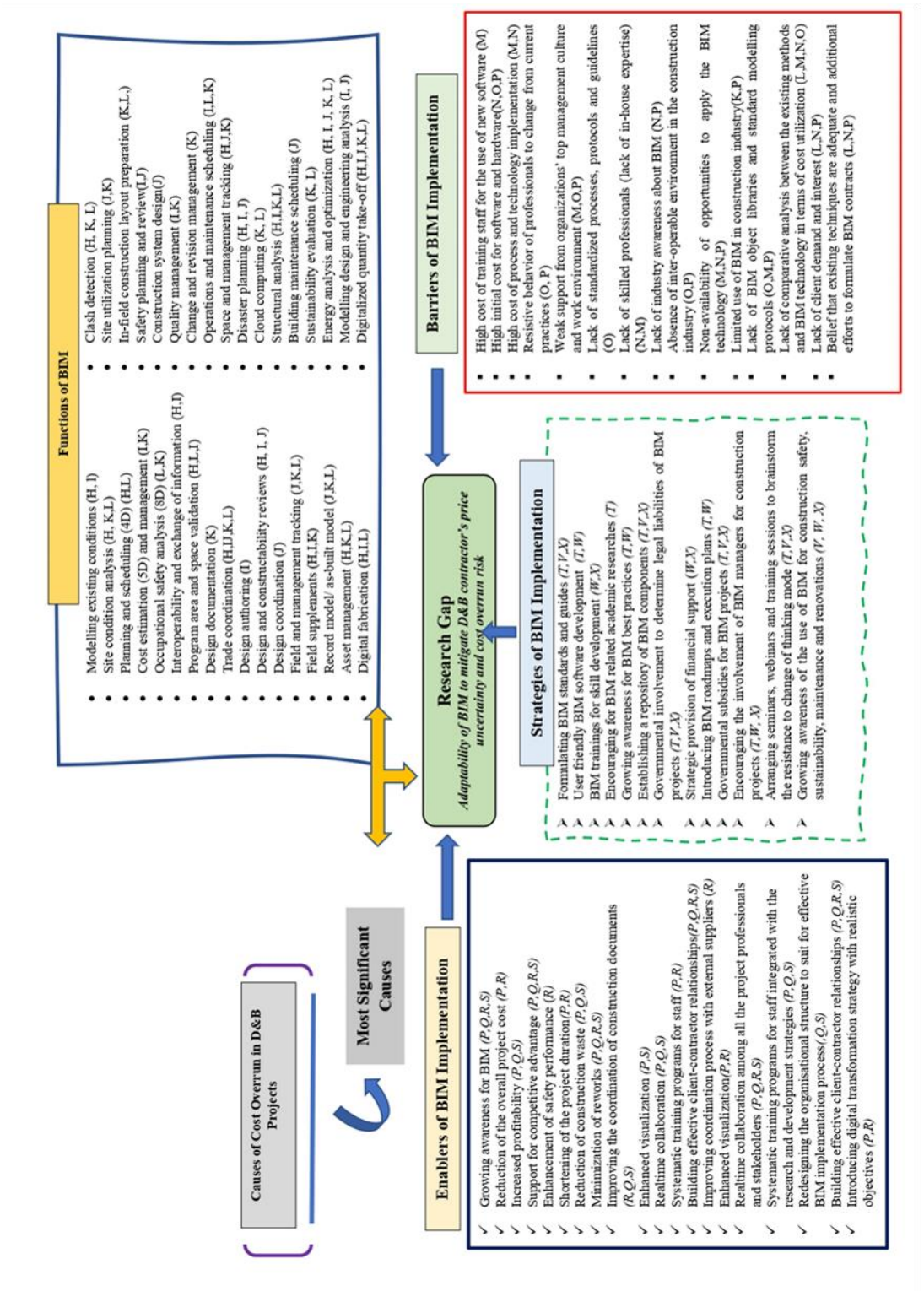

F - Saaidin et al. (2017), G - Yusoff et al. (2022), H- Gholizadeh et al. (2018), I -Kang et al. (2013), J - Ganbat et al. (2020), K - Charehzehi et al. (2017), L - Enshassi & AbuHamra (2016), M - Sun et al., (2015) , N - Oesterreich & Teuteberg, (2019), O - Won et al, (2013), P - Olanrewaju et al. (2020) , Q - Sinoh et al. (2020) ,R - Badi & Diamantidou (2017), S - Shojaei et al. (2022), T - Zhou et al. (2019) , U - Besné et al. (2021), V - Manzoor et al. (2021) , W - Ullah et al. (2022)

Figure 1: Theoretical Framework

Source: created by author

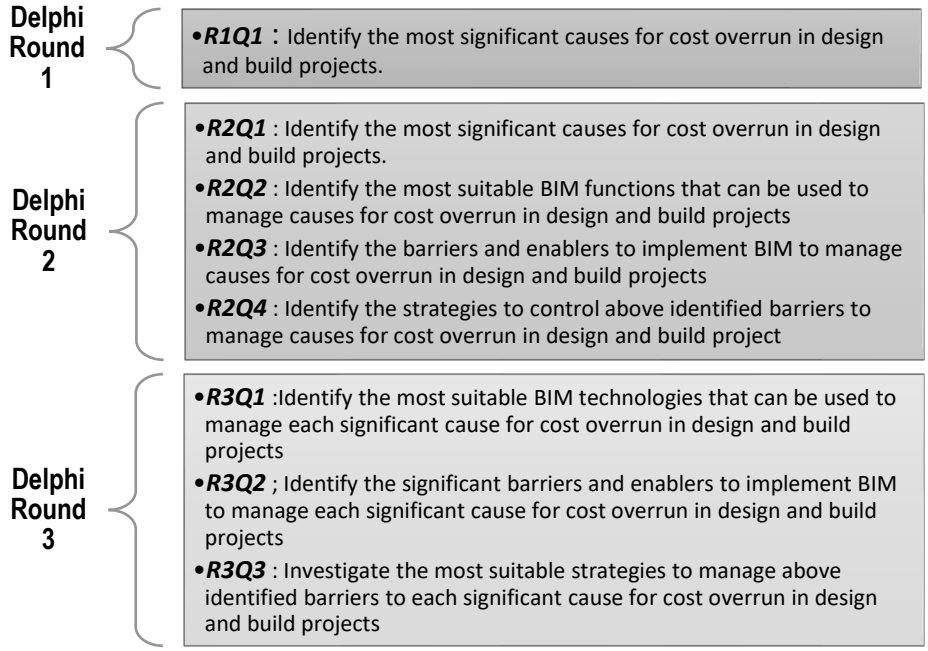

Figure 2: Summary of Delphi Rounds 1, 2, 3

Source: created by author

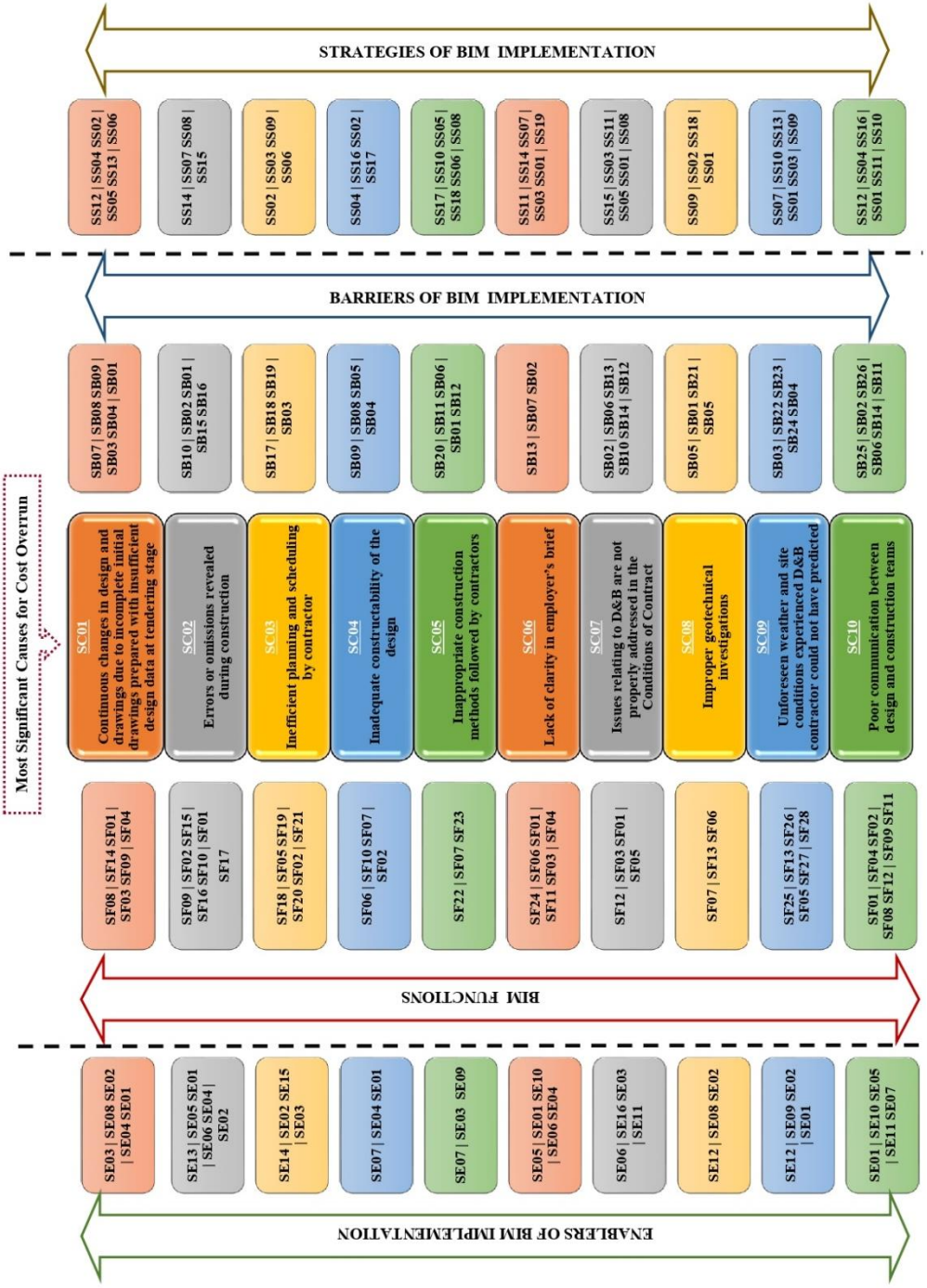

Figure 3: BIM adaptability framework for mitigating cost overruns in D&B projects

Source: created by author

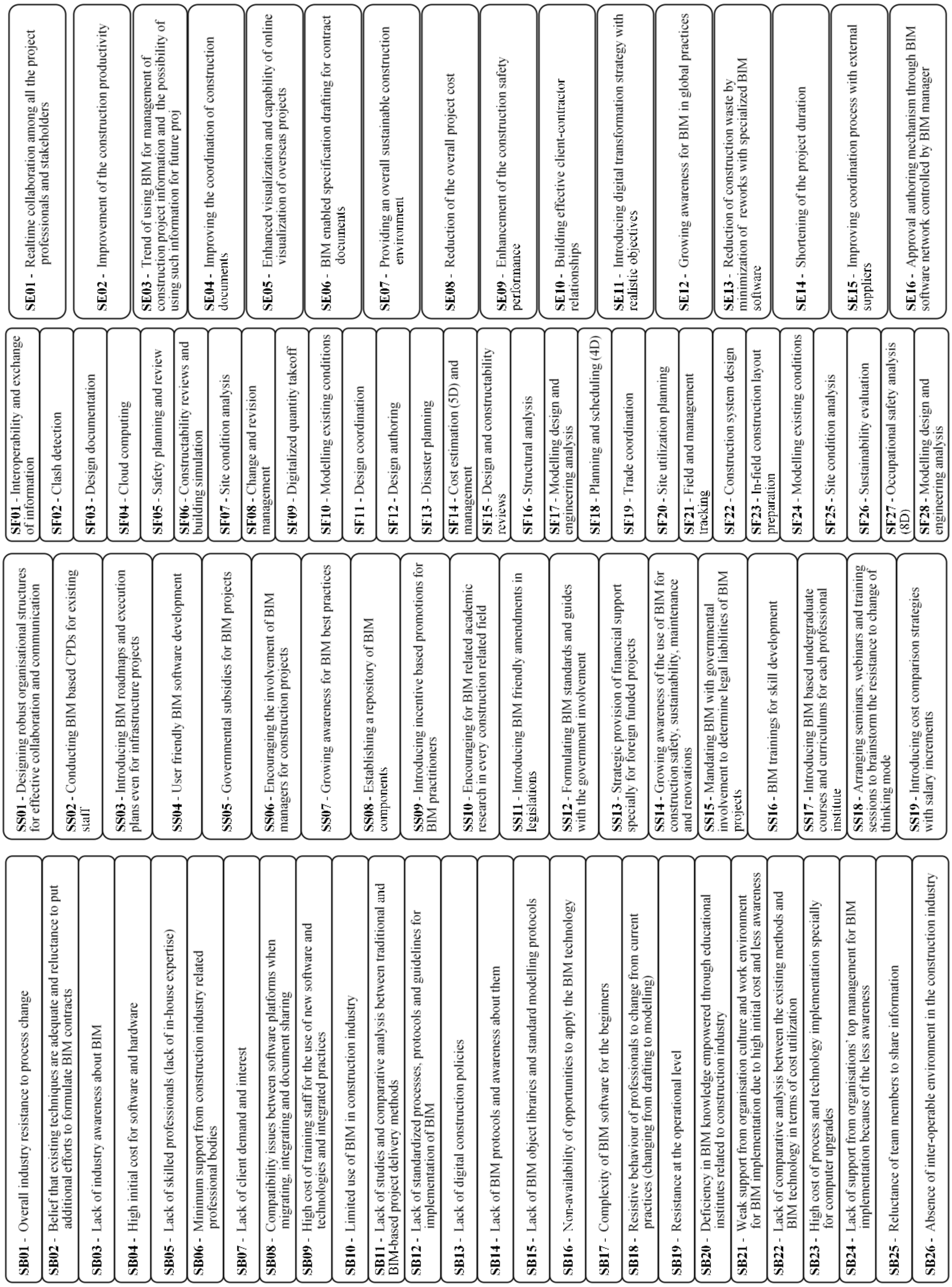

Figure 4: Legend for the BIM adaptability Framework

Source: created by author

Table 1: Causes for price uncertainty and cost overrun in D&B projects

Source: created by author

Cause for price uncertainty and cost overrun in D&B projects	Authors							
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Delay in revising and approving design documents by consultant or employer	✓	✓	✓		✓	✓	✓	✓
Lack of materials at the site due to difficulty in extracting exact material quantity from incomplete and unapproved drawings	✓	✓	✓	✓	✓	✓	✓	
Insufficient pricing for project preliminaries and less allocations for contingencies	✓	✓	✓	✓	✓	✓	✓	
Inadequate constructability of the design	✓	✓	✓	✓	✓	✓	✓	
Poor communication between design and construction teams		✓	✓	✓	✓	✓	✓	
Mistakes in quantity take off at the time of tendering	✓	✓	✓	✓	✓	✓		
Poor judgement in estimating time and resources due to inadequate experience of the contractor		✓	✓	✓	✓			✓
Errors or omissions revealed during construction	✓	✓	✓		✓			✓
Delays in getting approvals from local agencies	✓				✓	✓	✓	
Slowness in decision making by employer and consultant which cause for additional cost for material idling	✓	✓	✓			✓		
Rework due to design clashes, poor and inaccurate identification of employer requirements and lack of final quality caused by work acceleration	✓	✓	✓		✓			
Unforeseen weather and site conditions	✓	✓	✓		✓			
Fluctuation in cost of construction materials and fossil fuels	✓		✓	✓	✓			
Continuous changes in design and drawings due to incomplete initial drawings prepared with insufficient design data at tendering stage	✓			✓		✓		
Delay in material approval by consultant or employer	✓	✓			✓			
Delays in early procurement of the specialist subcontracting works due to incomplete designs and specifications	✓				✓		✓	
Dependency on specialist works without alternative plans		✓	✓				✓	
Cash flow problems faced by contractor due to the delayed payment from the client	✓	✓					✓	
Additional works required on site conditions and employer's request		✓		✓	✓			
Inefficient planning and scheduling by contractor			✓		✓	✓		
Catastrophes	✓		✓	✓				
Poor material selection and waste management strategies			✓		✓			
Mistakes in tender document preparation and misinterpretation of contractual clauses	✓				✓			
Improper geotechnical investigations		✓			✓			
Environmental issues			✓		✓			
Quality control and assurance related causes			✓		✓			

Cause for price uncertainty and cost overrun in D&B projects	Authors							
	A	B	C	D	E	F	G	H
Unqualified work force	✓				✓			
Inappropriate construction methods followed by contractors			✓		✓			
Shortage of local materials which cause cost for additional transport		✓	✓					
Frequent change of construction drawing during execution of construction works	✓						✓	
A - Ramanathan *et al.* (2011), B - Ogunsanmi *et al.* (2011), C - Ramanathan and Narayanan (2014), D - Pham *et al.* (2021), E - Rostiyanti *et al.* (2019), F - Saaidin *et al.* (2017), G - Yusoff *et al.* (2022), H-Young *et al.* (2021)								

Table 2: Profile details of the interviewees

Source: created by author

Respondent Category	Criteria												Number of Responses		
	Compulsory qualifications						Additional qualifications (Respondents must possess at least 3 qualifications)					C9			
	C1			C2		C3	C4	C5	C6	C7	C8				
	Should possess at least 10 years of experience in the construction industry			Should possess at least5years of experience in D&B projects		Should possess at least 3 years of experience in BIM	Should possess a degree in the construction industry	ree in the Information Technology	Should possess a master's degree in the construction industry field	Should possess a charted qualification in relation to construction industry	Should be interested in innovative technology of and construction practices	Should be accessible	Delphi Round 1	Delphi Round 2	Delphi Round 3
	10 - 15	15 – 20	> 20	5-10	> 10										
Quantity Surveyor	✓			✓		✓	✓	-	✓	✓	✓	✓	**6**	**5**	**7**
	✓			✓		✓	✓	✓	-	✓	✓	✓	**4**	**4**	**4**
		✓		✓		✓	✓	-	✓	✓	✓	✓	**5**	**4**	**4**
		✓			✓	✓	✓	-	✓	✓	✓	✓	**2**	**2**	**2**
			✓		✓	✓	✓	✓	✓	✓	✓	✓	**1**	**1**	**2**
Architect	✓			✓		✓	✓	-	✓	✓	✓	✓	**5**	**5**	**5**
	✓			✓		✓	✓	✓	✓	✓	✓	✓	**2**	**3**	**2**
		✓		✓		✓	✓	-	✓	✓	✓	✓	**2**	**2**	**1**
Engineer (Civil/MEP)	✓			✓		✓	✓	-	-	✓	✓	✓	**4**	**4**	**4**
	✓			✓		✓	✓	-	✓	✓	✓	✓	**2**	**2**	**2**
	✓			✓		✓	✓	✓	-	✓	✓	✓	**2**	**2**	**3**
Project Manager		✓			✓	✓	✓	-	✓	✓	✓	✓	**3**	**3**	**3**
			✓		✓	✓	✓	✓	✓	✓	✓	✓	**4**	**3**	**2**
Academic researcher	✓			✓		✓	✓	-	✓	✓	✓	✓	**3**	**4**	**4**
	✓			✓		✓	✓	-	-	✓	✓	✓	**2**	**2**	**2**
		✓		✓		✓	✓	✓	-	✓	✓	✓	**2**	**1**	**1**
		✓			✓	✓	✓	✓	✓	✓	✓	✓	**1**	**1**	**1**
TOTAL													***50***	***48***	***49***

Table 3: Identification of the most significant causes for cost overruns in D&B projects

Source: created by author

No	Item Code	Description	Total Marks	WMR	SD	Rank
01	C14	Continuous changes in design and drawings due to incomplete initial drawings prepared with insufficient design data at tendering stage	135	4.355	0.661	1
02	C8	Errors or omissions revealed during construction	133	4.290	0.739	2
03	C20	Inefficient planning and scheduling by contractor	130	4.194	0.749	3
04	C4	Inadequate constructability of the design	129	4.161	0.688	4
05	C28	Inappropriate construction methods followed by contractors	128	4.129	0.885	5
06	**CN1**	**Lack of clarity in employer's brief**	127	4.097	0.651	6
07	**CN03**	**Issues relating to D&B are not properly addressed in the Conditions of Contract**	126	4.065	0.772	7
08	C24	Improper geotechnical investigations	126	4.065	0.680	8
09	C12	Unforeseen weather and site conditions *experienced D&B contractor could not have predicted*	125	4.032	0.836	9
10	C5	Poor communication between design and construction teams	125	4.032	0.657	10
11	C30	Frequent change of construction drawing during execution of construction works	117	3.774	1.023	11
12	C1	Delay in revising and approving design documents by consultant or employer	111	3.581	1.025	12
13	C18	Cash flow problems faced by contractor due to the delayed payment from the client	110	3.548	0.675	13
14	C26	Quality control and assurance related causes	109	3.516	0.926	14
15	C10	Slowness in decision making by employer and consultant which cause for additional cost for material idling	108	3.484	0.724	15
16	C23	Mistakes in tender document preparation and misinterpretation of contractual clauses	106	3.419	0.807	16
17	**CN02**	**Mistakes in communicating the requirements of basic design parameters**	102	3.290	0.643	17
18	C22	Poor material selection and waste management strategies	100	3.226	0.805	18
19	**CN04**	**Inexperience of client's and/or contractor's project management teams**	100	3.226	0.762	18

No	Item Code	Description	Total Marks	WMR	SD	Rank
20	C2	Lack of materials at the site due to difficulty in extracting exact material quantity from incomplete and unapproved drawings	98	3.161	1.003	20
21	C11	Rework due to design clashes, poor and inaccurate identification of employer requirements and lack of final quality caused by work acceleration	97	3.129	1.024	21
22	C7	Poor judgement in estimating time and resources due to inadequate experience of the contractor	97	3.129	0.957	21
23	C6	Mistakes in quantity take-off at the time of tender *pricing by design and build contractor*	96	3.097	1.106	23
24	C16	Delays in early procurement of the specialist subcontracting works due to incomplete designs and specifications	95	3.065	0.929	24
25	C19	Additional works required on site conditions and employer's request	94	3.032	0.752	25

Table 4: Most suitable BIM functions that can be used to manage the most significant causes for cost overruns in D&B projects

Source: created by author

The most Significant Cause No	BIM Functions	Rank	WMR
C14	Change and revision management	1	4.323
	Cost estimation (5D) and management	2	4.258
	Interoperability and exchange of information	3	4.082
	Design documentation	4	3.942
	Digitalized quantity take-off	5	3.428
	Cloud computing	6	3.187
C8	Digitalized quantity take-off	1	4.520
	Clash detection	2	4.412
	Design and constructability reviews	3	4.286
	Structural analysis	4	4.015
	Modelling existing conditions	5	3.845
	Interoperability and exchange of information	6	3.624
	Modelling design and engineering analysis	7	3.073
C20	Planning and scheduling (4D)	1	4.281
	Safety planning and review	2	4.235
	Trade coordination	3	4.184
	Site utilization planning	4	3.947
	Clash detection	5	3.564
	Field and management tracking	6	3.161
C4	Constructability reviews and building simulation	1	4.364
	Modelling existing conditions	2	4.156
	Site condition analysis	3	3.847
	Clash detection	4	3.594
C28	Construction system design	1	4.008

The most Significant Cause No	BIM Functions	Rank	WMR
	Site condition analysis	2	3.745
	In-field construction layout preparation	3	3.214
CN1	Modelling existing conditions	1	4.532
	Constructability reviews and building simulation	2	4.320
	Interoperability and exchange of information	3	4.276
	Design coordination	4	4.085
	Design documentation	5	3.945
	Cloud computing	6	3.583
CN3	Design authoring	1	4.533
	Design documentation	2	4.152
	Interoperability and exchange of information	3	3.864
	Safety planning and review	4	3.740
C24	Site condition analysis	1	4.012
	Disaster planning	2	3.985
	Constructability reviews and building simulation	3	3.125
C12	Site condition analysis	1	4.689
	Disaster planning	2	4.591
	Sustainability evaluation	3	4.258
	Safety planning and review	4	4.015
	Occupational safety analysis (8D)	5	3.761
	Modelling design and engineering analysis	6	3.620
C5	Interoperability and exchange of information	1	4.529
	Cloud computing	2	4.236
	Clash detection	3	4.174
	Change and revision management	4	4.059
	Design authoring	5	3.910
	Digitalized quantity take-off	6	3.856
	Design coordination	7	3.452

Table 5: Significant enablers and barriers to implement BIM to manage the most significant causes for cost overruns in D&B projects

Source: created by author

Cause	Enablers	Rank	WMR	Barriers	Rank	WMR
C14	Trend of using BIM for management of construction project information **and the possibility of using such information for future projects**	1	4.315	Lack of client demand and interest	1	4.494
				Compatibility issues between software platforms when migrating, integrating and document sharing	2	4.316
	Reduction of the overall project cost	2	3.993	High cost of training staff for the use of new software and technologies and integrated practices	3	3.528
	Improvement of the construction productivity	3	3.255	Lack of industry awareness about BIM	4	3.317
	Improving the coordination of construction documents	4	3.186	High initial cost for software and hardware	5	3.152
	Realtime collaboration among all the project professionals and stakeholders	5	3.099	Overall industry resistance to process change	6	3.008
C8	Reduction of construction waste by minimization of reworks **with specialized BIM software**	1	4.215	Limited use of BIM in construction industry	1	4.283
	Enhanced visualization **and capability of online visualization of overseas projects**	2	4.134	Belief that existing techniques are adequate and reluctance to put additional efforts to formulate BIM contracts	2	4.189
	Realtime collaboration among all the project professionals and stakeholders	3	4.065	Overall industry resistance to process change	3	4.075
	BIM enabled specification drafting for contract documents	4	3.845	Lack of BIM object libraries and standard modelling protocols	4	3.845
	Improving the coordination of construction documents	5	3.689	Non-availability of opportunities to apply the BIM technology	5	3.494
	Improvement of the construction productivity	6	3.543			
C20	Shortening of the project duration	1	4.372	***Complexity of BIM software for the beginners***	1	4.275
	Improvement of the construction productivity	2	4.342	Resistive behaviour of professionals to change from current practices	2	4.056
	Improving coordination process with external suppliers	3	3.891	Resistance at the operational level	3	4.003
	Trend of using BIM for management of construction project information **and the possibility of using such information for future projects**	4	3.759	Lack of industry awareness about BIM	4	3.964
C4	Providing an overall sustainable construction environment	1	4.440	High cost of training staff for the use of new software and technologies and integrated practices	1	4.394
	Improving the coordination of construction documents	2	4.144	Compatibility issues between software platforms when migrating, integrating and document sharing	2	4.125
	Realtime collaboration among all the project professionals and stakeholders	3	3.530	Lack of skilled professionals (lack of in-house expertise)	3	3.958
				High initial cost for software and hardware	4	3.875
C28	Providing an overall sustainable construction environment	1	4.175	***Deficiency in BIM knowledge empowered through educational institutes related to construction industry***	1	4.382

Cause	Enablers	Rank	WMR	Barriers	Rank	WMR
	Trend of using BIM for management of construction project information **and the possibility of using such information for future projects**	2	4.010	Lack of studies and comparative analysis between traditional and BIM-based project delivery methods	2	4.165
				Minimum support from construction industry related professional bodies	3	3.819
	Enhancement of the construction safety performance	3	3.627	Overall industry resistance to process change	4	3.543
				Lack of standardized processes, protocols and guidelines for implementation of BIM	5	3.498
CN 01	Enhanced visualization **and capability of online visualization of overseas projects**	1	4.395	***Lack of digital construction policies***	1	4.158
	Realtime collaboration among all the project professionals and stakeholders	2	4.191	Lack of client demand and interest	2	3.976
	Building effective client-contractor relationships	3	3.834	Belief that existing techniques are adequate and reluctance to put additional efforts to formulate BIM contracts.	3	3.854
	BIM enabled specification drafting for contract documents	4	3.575			
	Improving the coordination of construction documents	5	3.015			
CN 03	***BIM enabled specification drafting for contract documents***	1	4.450	Belief that existing techniques are adequate and reluctance to put additional efforts to formulate BIM contracts	1	4.357
	Approval authoring mechanism through BIM software network controlled by BIM manager	2	3.964	***Minimum support from construction industry related professional bodies***	2	4.289
	Trend of using BIM for management of construction project information **and the possibility of using such information for future projects**	3	3.672	***Lack of digital construction policies***	3	4.127
	Introducing digital transformation strategy with realistic objectives	4	3.453	Limited use of BIM in construction industry	4	3.944
				Lack of BIM protocols and awareness about them	5	3.452
				Lack of standardized processes, protocols and guidelines for implementation of BIM	6	3.194
C24	Growing awareness for BIM in global practices	1	4.012	Lack of skilled professionals (lack of in-house expertise)	1	4.221
	Reduction of the overall project cost	2	3.921	Overall industry resistance to process change	2	4.120
	Improvement of the construction productivity	3	3.594	Weak support from organisation culture and work environment for BIM implementation **due to high initial cost and less awareness**	3	3.785
				Lack of skilled professionals (lack of in-house expertise)	4	3.247
C12	Growing awareness for BIM in global practices	1	4.344	Lack of industry awareness about BIM	1	4.254
	Enhancement of the construction safety performance	2	4.150	Lack of comparative analysis between the existing methods and BIM technology in terms of cost utilization	2	4.195
	Improvement of the construction productivity	3	3.733	High cost of process and technology implementation **specially for computer upgrades**	3	4.078

Cause	Enablers	Rank	WMR	Barriers	Rank	WMR
	Realtime collaboration among all the project professionals and stakeholders	4	3.682	Lack of support from organisations' top management for BIM implementation **because of the less awareness**	4	3.856
				High initial cost for software and hardware	5	3.749
C5	Realtime collaboration among all the project professionals and stakeholders	1	4.228	Reluctance of team members to share information	1	4.481
	Building effective client-contractor relationships	2	4.187	Belief that existing techniques are adequate and reluctance to put additional efforts to formulate BIM contracts	2	4.259
	Enhanced visualization **and capability of online visualization of overseas projects**	3	3.892	Absence of inter-operable environment in the construction industry	3	4.087
	Introducing digital transformation strategy with realistic objectives	4	3.451	***Minimum support from construction industry related professional bodies***	4	3.681
	Providing an overall sustainable construction environment	5	3.246	***Lack of BIM protocols and awareness about them***	5	3.456
				Lack of studies and comparative analysis between traditional and BIM-based project delivery methods	6	3.176

Table 6: Strategies to control the barriers and enhance the enablers of implementing BIM to manage the most significant causes for cost overruns in D&B projects

Source: created by author

Significant Cause	Strategies	Rank	WMR
C14	Formulating BIM standards and guides **with the government involvement**	1	3.975
	User friendly BIM software development	2	3.754
	Conducting BIM based CPDs for existing staff	3	3.543
	Governmental subsidies for BIM projects	4	3.321
	Strategic provision of financial support **specially for foreign funded projects**	5	3.125
	Encouraging the involvement of BIM managers for construction projects	6	3.015
C8	Growing awareness of the use of BIM for construction safety, sustainability, maintenance and renovations	1	3.843
	Growing awareness for BIM best practices	2	3.792
	Establishing a repository of BIM components	3	3.668
	Mandating BIM with governmental involvement to determine legal liabilities of BIM projects	4	3.535
C20	***Conducting BIM based CPDs for existing staff***	1	3.990
	Introducing BIM roadmaps and execution plans **even for infrastructure projects**	2	3.698
	Introducing incentive-based promotions for BIM practitioners	3	3.643
	Encouraging the involvement of BIM managers for construction projects	4	3.510
C4	User friendly BIM software development	1	3.655
	BIM trainings for skill development	2	3.285
	Conducting BIM based CPDs for existing staff	3	3.824
	Introducing BIM based undergraduate courses and curriculums for each professional institute	4	3.795
C28	***Introducing BIM based undergraduate courses and curriculums for each professional institute***	1	3.962
	Encouraging for BIM related academic research **in every construction related field**	2	3.883
	Governmental subsidies for BIM projects	3	3.582
	Arranging seminars, webinars and training sessions to brainstorm the resistance to change of thinking mode	4	3.356
	Encouraging the involvement of BIM managers for construction projects	5	3.214
	Establishing a repository of BIM components	6	3.145
CN01	***Introducing BIM friendly amendments in legislations***	1	3.953
	Growing awareness of the use of BIM for construction safety, sustainability, maintenance and renovations	2	3.742
	Growing awareness for BIM best practices	3	3.692
	Introducing BIM roadmaps and execution plans **even for infrastructure projects**	4	3.610
	Designing robust organisational structures for effective collaboration and communication	5	3.597
	Introducing cost comparison strategies with salary increments	6	3.525
CN03	**Mandating BIM with** governmental involvement to determine legal liabilities of BIM projects	1	3.786
	Introducing BIM roadmaps and execution plans **even for infrastructure projects**	2	3.482
	Introducing BIM friendly amendments in legislations	3	3.023
	Governmental subsidies for BIM projects	4	3.863
	Designing robust organisational structures for effective collaboration and communication	5	3.772
	Establishing a repository of BIM components	6	3.648
C24	***Introducing incentive-based promotions for BIM practitioners***	1	3.739

Significant Cause	Strategies	Rank	WMR
	Conducting BIM based CPDs for existing staff	2	3.641
	Arranging seminars, webinars and training sessions to brainstorm the resistance to change of thinking mode	3	3.583
	Designing robust organisational structures for effective collaboration and communication	4	3.577
C12	Growing awareness for BIM best practices	1	4.015
	Encouraging for BIM related academic research **in every construction related field**	2	4.009
	Strategic provision of financial support **specially for foreign funded projects**	3	3.914
	Designing robust organisational structures for effective collaboration and communication	4	3.874
	Introducing BIM roadmaps and execution plans **even for infrastructure projects**	5	3.689
	Introducing incentive-based promotions for BIM practitioners	6	3.526
C5	Formulating BIM standards and guides **with the government involvement**	1	3.830
	User friendly BIM software development	2	3.698
	BIM trainings for skill development	3	3.550
	Designing robust organisational structures for effective collaboration and communication	4	3.453
	Introducing BIM friendly amendments in legislations	5	3.248
	Encouraging for BIM related academic research **in every construction related field**	6	3.045