DEVELOPMENT OF A BIM AND LEAN CONSTRUCTION PROCESS PROTOCOL FOR THE CONSTRUCTION INDUSTRY IN KUWAIT: FROM A CLIENT PERSPECTIVE

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Abstract

In Kuwait, there are substantial development plans for the construction industry; however, this is not without obstacles, as it suffers from problems and faces many challenges that have led to poor performance in the industry. This research focuses on the public sector as a sector that could bring innovation to the government and support the aim Kuwait's vision for 2035 for the construction industry. Moreover, it could help to introduce advanced methods that enable the digitisation of the industry. This study investigates the most common problems facing the Kuwaiti construction industry, identifies an appropriate solution to resolve these issues, and thus, improve the industry.

Lean Construction (LC) and Building Information Modelling (BIM) have demonstrated their effectiveness in improving the construction industry in many countries around the world. Lean Construction is a management philosophy to minimise waste and add value for the customer, whereas BIM is a process that manages information through the project lifecycle, from planning and designing through to project completion. Since there is a lack of awareness of Lean Construction and Building Information Modelling in Kuwait, it is essential to consider these two resources when exploring ways to improve the efficiency of the construction industry.

Mixed methods research is applied in this study, starting with a survey that explores the challenges and examines the possible solutions applied in construction projects in Kuwait. Subsequently, two case studies are selected to obtain in-depth information on the challenges, project management practices, and adoption of advanced technologies, such as BIM and Lean Construction, in construction projects in Kuwait.

Delays, a lack of communication and coordination between stakeholders, poor planning and control, and change in orders by the client have been noted as the main risks in the industry. Yet, public construction organisations can also adopt project management approaches that are ineffective and need improvement. In addition, there is a lack of awareness of Lean Construction, while BIM has been improperly implemented in the industry. In short, the construction industry in Kuwait needs to be developed and modernised to keep pace with other developing countries in terms of its performance and productivity.

Therefore, this research will propose the development of a framework based on Lean Construction principles and utilising Building Information Modelling to address the challenges identified in the Kuwaiti construction industry and improve the industry's performance and effectiveness in terms of time, cost, and quality. The outcome of the study will help to build knowledge for the implementation of BIM using the new International BIM Standard (ISO 19650) with principles of Lean Construction in the construction industry.

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Declaration

I, Manal Al-Adwani, declare that this dissertation report is my original work, and has not been submitted elsewhere for any award. Any section, part or phrasing that has been used or copied from other literature or documents copied has been clearly referenced at the point of use as well as in the reference section of the thesis work.

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Signature Date

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Approved by

Mr. Andy Fleming (Supervisor)

List of Publications

1. Al-Adwani, M., Mollasalehi, S., & Fleming, A. (2018). *A study of root causes of delays in the public-sector construction projects in Kuwait.* Paper presented at the Proceedings, International Conference on Construction Futures (ICCF).

2. Aladwani, M., & Fleming, A. (2019, 16 - 17 December). *IMPROVING THE CONSTRUCTION INDUSTRY IN THE STATE OF KUWAIT.* Paper presented at the The 14th International Postgraduate Research Conference 2019, University of Salford, UK.

Abbreviations:

AIM	Asset Information Model
AIR	Asset Information Requirements
BEP	BIM Execution Plan
BIM	Building Information Modelling
BREEAM	Building Research Establishment Environmental Assessment Methodology
CDE	Common Data Environment
CIM	Client Information Model
D&D	Design and Build
D-B-B	Design-Bid-Build
EIR	Exchange Information Requirements
FF&E	Furniture Fixture and Equipment
FM	Facility Management
GIS	Geographic Information System
H&S	Health and Safety
IPD	Integrated Project Delivery
IT	Information Technology
LEED	Leadership in Energy and Environmental Design
LOD	Level of Development

MEP	Mechanical, Electrical and Plumbing
MEPFP	Mechanical, Electrical, Plumping and Fire Protection
MIDP	Master Information Delivery Plan
MPW	Ministry of Public Works
O&M	Operation and Maintenance
OIR	Organisational Information Requirements
PID	Project Initiation Document
PIR	Project Information Requirements
PM	Project Manager
QA	Quality Assurance
QC	Quality Control
RACI	Responsibility Matrix (RACI)
RFI	Request for Information
ROI	Return on Investment
TIDP	Task Information Delivery Plan
TOR	Terms of Reference

Chapter 1: Introduction

1.1 Background

The construction industry plays an important and vital role in enhancing the productivity of countries around the world (Othman & Ismail, 2014). On a global level, the construction industry has recently become highly competitive, whilst increasing project complexities create significant challenges. In order to compete within this market, ensure a successful project, and build/maintain a good reputation, it is important to control the risks associated with time, budget and quality. These are also indicators of the work efficiency of project delivery within the industry (Al-Marri, Ibrahem, & Nassar, 2012; Shahhossein, Afshar, & Amiri, 2017). Although these goals are difficult to achieve immediately, the implementation of collaborative and integrated procurement delivery systems through the use of innovative tools, such as Building Information Modelling, could help to accomplish these targets (Abdulfattah, Khalafallah, & Kartam, 2017).

In the Middle East, construction problems are increasing and there is a significant need to develop this sector in order to keep pace with developed countries. Kuwait is one such developing country that is struggling to address its construction challenges. Although Kuwait is an oil-rich country and its currency, the Kuwaiti Dinar (KWD), has the highest value in the world (BookMyForex, 2017), its construction industry faces many problems and lags behind in terms of productivity and performance. Therefore, this research will focus on improving the efficiency of the construction industry in Kuwait. Firstly, global construction problems will be explored followed by construction issues in the Middle East, which will be narrowed to those specifically encountered in Kuwait. Moreover, possible solutions to these problems will also be discussed.

Globally, the construction industry is facing significant risks to completing projects on time and within budget, achieving the desired quality, and improving its low productivity (Al-Hazim, Salem, & Ahmad, 2017; Farmer, 2016; Laskar & Murty, 2004; Venkateswaran & Murugasan, 2017). Hussin, Rahman, and Memon (2013) described the nature of this industry as fragmented, complicated and constantly facing challenges. For instance, 70% of projects suffer delays, cost overruns, which (on average) comprise 14% of the contract cost, whilst approximately 10% of the total costs are waste. Furthermore, around 57% of time is wasted by poor productivity (Ansah, Sorooshian, & Mustafa, 2016). However, over the past 40 years, the productivity of the construction industry worldwide has trailed behind most other industries (Moud, 2013; Ningappa, 2011). It has remained static, whereas the manufacturing industry has approximately doubled, as shown in Figure 1.

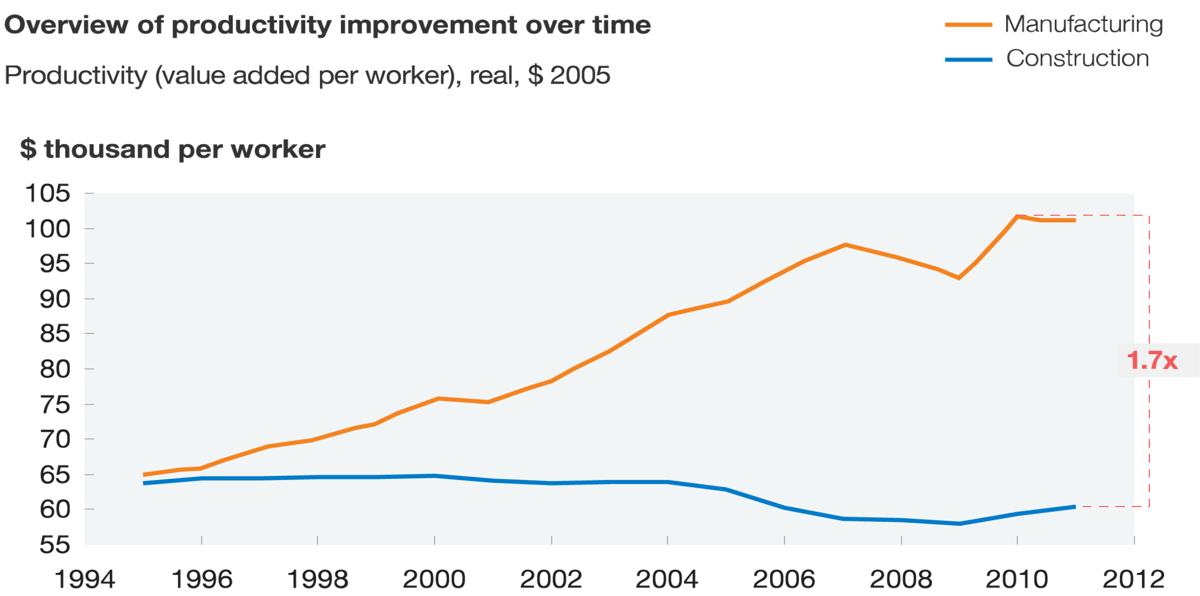


Figure 1: Overview of productivity improvements over time (Changali;, Mohammad;, & Nieuwland, 2015)

Moud (2013) argued that the low productivity of the construction sector could be attributed to the absence of innovation in the industry. However, one reason for huge improvements in the productivity of the manufacturing industry (as shown in Figure 1) is the adoption of new management philosophies, such as Lean Production, which was developed by Toyota Manufacturing. Furthermore, the Toyota Production System has proven its efficiency in terms of waste reduction and productivity enhancement (Liker, 2004). Thus, Gao (2014) and Aziz & Hafez (2013) argued that the productivity of the construction industry could be improved by implementing Lean Construction.

Lean Construction (LC) is now an established global method to improve the efficiency of construction by reducing waste, improving customer value and evolving management practices (Howell & Koskela, 2000). According to Bertelsen, Christoffersen, Jensen, and Sander (2001), Danish contractors have implemented Lean principles in their projects. As a result, they have increased productivity by 20%, reduced the duration of projects by 10%, enhanced efficiency by 20%, and improved profitability by 20%-40% on projects where Lean thinking has been applied.

In late 2008, the economic crisis had an adverse impact on the general economic development of Middle East construction industries. Therefore, investors' trust in this sector has fallen sharply, whilst delays in projects represent one of the greatest barriers to success (Al-Kharashi & Skitmore, 2009). For example, Albogamy, Scott, Dawood, and Bekr (2013) noted that 70% of all governmental construction projects in the Middle East region suffered from delays. This issue is due to the overlapping functions and benefits of the project stakeholders within a multicultural community (Motaleb & Kishk, 2011). Moreover, Farmer's (2016) report noted that approximately 75% of the total production is not in the government's direct control, and there is insufficient coordination between public and private stakeholders within the industry.

As a result of such challenges in the UK, its government mandated the implementation of Building Information Modelling on their projects (HMGovernment, 2013). Building Information Modelling (BIM) is a revolutionary technology that is renovating the design process of the Architecture, Engineering and Construction (AEC) industry (Abdalla, 2016). Moreover, BIM supports project visualisation and improves collaboration among project stakeholders which helps to achieve Lean principles (Sacks, Koskela, Dave, & Owen, 2010). According to Mehran (2016), governments around the world have acknowledged the inefficiencies impacting the construction industry and have suggested, or requested, the implementation of Building Information Modelling (BIM) to overcome low productivity.

Similarly, the Kuwaiti construction industry is facing severe problems. These challenges include time and cost overruns, a lack of communication and coordination between stakeholders, construction accidents, and conflict (Al-Humaidi, 2013; Al-Humaidi & Tan, 2009; Al Tabtabai, 2002; AlSanad, 2017; Soliman, 2017a). Al-Marri et al. (2012) revealed that numerous large-scale projects suffer from delays, or sometimes suspension or abandonment. The literature review revealed that 81% of the studies on the challenges and problems in the Kuwaiti construction industry concerned delays to projects. In 2017, the Ministry of Public Works reported to the Council of Ministers that 47 projects were delayed at a total value of more than $1.5 billion (Al-Zahi, 2019). Likewise, Alshahed (2017) reported that 90% of the Ministry of Public Works' (MPW) projects suffer from delay, whilst the volume of waste materials in Kuwaiti construction is huge for such a small country, as shown in Figure 2. For instance, a comparison of the construction waste in Kuwait with that of Canada, which is a large country, shows that construction and demolition waste in the Canadian industry amounts to approximately 9 million tones per year, whilst in Kuwait, the figure is around 10 million tonnes per year (Yeheyis, Hewage, Alam, Eskicioglu, & Sadiq, 2013).

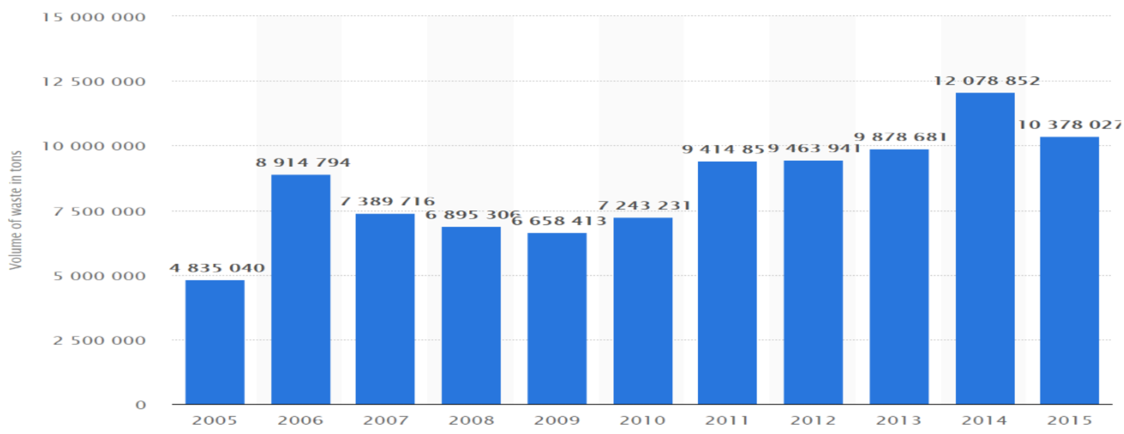


Figure 2: Volume of construction waste in Kuwait (Source: Statista, 2018)

In this regard, traditional management is insufficient for the successful delivery of a project. Thus, Love, Holt, & Li (2002) and Wing, Raftery, & Walker (1998) agreed that the aforementioned challenges reflect the practical problems in construction management practices that need to be resolved or better understood. Howell and Koskela (2000) noted that traditional project management practice is counterproductive; it generates self-inflicted issues that seriously impair performance. Moreover, they believed that adopting production management could refine this practice; therefore, Lean Construction was developed from Lean Production to manage waste in the construction industry. In addition, Building Information Modelling is an effective tool to support the implementation of Lean Construction in order to achieve its purpose.

Lean Construction and Building Information Modelling have been used widely in many developed countries, such as the United Kingdom and the United States. Since BIM is a popular system that has exploited the use of software and technologies, it has been adopted in many developed countries. Therefore, the employment of BIM has become a necessity to support the evolution of the construction industry.

Correspondingly, Lean Construction and BIM have been found in the Middle East region. The literature review provides evidence that Lean Construction has been implemented in Saudi Arabia (Alsehaimi, 2011; Mohamed, 2016; Sarhan, Olanipekun, & Xia, 2016), Turkey (Tezel & Nielsen, 2012), Lebanon (Awada, Lakkis, Doughan, & Hamzeh, 2016), and the United Arab Emirates (Kanafani, 2015; Small, Al Hamouri, & Al Hamouri, 2017). Furthermore, the Municipality of Dubai in the UAE has mandated the adoption of BIM (Abdalla, 2016). However, there is no evidence of the implementation of Lean Construction and BIM in Kuwait. Therefore, a gap in knowledge was identified concerning the Kuwaiti construction industry.

1.2 Rationale

The Kuwaiti construction industry is expected to spend around KD 34 bn ($112.5bn) on an infrastructure development plan to provide construction facilities that can fulfil Kuwait's 2035 vision (Mahdi, 2017). However, such public construction projects in Kuwait face enormous challenges. Consequently, the need for infrastructure development is constrained by low productivity levels (Al-Zubaidi & Al-Otaibi, 2008) and cost overruns (Alaryan, 2014; P. Koushki, Al-Rashid, & Kartam, 2005), which are caused by factors such as delays in the delivery of projects (AlSanad, 2017). As mentioned in the research background, 90% of the Ministry of Public Works' (MPW) projects suffer from delays, whilst the volume of construction waste materials in Kuwait is huge for such a small country (Alshahed, 2017; Statista, 2018). Therefore, there is an increased need for the Kuwaiti government to develop processes that are more efficient, which means raising the level of investment to enable the development of an advanced and sustainable infrastructure, and to promote the desire to achieve this future vision.

Additionally, the author’s experience and observations of the public sector and the Kuwaiti construction industry have also indicated many problems and challenges. These problems include time and cost overruns, poor communication between project parties, and lengthy approval and permit processes. Furthermore, a comprehensive and systematic literature review was conducted on the challenges facing the construction industry globally in order to understand the nature of these challenges and the potential solutions. Afterwards, the research focus was narrowed to the Middle East region, and specifically Kuwait, on which relevant literature focused. It was found that low productivity and inefficiency were the most common issues leading to time and cost overruns in the industry. These have emerged due to a culture that resists change and a reluctance to adopt new technologies and approaches within the industry (Kiani, Sadeghifam, Ghomi, & Marsono, 2015).

Moreover, Al-Zubaidi and Al-Otaibi (2008) confirmed that the frequency of time overruns in Kuwaiti construction projects is significantly high. Delays in such projects are influenced by several factors. These include: Inadequate project management practices (Al Tabtabai, 2002; Koushki & Kartam, 2004); ineffective initial planning for the project (Al-Marri et al., 2012; AlSanad, 2015); order changes (Al-Tabtabai & Thomas, 2004; Alaryan, 2014; Koushki & Kartam, 2004); an insufficient definition of scope and lengthy planning approval processes between authorities (Al-Reshaid, Kartam, Tewari, & Al-Bader, 2005; Al-Zubaidi & Al-Otaibi, 2008; Al Tabtabai, 2002); the absence of electronic documents and contracts (Al Tabtabai, 2002; Almutairi, 2016b), and a lack of correlation between stakeholders (Almutairi, 2016b; Soliman, 2017a). Also, insufficient contract details and contract errors lead to problems and difficulties during the execution (Al-Marri et al., 2012; Almutairi, 2016b; Soliman, 2017b). A common phrase used in the construction industry is "Time is money", which indicates that expediting the project delivery schedule creates an increase in project costs and sometimes leads to poor construction quality.

Likewise, Motaleb and Kishk (2011) conducted a survey to review literature on construction industry delays between 2000-2011 in order to identify relevant measures for delay risk control. The survey revealed that 60% of the study's delays were due to issues with decision-making, performance, risk management changes, poor management and limited stakeholder knowledge. Moreover, 20% of these studies were in the Middle East region. In another study, conducted by Dolage and Rathnamali (2013, p. 9), the "inaccurate planning and scheduling of a project" was identified by clients, consultants and contractors as one of the three major issues resulting in time overruns. Moreover, Charrel and Galarreta (2007) emphasised that a project's management should be ready for any adjustments that may occur and be able to counter any problems and efficiently modify changes to enable the success of a project. Therefore, it is necessary to develop a comprehensive view of all project components, as well as the communication and collaboration amongst all project parties.

In addition, improving construction productivity has been the ambition globally across the sector for decades. For instance, the Egan (1998) report argues for improvements to the quality and efficiency of the UK construction industry through a focus on seven objectives, which are: reducing capital cost; minimising construction time; increasing predictability and productivity; mitigating defects and accidents, and raising profits. Egan (1998) pointed out that a transparent process and the development of cooperative project relationships were essential, confirming that collaboration is key to a successful project. He also argued that the report was a challenge to the industry, which required a pledge to facilitate a transformation by working together, and that, in doing so, a modern industry could be created.

Generally, construction operations are executed through several sub-operations. In order to successfully complete a project, continuity between these sub-processes should be ensured (Ningappa, 2011). In other words, this means creating a steady flow of activities throughout the construction project cycle. This could be achieved by using Lean principles, the Lean principle of flow, and Building Information Modelling.

In Lean Construction, planning and control are considered complementary and dynamic operations are maintained throughout the project (Ansah et al., 2016). Planning determines the standards and generates the desired strategies to achieve the objectives of a project. Meanwhile, control confirms that each activity will be achieved according to the schedule (AlSehaimi, Tzortzopoulos & Koskela, 2009). Ballard (1994) mentioned that Lean Construction is one of the most powerful methods to escalate productivity. Therefore, the implementation of Lean Construction helps stakeholders to plan more efficiently, enhance production by minimising delays, achieve tasks in the best structural sequence, ensure proper manpower for the work, and coordinate multiple, interrelated activities (Howell & Ballard, 1998).

Nevertheless, the Kuwaiti government started to make changes several years ago by improving its education through the release of scholarships for citizens working in the public sector. It encouraged them to acquire knowledge from developed countries in order to apply this in their home country. This is evidence that the Kuwaiti government is ready to change for the benefit of the country. Since completing a Master's programme in Project Management in Construction, the author has become more aware of these challenges and the potential solutions. For example, this programme highlighted the efficiencies of Lean Construction and Building Information Modelling in terms of waste reduction, communication, productivity, and information management.

However, Lean Construction has proven its effectiveness in enhancing construction processes and has been widely implemented in many countries. In the Middle East, Lean Construction tools, such as the Last Planner System (LPS), has enabled the better coordination of production planning in the construction industry (El-Sabek & McCabe, 2017). It has been used in Saudi Arabia where it has: improved construction projects (AlSehaimi et al., 2009) by improving the construction planning and control processes (Alsehaimi, 2011); enhanced site management and planning preparation (AlSehaimi, Tzortzopoulos Fazenda, & Koskela, 2014); and reduced risks in large-scale construction projects in Saudi Arabia (Mohamed, 2016). As Saudi Arabia and Kuwait are located in the same region and share very similar cultures, maturities, and knowledge, the Kuwaiti construction industry could potentially use the same methods as those adopted in the KSA, which have proven efficient.

On the other hand, Building Information Modelling has increased remarkably in the Middle East region as Municipalities of Dubai, Abu Dhabi, and Ajman in the United Arab Emirates have mandated its adoption on their projects (Aguinaldo, 2019; Gerges, Ahiakwo, Jaeger, & Asaad, 2016; Pradeep, 2020), as well as in construction projects in Qatar (Abdulfattah et al., 2017). However, developing countries, such as Kuwait, tend to lag behind in adopting this advanced technology. According to Abdulfattah et al. (2017), the level of awareness of BIM in the construction industry is high, but it lacks adoption in Kuwait where industry stakeholders are aware of the benefits and barriers of BIM but lack a practical way to implement this technology. Although Building Information Modelling is known to be a collaborative system that manages information, it does not provide a strategy to promote cooperative action (Al-Mohannadi, Arif, Aziz, & Richardson, 2013). Accordingly, integrating Lean Construction and Building Information Modelling present a better choice, because Lean Construction is a management philosophy that helps to create an improvement strategy and employs BIM to achieve its purpose. The integration of Lean Construction and BIM can be exploited to develop construction processes that exceed the degree of enhancement if applied individually (Sacks et al., 2010).

The researcher believes that Lean Construction is a way of thinking and BIM is an important construction technology that will be used in the future. It is assumed that the adoption of both Lean Construction and BIM will help to optimise the performance of Kuwait's construction industry, as there is a need for an advanced system that enables the integration of project stakeholders, operations, and information in an organised way. The Greek philosopher, Heraclitus, said “Change is the only constant in life”; thus, Kuwait’s construction industry needs to be modernised by adopting new methods and exploiting intelligent technologies to keep pace with evolution.

This research aims to improve the knowledge base that currently exists in the Middle East and specifically in Kuwait on how challenges outlined in the literature may be addressed through the use of a Lean Construction philosophy. Although Lean Construction and BIM have been implemented in similar contexts, as mentioned in the research background, this has not yet been attempted in Kuwait. Accordingly, there is a lack of knowledge and awareness of Lean Construction in Kuwait, since there is no research evidence on this subject area based in the country. There is also limited evidence of research on Building Information Modelling in Kuwait and its implementation is still limited, slow, and lacks client demand (Abdulfattah et al., 2017) even though it has been mandated in the UAE and Qatari construction industries.

In complex projects, it is necessary to develop a comprehensive system to allow for the successful management of design and construction data through accurate modelling, collaboration and integration during the project lifecycle, including different project disciplines

(Koseoglu, Sakin, & Arayici, 2018). In this study, the focus is on public-sector construction projects because the government has a significant impact on the implementation of BIM in the industry. Furthermore, Isikdag and Zlatanova (2009) believed that the government should lead such an implementation. Internationally, governments have realised the shortcomings affecting the construction industry in general and have suggested and/or mandated the implementation of Building Information Modelling (BIM) as a master plan to address low productivity (Mehran, 2016). Mandating BIM would accelerate awareness and thus raise levels of implementation in the construction industry. For example, the UK government mandated BIM in 2016 and a recent report published by NBS (2020) reveals that, as a result, awareness and adoption in the UK construction industry is 26% and 73%, respectively (see Figure 3).

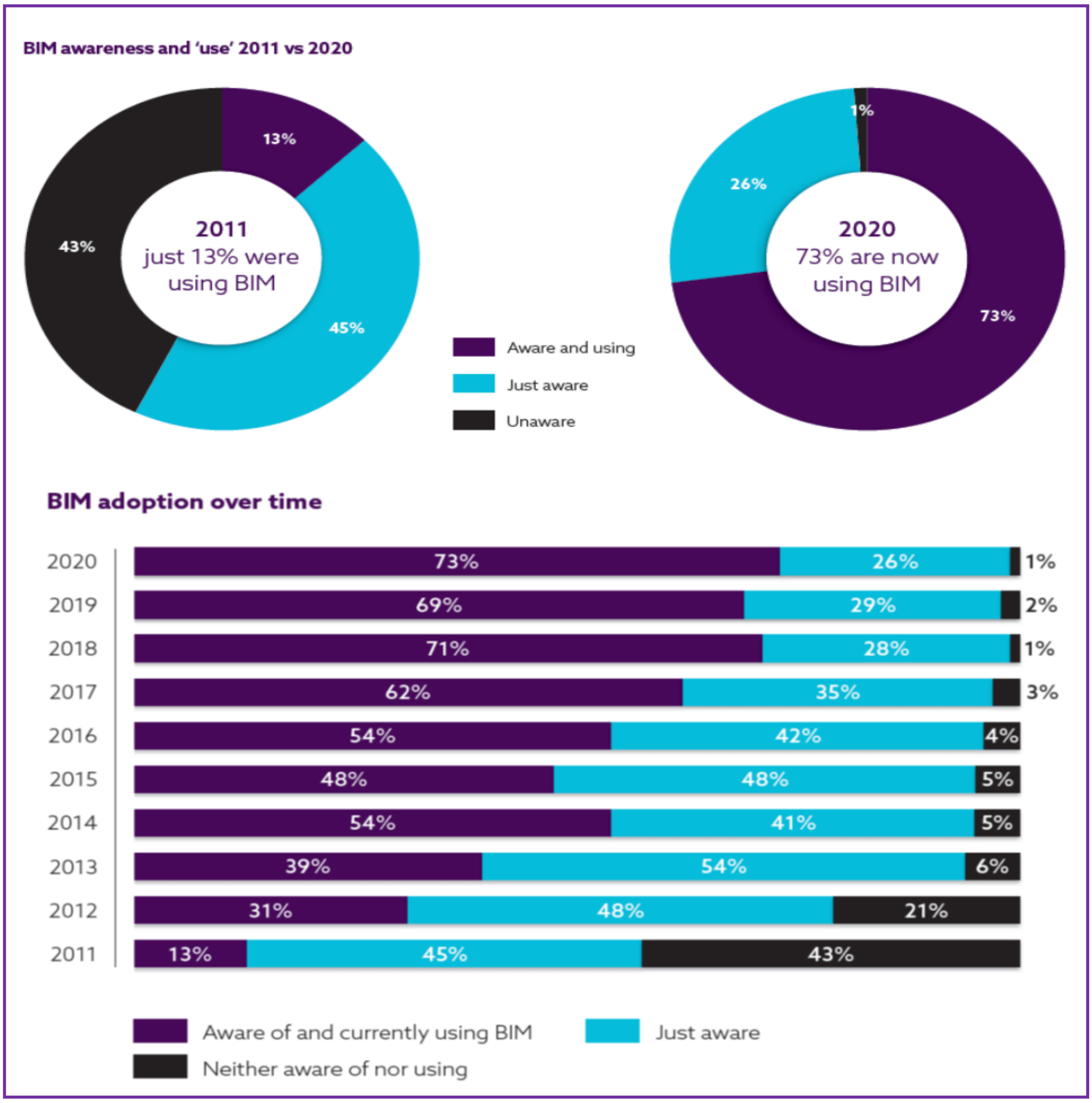


Figure 3: BIM usage and awareness, and the adoption of BIM over nine years (NBS, 2020)

Therefore, this study focuses on benefits to the Kuwaiti construction industry in public sector projects by proposing a development strategy to tackle the challenges faced. This strategy is a process protocol/framework based on the adoption of Lean principles and uses Building Information Modelling technology as a supporting method. Thus, a framework will be developed based on both Lean Construction and BIM and proposed as a mechanism to help achieve improvements to the industry.

1.3 Problem Statement:

The construction industry in Kuwait has faced many challenges over the last five decades, including the need to reduce waste, eliminate inefficiency and improve productivity, whilst also considering the sustainability of construction projects (Koushki et al., 2005). The industry suffers from poor project performances, which are measured by specific indicators, as previously mentioned in the research background and rationale (time and cost overruns, low productivity, waste, etc.).

According to Mahdi (2018), the government of Kuwait has launched a new vision for Kuwait 2035 that includes a digital transformation of the entire sectors of the country as stated in the Kuwait National Development Plan. This plan incorporates development of the construction industry, in which digital transformation is necessary to enable the development of smart cities for citizens and provide a sustainable environment. This digital transformation requires a high level of collaboration and coordination between the parties involved in the project in order to support the implementation of advanced project management technologies.

In fact, there is a lack of awareness and a limited adoption of advanced project management techniques and tools, such as Building Information Modelling (Abdulfattah et al., 2017) and Lean Construction (Al-Adwani, Mollasalehi, & Fleming, 2018). Consequently, there is a lack of local expertise in this area according to the literature. Nonetheless, the Kuwaiti government is currently trying to develop the industry’s capabilities, skills, and knowledge in this field through upskilling the current level of the workforce by educating them overseas in various degree and training programs (Al-Jassim, 2019).

In this research, the challenges of the Kuwaiti construction industry identified in the literature review will be examined through the data collection procedures. Accordingly, a potential solution will be proposed to address these issues and facilitate the development of the industry to keep pace with other developed countries.

1.4 Research Aim and Objectives:

The aim of this research is to develop a framework to improve the performance of the construction project lifecycle in client organisations in Kuwait by applying Lean Construction principles and BIM technology/processes. It is expected that this framework will help to improve the awareness and understanding of individuals and organisations about the adoption of Lean Principles and BIM and their impact on project performances. The research will focus on public sector construction projects, as these highlight many cost and time performance challenges.

In order to achieve the aim, the following objectives will be fulfilled:

1. To identify the challenges in the construction industry globally, especially in Kuwait, and their causes and consequences.
2. To review and identify improvement methods applied to construction in order to overcome the challenges it faces with specific applicability to the Kuwait Construction industry.
3. To establish and document general areas on Lean Principles, Building Information Modelling, and process protocols in the construction industry, specifically in Kuwait.
4. To explore and identify the drivers and the challenges of implementing Lean principles and Building Information Modelling in client organisations in the construction industry, and specifically in Kuwait.
5. To develop and evaluate a framework for improving the performance of client

organisations in the construction industry in Kuwait.

1.5 Outline Research Methodology

The research design is developed from the research problem, as described in Section 1.3, which dictated the methods used to gather data and achieve the research objectives and clarified the main steps of the research process (Table 1).

Table 1: Summary of key research objectives and methods

Objectives	Literature review	Questionnaire	Interviews	Interviews (Validation)
1. To identify the challenges in the construction industry globally, especially in Kuwait, and their causes and consequences.	Secondary Data	Primary Data		
2. To review and identify improvement methods applied to construction in order to overcome the challenges it faces with specific applicability to the Kuwait Construction industry.	Secondary Data	Primary Data		
3. To establish and document general areas on Lean Principles, Building Information Modelling, and process protocols in construction industry, specifically in Kuwait.	Secondary Data	Primary Data	Primary Data	
4. To explore and identify the drivers and the challenges of implementing Lean principles and Building Information Modelling in client organisations in the construction industry, and specifically in Kuwait.	Secondary Data	Primary Data	Primary Data	
5. To develop and evaluate a framework for improving the performance of client organisations in the construction industry in Kuwait.			Primary Data	Primary Data

In this study, a mixed methods research approach was used that combined the collection and analysis of quantitative and qualitative data. The mixed methods approach allows for the synthesis of evidence to understand complex interventions (Petticrew et al., 2013).

Survey and case study approaches have been adopted as research strategies for the mixed methods research design in this study. For the data collection, multiple sources of evidence were used. For example, an Internet questionnaire was chosen for the survey approach, while in the case studies, semi-structured interviews and documents were used. A questionnaire and interviews were used to gather data from practitioners in the Kuwaiti construction industry in order to develop a proposed solution. Moreover, structured interviews were conducted to validate and update the proposed framework. Additionally, the study focuses on the client organisation, particularly construction projects in the public sector.

However, presenting a summary of the research design is important to ensure a clearer research methodology. Research design contains a series of steps or milestones in which to effectively conduct a study; Figure 4 represents the preferred sequencing steps for this research (research flowchart).

A comprehensive review of the literature was carried out to investigate the challenges facing the construction industry that effect the industry's performance. Nevertheless, new management philosophies, such as Lean construction, and the exploitation of advanced process technologies for the construction industry, such as BIM, were found to be the best approach to improve the performance of the industry. These need further exploration because misunderstanding of these new approaches will create problems at the level of adoption, leading to the prevention of successful implementation.

The researcher started this study by systematically reviewing the literature to find a gap in knowledge in the selected context, which is the construction industry in Kuwait. The literature review covered academic articles and journals, institutional publications, reviews and textbooks. It also highlighted some of the factors affecting the performance of the construction industry in Kuwait by reviewing studies related to this study.

After that, the assumptions drawn from the literature review were tested and described further by the primary data collection. In this study, the primary data collection procedure was divided into three phases. In the first phase, the questionnaire survey was conducted to describe the nature of the problem and to determine the level of awareness and implementation of BIM and LC in the industry. In the second phase, semi-structured interviews were carried out to investigate the problem in-depth and to develop the conceptual framework. Finally, a number of structured interviews were conducted in order to validate and finalise the proposed process protocol/ framework.

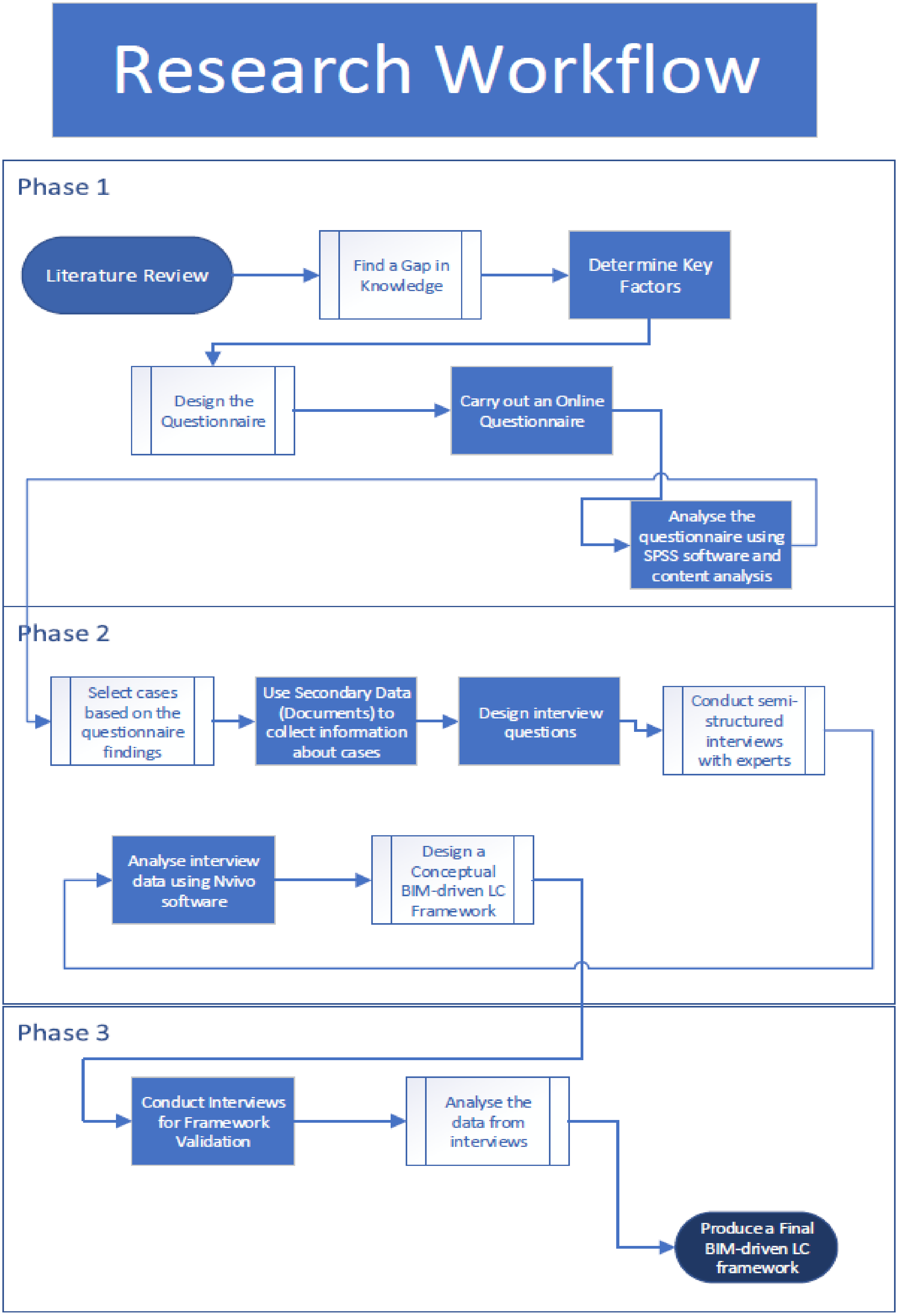


Figure 4: Research workflow

1.6 Structure of Thesis

This thesis is divided into seven chapters. In Chapter 1, the challenges facing the construction industry have been outlined, which indicate the fragmented nature of the industry. In comparison, the evolution and improvement of the manufacturing industry highlighted the advanced technologies and management tools that have been applied. The chapter emphasised that the construction industry needs to learn from the manufacturing industry by adopting new technologies and focusing on process development.

As a result, the construction industry needs a transformation where collaboration and coordination are achieved between project parties through the application of BIM technology as a tool to improve the industry's performance. In addition, Lean Construction has been identified as a management philosophy that focuses on reducing waste and adding value to the client. It has proven effective in facilitating process improvement in the construction industry. Finally, in this chapter, the aim and objectives of the research, as well as the research methodology have been defined. The remaining chapters are formed as follows:

Chapter 2 highlights the challenges facing the construction industry including time and cost overruns, a lack of collaboration between project stakeholders, low productivity, waste and poor project management practices. The impact of implementing Lean Construction and BIM approaches, and their synergies for the construction industry are explored.

Chapter 3 discusses potential optimisation tools to improve the construction industry. Existing BIM and Lean Construction frameworks are examined in order to highlight their limitations and understand their combined application. Besides, Business Process Management purposes and tools are investigated, which leads to the examination of construction project process frameworks and models, such as RIBA Plan of Works, the GDCPP, and the BIM ISO 19650 standards.

Chapter 4 focuses on research design and methodology; it begins by exploring different methodological options and strategies and provides justifications for the chosen methodologies. A mixed methods research approach is adopted in this research, which starts with the collection of quantitative data through an online questionnaire, following which qualitative data are collected by first conducting semi-structured interviews, and then structured interviews to validate the proposed solution. Moreover, analysis procedures for the data collection methods were described along with the research design structure.

Chapter 5 discusses the findings of the quantitative and qualitative data analysis based on the selected data collection analysis approaches outlined in Chapter 4. In addition, changes to the proposed framework are highlighted after analysing the structured interviews for validation.

Chapter 6 discusses the recommended BIM and Lean Process Protocol (final version) to improve construction projects for the public sector in Kuwait. It includes ten phases, which involve the tasks, deliverables and project teams. Each phase has pre-requisitions, participants, a key high-level objective, outputs, minimum requirements, processes/tasks, and stage outcomes. Also, the preparation stage is explained before the process protocol/framework is implemented in order to help establish BIM internally within the client organisation.

Chapter 7 presents the discussion and conclusions of the study and outlines how the research aim and objectives were fulfilled. Furthermore, the expected contributions to knowledge and practice are identified, along with study limitations and recommendations for future research.

1.7 Summary

The construction industry has frequently been considered inefficient and wasteful due to the re-work and waste of resources and/or information. This is attributed to the lack of communication and collaboration between stakeholders, whereby project information is regularly lost. It prompts the requirement for later reinsertion and results in major issues in keeping data up-to-date. The fragmented nature of the construction industry is a core reason for the lack of exploitation of project information. In fact, it includes many partners, which requires massive amounts of collaboration and coordination between project stakeholders.

Recent studies have demonstrated that many projects are behind schedule and over budget, and that clients are demanding more value through improved quality, delivery cost and time. However, the performance of the construction industry can be enhanced through the implementation of a collaborative environment and the digitisation of project information. This can be achieved by adopting Lean Construction and BIM technology.

In this specific circumstance, clients should steer the collaboration process by driving the project throughout the beginning phase. In this chapter, the challenges facing the construction industry have been identified and the potential improvement solutions highlighted. It can be concluded that the industry needs to keep pace with other industries, such as manufacturing, in order to achieve optimal performance, overcome challenges, and take advantage of existing technologies and tools to do so.

Chapter 2: Summary of Literature Review

2.1 Introduction

In this chapter, the challenges facing the construction industry around the world, and especially the construction industry in Kuwait, will be highlighted. Next, potential approaches, such as Lean principles and BIM, to enhance the practices and performance of the construction industry and overcome the challenges will be discussed. Furthermore, these approaches and their implementation in construction projects will be examined in this chapter. Finally, the synergies between BIM and Lean will be identified.

2.2 Challenges in the construction industry around the world

In developing countries, it has been found that delays and cost overruns are the most common problems facing the construction industry (Anysz, 2019; Biswas, Karmaker, & Biswas, 2016; Dlamini & Cumberlege, 2021; Eizakshiri, Chan, & Emsley, 2011; Ghenbasha, Sabki, & Ayob, 2016; Mályusz & Varga, 2017; Memon, Rahman, Zainun, & Karim, 2014; Subramani, Lishitha, & Kavitha, 2014). Majerowicz and Shinn (2016) claimed that it is common for cost overruns to be directly linked to delays in construction projects. Additionally, several challenges were found in this area related to the project management practice, which are: construction project process (Chen, 2019; Thunberg, Rudberg, & Karrbom Gustavsson, 2017); poor project management such as poor planning, a lack of clear goals, and an incompetent project management team (AlSehaimi & Koskela, 2008; Zhong, 2018); solid waste management (Guerrero, Maas, & Hogland, 2013); decision-making in the management of construction project (Szafranko, 2017), and technology implementation (Piroozfar, ESSA, & Farr, 2017). Table 2 lists studies which address the challenges in developing countries over the last ten years.

Table 2: The studies about challenges in the developing countries in the last ten years

Problems/ Challenges		Cost Overrun	Time overrun/ Delay	Poor Project Management
No.	References	1	2	3
1	(Elzakshiri, Chan, & Emsley, 2011)	✓	✓	
2	(Pourrostam & Ismail, 2011)		✓	
3	(Ma, 2011)	✓		
4	(González, González, Molenaar, & Orozco, 2013)		✓	
5	(Guerrero, Maas, & Hogland, 2013)			✓
6	(Subramani, Lishitha, & Kavitha, 2014)	✓	✓	
7	(Memon, Rahman, Zainun, & Karim, 2014)	✓	✓	
8	(Cheng, 2014)	✓		
9	(Ahiaga-Dagbui & Smith, 2014)	✓		
10	(Smith, 2014)	✓		
11	(Polat, Okay, & Eray, 2014)	✓		
12	(Ghenbasha, Sabki, & Ayob, 2016)	✓	✓	
13	(Love, Ahiaga-Dagbui, & Irani, 2016)	✓		
14	(Rauzana, 2016b)	✓		
15	(Jung, Kim, & Lee, 2016)	✓		
16	(Majerowicz & Shinn, 2016)	✓	✓	
17	(Biswas, Karmaker, & Biswas, 2016)	✓	✓	
18	(Sivaprakasam, Dinesh, & Jayashree, 2017)		✓	
19	(Mályusz & Varga, 2017)	✓	✓	
20	(Soliman, 2017)		✓	
21	(Sadeh & Shahbodaghlou, 2017)		✓	
22	(Moursi, 2017)		✓	
23	(M. Islam & Trigunarsyah, 2017)		✓	
24	(Sovacool, Enevoldsen, Koch, & Barthelmie, 2017)	✓		
25	(Juszczyk, 2017)	✓		
26	(Thunberg, Rudberg, & Karrbom Gustavsson, 2017)			✓
27	(Szafranko, 2017)			✓
28	(Piroozfar, ESSA, & Farr, 2017)			✓
29	(Belay & Torp, 2017)	✓		
30	(Arditi, Nayak, & Damci, 2017)		✓	
31	(Bilgin, Dikmen, & Birgonul, 2018)		✓	
32	(Khoiry, Kalaisilven, & Abdullah, 2018)		✓	
33	(Shahsavand, Marefat, & Parchamijalal, 2018)		✓	
34	(Amusan, Afolabi, Ojelabi, Omuh, & Okagbue, 2018)	✓		
35	(Panova & Hilletofth, 2018)	✓	✓	✓
36	(Choong Kog, 2018)		✓	
37	(Zhong, 2018)			✓
38	(Khahro & Memon, 2018)		✓	
39	(Hossein, Ochoa, Konstantinos, Wolfgang, & Vivian, 2019)		✓	
40	(Macarìola & Silva, 2019)		✓	
41	(Durdyev & Hosseini, 2019)		✓	
42	(Meszek, Rejment, & Dziadosz, 2019)		✓	
43	(Anysz, 2019)	✓	✓	
44	(Leśniak, Juszczyk, & Piskorz, 2019)		✓	
45	(Chen, 2019)			✓
46	(Asmi, Djamaris, & Ihsan, 2019)		✓	
47	(Türkakın, Manisalı, & Arditi, 2020)		✓	
48	(Abwunza, Peter, & Muigua, 2020)		✓	
49	(Hai Nguyen, 2020)		✓	
50	(Guévremont & Hammad, 2020)		✓	
51	(Arantes & Ferreira, 2020)		✓	
52	(Liu et al., 2021)		✓	
53	(Bektas, Talat Birgonul, & Dikmen, 2021)		✓	
54	(Dlamini & Cumberlege, 2021)	✓	✓	
55	(Çevikbaş & Işık, 2021)		✓	

As listed in Table 2, delays in construction projects are the most significant challenge in this industry over the past 10 years. In fact, AlSehaimi and Koskela (2008) indicated that the causes of delay in construction projects have been investigated in numerous studies in different developing countries. They argued that the main reason behind this issue is poor project management, which was similarly reported in several other papers.

All project disruptions resulting from errors or omissions in the project planning process, including poor planning, poor control, and poor project scheduling, have an impact on time performance and cause delays (González, González, Molenaar, & Orozco, 2013). In addition, Moursi (2017) conducted a study to explore the root causes of delay in building projects around the world. He reported 14 root causes for time overruns in projects and classified them into three categories: project parties' management efficiency, inter-relationship work environment, and specific project characteristics. The root factors of delays are as follows:

1. Designer management deficiencies
2. Quality of design work documents
3. Contractor management deficiencies
4. Contractor financial problems
5. Client management deficiencies
6. Client financial problems
7. Efficiency level of communication
8. Level of interaction at the preconstruction stage
9. Trust between project parties
10. Level of project complexity and required technology
11. Level of harmony between objective
12. Site characteristics

13. Project characteristics
14. Project contract and procurement strategy.

In another study, Ma (2011) inspected the cost overrun in tunnel projects. He cited that the major reason behind cost excess in these projects is fundamentally related to unexpected geological conditions along with the extended time schedule. Love, Ahiaga-Dagbui, and Irani (2016) identified that cost overrun could be caused by the long duration between the determination of the initial cost and the granting of contracts, where the prices of material and labour rise as well as the changes in project scope during the design phase.

On the other hand, there are several methods to minimise delays in construction projects. Khoiry, Kalaisilven, and Abdullah (2018) mentioned that delay problems in the industry can be reduced by using proper management, interpersonal, technical expertise and technology. To avoid delays, management ensures that the time, finance and control systems in construction are properly managed. The interpersonal element promotes a positive relationship between project stakeholders, the hiring of professional and qualified labour, and the client's duty to prevent delays. Furthermore, technical expertise ensures project efficiency, and technology has the potential to increase construction productivity through advanced tools and software. Therefore, there is a great need to apply new advanced project management practices in order to improve the efficiency and productivity of the construction industry (Zhong, 2018).

A literature review has been carried out following the content analysis method. Relevant literature has been collected from 48 countries around the world from the academic papers published in the last 10 years. These 48 countries were classified into six regions: Asia, Africa, America, Europe, Oceania, and the Middle East. From these regions, 79 studies cited those delays are an inevitable problem in the construction industry, while 47 papers mentioned that cost overruns are the most common risk in the industry. However, 26 studies discovered a correlation between time and cost overruns in construction projects, and both are common risks in the building sector.

In Asia, five challenges have been found from reviewing the literature of 35 academic papers. These challenges are: project delays (Dolage & Rathnamali, 2013; Islam, Trigunarsyah, Hassanain, & Assaf, 2015; Kog, 2019; Wanjari & Dobariya, 2016; Wuala & Rarasati, 2020; Zhang, Zhang, & Cheng, 2020), cost overruns (Toh, Ting, Ali, Aliagha, & Munir, 2012), rework (Yap, Low, & Wang, 2017), solid waste management (Yeboah-Assiamah, Asamoah, & Kyeremeh, 2017), and the effectiveness of the quality planning (Othman, Shafiq, & Nuruddin, 2017) as shown in Table 3. Time and cost overrun are the most common problems in Malaysia (Ramanathan, Narayanan, & Idrus, 2012; Shehu, Endut, & Akintoye, 2014; Ullah, Abdullah, Nagapan, Suhoo, & Khan, 2017; Yap, Goay, Woon, & Skitmore, 2021; Yap et al., 2017), Nepal (Sha, Shahi, Pandit, & Pandey, 2017), India (Abhishek & Harish, 2018; Devi & Ananthanarayanan, 2017; K.V, V, R, & Bhat, 2019; Rajan, Gopinath, & Behera, 2013; Venkateswaran & Murugasan, 2017; Wanjari & Dobariya, 2016), China (Ji et al., 2018; T.-K. Wang, Ford, Chong, & Zhang, 2018; Zhang et al., 2020), and Indonesia (Susanti, Fauziyah, & Suwarto, 2021). While in Pakistan (Akram, TauhaHussain Ali, & Khahro, 2017; Sohu et al., 2017), Afghanistan (Niazi & Painting, 2017), Cambodia (Durdyev, Omarov, Ismail, & Lim, 2017), and Vietnam (Kim, Tuan, Do Lee, & Pham, 2018) costs excess in projects is the highest risk in the construction industry.

Table 3: Construction Challenges in Asia

Problems/ Challenges			Cost Overrun	Time Overrun/ Delay	Rework	Solid Waste Management	Quality level/ Poor Quality Planning
No.	References	Country	1	2	3	4	5
1	(Ramanathan, Narayanan, & Idrus, 2012)	Malaysia	✔	✔			
2	(Toh, Ting, Ali, Aliagha, & Munir, 2012)	Malaysia	✔				
3	(Dolage & Rathnamali, 2013)	Sri Lanka		✔			
4	(Rahman, Memon, & Karim, 2013)	Malaysia	✔				
5	(Rajan, Gopinath, & Behera, 2013)	India	✔	✔			
6	(Shehu, Endut, & Akintoye, 2014)	Malaysia	✔	✔			
7	(Shehu, Endut, Akintoye, & Holt, 2014)	Malaysia	✔				
8	(M. S. Islam, Trigunarsyah, Hassanain, & Assaf, 2015)	Bangladesh		✔			
9	(Wanjari & Dobariya, 2016)	India		✔			
10	(Rauzana, 2016a)	Indonesia		✔			
11	(Kaleem Ullah, Abdullah, & Nagapan, 2016)	Malaysia	✔				
12	(Sha, Shahi, Pandit, & Pandey, 2017)	Nepal	✔	✔			
13	(Yap, Low, & Wang, 2017)	Malaysia	✔	✔	✔		
14	(K Ullah, Abdullah, Nagapan, Suhoo, & Khan, 2017)	Malaysia	✔	✔			
15	(Venkateswaran & Murugasan, 2017)	India	✔	✔			
16	(Sohu et al., 2017)	Pakistan	✔				
17	(Devi & Ananthanarayanan, 2017)	India	✔				
18	(Niazi & Painting, 2017)	Afghanistan	✔				
19	(Durdyev, Omarov, Ismail, & Lim, 2017)	Cambodia	✔				
20	(Akram, TauhaHussain Ali, & Khahro, 2017)	Pakistan	✔				
21	(Yeboah-Assiamah, Asamoah, & Kyeremeh, 2017)	Ghana & India				✔	
22	(Othman, Shafiq, & Nuruddin, 2017)	Malaysia					✔
23	(Kim, Tuan, Do Lee, & Pham, 2018)	Vietnam	✔				
24	(Thapanont, Santi, & Pruethipong, 2018)	Thailand		✔			
25	(T.-K. Wang, Ford, Chong, & Zhang, 2018)	China		✔			
26	(Ji et al., 2018)	China		✔			
27	(K. Ullah, Khan, Lakhiar, Vighio, & Sohu, 2018)	Malaysia		✔			
28	(Abhishek & Harish, 2018)	India		✔			
29	(K.V, V, R, & Bhat, 2019)	India		✔			
30	(Kog, 2019)	Southeast Asia		✔			
31	(R. A. Khan & Umer, 2020)	Pakistan	✔	✔			
32	(Zhang, Zhang, & Cheng, 2020)	China		✔			
33	(Wuala & Rarasati, 2020)	Southeast Asia		✔			
34	(Yap, Goay, Woon, & Skitmore, 2021)	Malaysia		✔			
35	(Susanti, Fauziyah, & Suwarto, 2021)	Indonesia	✔	✔			

Likewise, the most significant risk in construction projects in Africa is delay (Bagaya & Song, 2016; Banobi & Jung, 2019; Gebrehiwet & Luo, 2017; Mukuka, Aigbavboa, & Thwala, 2015; Nyoni & Bonga, 2017), which often leads to cost overruns in many construction projects (Alinaitwe, Apolot, & Tindiwensi, 2013; Dahiru, 2015; Eze & Idiake, 2018; Famiyeh, Amoatey, Adaku, & Agbenohevi, 2017; Khair et al., 2018). Additionally, the cost of poor quality (Mashwama, Aigbavboa, & Thwala, 2017), rework (Eze & Idiake, 2018), poor sustainability (Aghimien, Adegbembo, Aghimien, & Awodele, 2018), and solid waste management (Yeboah-Assiamah et al., 2017) were found to be challenges in the construction industry in Africa (see Table 4).

Table 4: Construction Challenges in Africa

Problems/ Challenges			Delay/ Time overrun	Cost overrun	Cost of poor Quality	Rework	Poor Sustainability	Solid Waste Management
No.	**References**	**Country**	1	2	3	4	5	6
1	(Alinaitwe, Apolot, & Tindiwensi, 2013)	Uganda	✔	✔				
2	(Dahiru, 2015)	Nigeria	✔	✔				
3	(Mukuka, Aigbavboa, & Thwala, 2015)	South Africa	✔					
4	(Bagaya & Song, 2016)	Burkina Faso	✔					
5	(Gebrehiwet & Luo, 2017)	Ethiopia	✔					
6	(Famiyeh, Amoatey, Adaku, & Agbenohevi, 2017)	Ghana	✔	✔				
7	(Nyoni & Bonga, 2017)	Zimbabwe	✔					
8	(Asiedu, Frempong, & Alfen, 2017)	Ghana		✔				
9	(Yeboah-Assiamah, Asamoah, & Kyeremeh, 2017)	Ghana and India						✔
10	(Mashwama, Aigbavboa, & Thwala, 2017)	Swaziland			✔			
11	(Eze & Idiake, 2018)	Nigeria	✔	✔		✔		
12	(Khair et al., 2018)	Sudan	✔	✔				
13	(Aghimien, Adegbembo, Aghimien, & Awodele, 2018)	Nigeria					✔	
14	(Banobi & Jung, 2019)	Tanzania	✔					

In European countries, studies were carried out to investigate issues in construction projects. It was found that time and cost overruns (Ågren & Olander, 2012; Arantes & Ferreira, 2015; Cantarelli, Molin, van Wee, & Flyvbjerg, 2012; Eivindson, Innvær, Kolberg, Merschbrock, & Rolfsen, 2017; Invernizzi, Locatelli, & Brookes, 2017; Klakegg & Lichtenberg, 2016; Kowalczyk, Meszek, Rejment, & Dziadosz, 2018; Meng, 2012; Paraskevopoulou & Benardos, 2013), poor planning (Larsen, Shen, Lindhard, & Brunoe, 2015), and inefficiencies in construction practices (Eivindson et al., 2017) are the major construction challenges in this region (see Table 5).

Table 5: Construction Challenges in Europe

Problems/ Challenges			Delay/ Time overrun	Cost overrun	Quality Level/ Poor Quality Planning	Inefficiencies
No.	References	Country	1	2	3	4
1	(Cantarelli, Molin, van Wee, & Flyvbjerg, 2012)	Netherlands		✔		
2	(Ågren & Olander, 2012)	Sweden	✔	✔		
3	(Meng, 2012)	UK	✔	✔		
4	(Paraskevopoulou & Benardos, 2013)	Greece		✔		
5	(Larsen, Shen, Lindhard, & Brunoe, 2015)	Denmark	✔	✔	✔	
6	(Arantes & Ferreira, 2015)	Portugal	✔			
7	(Klakegg & Lichtenberg, 2016)	Scandinavia	✔	✔		
8	(Eivindson, Innvær, Kolberg, Merschbrock, & Rolfsen, 2017)	Norway				✔
9	(Invernizzi, Locatelli, & Brookes, 2017)	UK		✔		
10	(Kowalczyk, Meszek, Rejment, & Dziadosz, 2018)	Poland	✔			

Regarding America and Oceania, the main challenges in construction projects are mainly delays (Azhar, Nadeem, & Guo, 2013; Mohammadsoroush Tafazzoli & Pramen Shrestha, 2017; Tafazzoli & PP Shrestha, 2017), followed by cost overruns and poor project management practices (Doloi, 2012; Jergeas & Ruwanpura, 2009), as shown in Table 6.

Table 6: Construction Challenges in America and Oceania

Problems/ Challenges			Delay/ Time overrun	Cost overrun	Poor/ Failure in Project Management
No.	References	Country	1	2	3
1	(Jergeas & Ruwanpura, 2009)	Canada	✔	✔	
2	(Doloi, 2012)	Australia		✔	✔
3	(Azhar, Nadeem, & Guo, 2013)	U.S.	✔		
4	(Mohammadsoroush Tafazzoli & Pramen Shrestha, 2017)	U.S.	✔		
5	(M Tafazzoli & PP Shrestha, 2017)	U.S.	✔		

In the Middle East region, numerous studies reported the challenges faced by construction, which are: delays (Cûlfik, Sarikaya, & Altun, 2014; Emam, Farrell, & Abdelaal, 2014; Hassan Emam, Farrell, & Abdelaal, 2015; Kazaz, Ulubeyli, & Tuncbilekli, 2012; Marzouk & El-Rasas, 2014; Motaleb & Kishk, 2011; Shahrabi & Mohammadi, 2013), cost overruns (Abusafiya & Suliman, 2017; Alaryan, 2014; Bayram & Al-Jibouri, 2016; Mahamid, 2013; Mahamid &

Bruland, 2012), inadequate project management and poor planning (Al-Emad & Rahman, 2017; El-Sabek & McCabe, 2017; Shahhossein et al., 2017), health and safety (Alhajeri, 2011), conflict and claims (Al-Humaidi, 2013; Mishmish & El-Sayegh, 2018), and a lack of communication (Soliman, 2017a).

However, 35 studies indicated that delays in construction projects are the dominant issue in this region, as highlighted in Table 7. There are several delay factors in construction projects; for example, 'technical weaknesses of supervision to overcome technical and operational workshop problems', 'imprecise assessment of workload, equipment required, and project completion time', 'weak laws and regulations related to job responsibilities', and 'lack of expected fines and encouragements in the contracts' are the major factors for delays in the construction projects in Iran (Jahangoshai Rezaee, Yousefi, & Chakrabortty, 2019). In Oman, Umar, Rizeiqi, and Badr (2020) studied the main reasons behind delays in construction projects, and revealed that these reasons are related to project management practices, such as poor site management and supervision, ineffective planning and scheduling, unclear and inadequate drawings, incompetent contractors, a shortage of human resources, and delays in material delivery. Since there is a significant correlation between delays and cost overruns, a study was conducted in Oman to investigate the root causes of these issues in construction projects. The findings indicated that the main factors of time and cost overruns in the construction industry in Oman are changes of scope, delays in making decisions, poor contract management, a lack of expertise, the delayed approval of drawings, poor planning and management, and poor drawings (Amri & Marey-Pérez, 2020). Therefore, the focus should be on improving project management practices because these issues are key to address.

On the positive side, several studies discuss solutions to mitigate delays in construction projects. Shahsavand, Marefat, and Parchamijalal (2018, p. 509) "delays can be avoided or minimised when their causes are clearly identified". Abbasi, Noorzai, Gharouni Jafari, and Golabchi (2020) suggested that the use of Lean principles and BIM technology will help to overcome the root causes of delays, such as mismanagement and the lack of financial and human resources in addition to a lack of communication and coordination among project parties, thus improving the performance of the industry. Implementing BIM techniques, with its ability to detect clashes, would facilitate the reduction of problems, such as changes to orders and design details issues (Umar et al., 2020), and the monitoring the progress and productivity over the entire building process (Vacanas & Danezis, 2021). Likewise, Jahangoshai Rezaee et al. (2019) recommended the implementation of proper planning, management and decision-making tools to enhance the systematic management of construction projects.

Table 7: Construction Challenges in Middle East

	Problems/ Challenges		Delay/ Time overrun	Cost overrun	Poor/ Failure in Project Management	Quality Level/ Poor Quality Planning	Conctruction Leadership "Challenges of managing construction workforce"	Health and Safety	Change orders	Conflicts	Communication	Claims
No.	References	Country	1	2	3	4	5	6	7	8	9	10
1	(Alhajeri, 2011)	UAE						✓				
2	(Motaleb & Kishk, 2011)	Middle East	✓									
3	(Kazaz, Ulubeyli, & Tuncbilekli, 2012)	Turkey	✓									
4	(Mahamid & Bruland, 2012)	Palestine		✓								
5	(Shahrabi & Mohammadi, 2013)	Iran	✓									
6	(Albogamy, Scott, Dawood, & Bekr, 2013)	Saudi Arabia + J	✓									
7	(Mahamid, 2013)	Palestine		✓								
8	(Al-Humaidi, 2013)	Kuwait								✓		
9	(Cùlfik, Sarikaya, & Altun, 2014)	Turkey	✓									
10	(Marzouk & El-Rasas, 2014)	Egypt	✓									
11	(H Emam, Farrell, & Abdelaal, 2014)	GCC	✓									
12	(Alaryan, 2014)	Kuwait		✓					✓			
13	(Elawi, Algahtany, Kashiwagi, & Sullivan, 2015)	Saudi Arabia	✓									
14	(Rehman, 2015)	UAE	✓									
15	(Hassan Emam, Farrell, & Abdelaal, 2015a)	Qatar	✓									
16	(Shibnai & Salah, 2015)	Egypt	✓	✓								
17	(Hassan Emam, Farrell, & Abdelaal, 2015b)	Qatar	✓									
18	(Matin, 2016)	Iran	✓	✓								
19	(Bayram & Al-Jibouri, 2016)	Turkey		✓								
20	(Senouci, Ismail, & Eldin, 2016)	Qatar	✓	✓								
21	(Aziz & Abdel-Hakam, 2016)	Egypt	✓									
22	(Samarghandi, Tabatabaei, Taabayan, Hashemi, & Willou	Iran	✓	✓								
23	(Gunduz & AbuHassan, 2016)	Qatar	✓									
24	(Rahman, Al-Emad, & Nagapan, 2016)	Saudi Arabia	✓									
25	(AL-Adwani, 2016)	Kuwait	✓									
26	(Almutairi, 2016)	Kuwait	✓									
27	(Shahhossein, Afshar, & Amiri, 2017)	Iran	✓	✓	✓							
28	(Al-Emad & Rahman, 2017)	Saudi Arabia					✓					
29	(Alamri, Amoudi, & Njie, 2017)	Oman	✓									
30	(H. A. Abusafiya & S. M. Suliman, 2017)	Bahrain		✓								
31	(H. A. Abusafiya & S. A. Suliman, 2017)	Bahrain		✓								
32	(El-Sabek & McCabe, 2017)	Middle East				✓						
33	(Al-Hazim, Salem, & Ahmad, 2017)	Jordan	✓	✓								
34	(Mpofu, Ochieng, Moobela, & Pretorius, 2017)	UAE	✓									
35	(Oyegoke & Al Kiyumi, 2017)	Oman	✓									
36	(Al-Fadhali & Zainal, 2017)	Yemen	✓									
37	(Soliman, 2017a)	Kuwait	✓								✓	
38	(SOLIMAN, 2017b)	Kuwait	✓									
39	(Mishmish & El-Sayegh, 2018)	UAE										✓
40	(Shahsavand, Marefat, & Parchamijalal, 2018)	Iran	✓									
41	(Alhajri & Alshibani, 2018)	Saudi Arabia	✓									
42	(Jahangoshai Rezaee, Yousefi, & Chakrabortty, 2019)	Iran	✓									
43	(Umar, Rizeiqi, & Badr, 2020)	Oman	✓									
44	(Amri & Marey-Pérez, 2020)	Oman	✓	✓								
45	(Abbasi, Noorzai, Gharouni Jafari, & Golabchi, 2020)	Iran	✓									
46	(Vacanas & Danezis, 2021)	Cyprus	✓									

2.3 Background of the State of Kuwait

2.3.1 Introduction

Kuwait is a small wealthy country. It located in the Middle East region on the northeast of Arabian Peninsula as shown in Figures 4 & 5. In addition, Kuwait shares borders with Iraq and Saudi Arabia. Politically, Kuwait is considered as one of the six countries contained in the Gulf Cooperation Council (GCC). Moreover, the total area of Kuwait is 17.818 km^2, whereas statistical reports revealed that its total population in 2017 was 4,512,674 (PACI, 2017). Kuwait has a desert climate, meaning it is hot and dry. In summer, average daily high temperatures range from 42°C to 46°C, and the highest recorded temperature is 51°C (PACI, 2017). Moreover, Shaikh (2016) reported that the highest temperature ever recorded in the eastern hemisphere and almost certainly the highest temperature ever recorded on earth was in Kuwait at 54°C. However, the summer is harshly long, punctuated mostly by intense dust storms, while winter is short but harshly cold and dry, lowering temperatures to 3°C around evening time. Frosting occurs rarely while rain is more common, mostly in the spring (The Library of Congress Country Studies; CIA World Factbook).

Figure 5: Kuwait map (Source: Google Map)

Figure 6: Location of Kuwait from the satellite map (Source: Google Map).

2.3.2 Economy of the construction industry in Kuwait

Kuwait is an oil-rich country and its citizens enjoy a very high salary per capita. The regime of Kuwait is monarchical with a ruling royal family. The Kuwaiti Dinar is the most valuable currency in the world (BBC, 2018; BookMyForex, 2021). Kuwait's economy is ranked 61 in terms of GDP (Purchasing Power Parity) with an estimation of $165.8 billion in 2013. The real GDP growth rate is 2.3%, its GDP per capita is $42,100 and it ranks 24th in the world (WorldFactBook, 2017). According to the World Bank, Kuwait is geographically small, but its economy is petroleum-based, with crude oil holding about 102 billion barrels, just about 7% of the world stores. Historically, revenues from oil exports represent the largest share of the country's export earnings. A significant portion of this revenue is transferred to the government and epitomises the main source of government income, making income taxes unnecessary. Moreover, revenue is obtained from import charges and from different fees and profits from state-owned enterprises. In contrast, government spending represents a large part of its GDP. The oil and government sectors together account for about 95% of Kuwait's GDP, and oil exports are the main driving force of government spending (Lawler & Seddighi, 2001).

In 2017, its growth rate was negative at -2.1%, which is a significant decline from the annual growth of 2.5% in 2016. The growth of the country has been affected as well as oil outputs and exports, and oil cuts related to OPEC production; this is particularly significant given that hydrocarbons represent almost half of the gross domestic product (GDP). However, production should gradually recover, underpinned by non-oil activity and infrastructure development spending (CBK, 2017; MOF, 2017).

On the other hand, for the non-oil sector, activity has been supported by the implementation of the Five-Year Development Plan (2015-2020), which includes many infrastructure projects, transportation and industrial projects. The government plans to transform Kuwait into an investment centre in the region. The public sector controls the financial system and focuses on three-quarters of the country's wealth (CBK, 2017; MOP, 2007).

The construction industry occupies a very important place in the economic activity of the country. According to the Central Statistical Bureau, the construction industry’s contribution to the GDP of the non-oil sectors reached 3.8% in 2009 (CSB, 2009). There are three main government organisations responsible for implementing mega construction projects in Kuwait, which are the Ministry of Public Works (MPW), Kuwait National Petroleum Company (KNPC) and the Public Authority for Housing Welfare (PAHW). The government agency responsible for implementing most of the government projects include the Institutional and Commercial, highway construction, while heavy construction projects in Kuwait are under the Ministry of Public Works, and KNPC is responsible for industrial and specialized industrial construction projects. Finally, the Public Authority for Housing Welfare is responsible for implementing projects in residential areas and housing.

With regard to the award and procurement system for construction projects in Kuwait, the traditional system (Design-Bid-Build) is the usual method for the award of the tender. The tender is awarded to a bidder with the lowest bid price through the Central Agency for Public Tenders (CAPT). However, the design documents must be ready before starting the project.

At a conference of construction leaders in Kuwait, AL-Shammari highlighted an important issue related to the construction industry in Kuwait. He pointed out that the construction industry is one of the main pillars of the country’s development plan, which is closely linked to the vision of His Highness, the late Amir of the country, Sheikh Sabah Al-Ahmed Al-Jaber Al-Sabah for New Kuwait 2035 (CSB, 2009).

2.3.3 Problems in the Construction Industry in Kuwait

A new government report “KISR-Annual Report” warned of delays in the completion of projects and construction works in state organisations and demanded strict measures to avoid this. The study has been commissioned by the Prime Minister to assess the cost of construction projects carried out by the Ministry of Public Works on behalf of government agencies compared to construction projects directly implemented by government agencies. This study was conducted by the Institute of Energy and Construction Research and revealed that, in general, there are similarities in the obstacles and barriers facing the implementation of state projects regardless the executing company (AL-Zahi, 2016).

According to AL-Qabas newspaper, a government study that was prepared by the Kuwait Institute for Scientific Research (KISR) identified obstacles that stand in the way of these projects. These were as follows:

1. Several contractors failed to perform the required work according to their dates.
2. Errors occurred at the early stages of the preparation and design of project schemes and there was no visibility amongst the implementing organisations.
3. The planning approval process cycle took an unnecessarily long time and lacked an understanding of the specialties and competencies between the authorities of the state.
4. There was no unified database to link all the departments within the ministries and authorities involved.
5. Weak coordination occurred between the Ministry of Public Works, as the executing agency, and the other authorities.
6. Issues to change of orders during the execution impeded the work and postponed the completion period.

7. Technical conditions and specifications were not well studied prior to certain projects.
8. A lack of experience and qualifications were evident among some engineering consultants in charge of preparing tender documents.

As stated by the Minister of Public Works, the long documentary cycle and length of approval procedures for construction projects is the reason for the delay in Kuwaiti projects in (Alhakea, 2016).

Several studies were conducted in an attempt to assess the achievements of the project construction process in Kuwait. Many projects were not completed on time due to issues such as variations in orders, financial complications, and insufficient knowledge of owners in the construction industry (Alaryan, 2014; Al Tabtabai, 2002; Koushki et al., 2005). Design related issues and financial conflicts, such as payment delays between the parties involved in projects, come first in the causes of delays (Soliman, 2010). Al-Adwani and Fleming (2019), Al-Adwani et al. (2018), Al-Marri et al. (2012) and Soliman (2017a) agreed that inefficient communication and a lack of coordination and collaboration between the parties involved are the core reasons for all conflicts and delays. AlSanad (2017) conducted a study on the risks in mega-projects in Kuwait. Ten significant risks were found in the construction industry in Kuwait, namely: the lengthy of the documentary cycle during the project lifecycle; changes to project orders during the construction stage; delays in paying subcontractors bills; technical complications in obtaining utility permits; a lack of funding resources and the cashflow problem of partners; inaccurate estimations of project cost and times; delays in supplying materials and equipment; bureaucracy and corruption practices; a shortage of available manpower, and material price changes (AlSanad, 2017). These challenges may negatively affect the performance of projects and lead to time and cost overruns.

In a similar context, a study was conducted in Saudi Arabia to identify factors contributing to the poor performance in construction projects (Mahamid, 2016). It revealed that poor communication between project teams, the poor productivity of labour, and poor planning and scheduling were among the most important factor affecting the performance in construction projects from a client's perspective. From the contractor's point of view, the most severe factor is delays in payment, followed by increases to material prices and poor labour productivity. Similarly, the consultant agreed with the contractor and client in two factors: delays in payment, and poor planning and scheduling, respectively. Additionally, the consultant ranked poor site management factor as the third important factor contributing to the inadequate performance of the industry (Mahamid, 2016).

The literature review investigated the challenges and problems in the construction industry in Kuwait and identified 18 studies, which revealed four significant challenges facing the industry, as shown in Table 8. These challenges are: delays (AL-Adwani, 2016; Al-Adwani & Fleming, 2019; Al-Adwani et al., 2018; Al-Marri et al., 2012; Al-Tabtabai, 2003; Al-Zubaidi & Al-Otaibi, 2008; Al Tabtabai, 2002; Almutairi, 2016a; Soliman, 2010, 2017a, 2017b) that lead to cost overruns (Al-Reshaid et al., 2005; Alaryan, 2014; Koushki et al., 2005; Koushki & Kartam, 2004), followed by conflict (Al-Humaidi, 2013; Al-Tabtabai & Thomas, 2004) and safety on construction sites (Al-Humaidi & Tan, 2010).

Table 8: Studies of the challenges in the Kuwaiti Construction Industry, including the project's owner and its type.

		Problems / Challenges					
No.	Previous Studies	Delay/ Time overrun	Cost Overrun	Conflicts	Safety/ Construciton Accidents	Project owner	Project type
1	(Al Tabtabai, 2002)	*				Public	Housing "PAHW Projects"
2	(H. Al-Tabtabai, 2003)	*				Public	N/A
3	(H. M. Al-Tabtabai & Thomas, 2004)			*		Public	Large-scale construction Projects
4	(P. A. Koushki & Kartam, 2004)	*	*			Private	Residential projects
5	(Al-Reshaid, Kartam, Tewari, & Al-Bader, 2005)	*	*			Public	N/A
6	(P. Koushki, Al-Rashid, & Kartam, 2005)	*	*			Private	Residential projects
7	(Al Zubaidi & Al Otaibi, 2008)	*				Public	Building and Infrastructure
8	(Al-Humaidi & Tan, 2010)				*	N/A	N/A
9	(Soliman, 2010)	*				N/A	N/A
10	(Al Marri, Ibrahem, & Nassar, 2012)	*				Public	Highways construction projects
11	(Al-Humaidi, 2013)			*		N/A	N/A
12	(Alaryan, 2014)	*	*			Public and Private	N/A
13	(AL-Adwani, 2016)	*				Public	Educational Buildings
14	(Almutairi, 2016)	*				N/A	N/A
15	(Soliman, 2017a)	*				Public	Housing "PAHW Projects"
16	(SOLIMAN, 2017b)	*				N/A	N/A
17	(M Al-Adwani et al., 2018)	*				Public	Housing & large-scale Construction ptojects
18	(M. Al-Adwani & Fleming, 2019)	*				Public	N/A

Table 8 shows that delays represent the most common issue in this field according to the studies found on the challenges facing the construction industry in Kuwait.

For example, Al Tabtabai (2002) investigated the causes of delays in building and housing projects undertaken by government organisations in Kuwait and revealed that they are associated with poor project management factors, the client's management, and site supervision practices. In an effort to solve the problem of delays in public projects in Kuwait, Al-Tabtabai (2003) indicated that this issue was due to the lengthy approval processes that resulted from subsequent changes due to inadequate definition of scope. Similarly, Al-Zubaidi and Al-Otaibi (2008) identified the critical risk factors of delays in construction projects in Kuwait by analysing 28 building and infrastructure projects. The findings indicated that the frequency of delays in construction projects in Kuwait is very high due to the following five factors: delays in government approval/permits; delays in the preparation and approval of change orders; additional work outside the original scope; changed engineering conditions of the contract document, and a decrease in labour productivity due to harsh climatic conditions. According to

Al-Adwani et al. (2018), the main causes of delays in public-sector construction projects in Kuwait are the lack of new construction management methods adopted, a lack of collaboration and communication between project parties, conventional procurement systems, and long approval processes. However, the causes of delays in these projects include all problems from the pre-project to construction stages (Al-Marri et al., 2012)

In addition, it appears there is a strong correlation between time overruns and cost overruns. Since time is money, this demonstrates the linkage between them. Therefore, to eliminate these risks, it is important to determine the factors that cause these issues.

There are several reasons for delays and budget overruns in construction projects in Kuwait. These include: material – related factors such as selection times, the types of building materials, their availability in the local market (Koushki et al., 2005; Koushki & Kartam, 2004), fluctuations in the price of materials, and changed orders which lead to increases to budgets and the duration of individual activities and subsequently require additional financing for contractors (Alaryan, 2014). Table 9 illustrates the causes of time and cost overruns in the construction industry in Kuwait according to previous studies.

Table 9: Causes of time and cost overruns in construction projects in Kuwait from previous studies.

Causes of Time and Cost overruns in Kuwaiti Construction Projects	Studies																
	(Al Tabtabai, 2002)	(H. Al-Tabtabai, 2003)	(H. M. Al-Tabtabai & Thomas, 2004)	(P. A. Koushki & Kartam, 2004)	(Al-Reshaid, Kartam, Tewari, & Al-Bader, 2005)	(P. Koushki, Al-Rashid, & Kartam, 2005)	(Al Zubaidi & Al Otaibi, 2008)	(Soliman, 2010)	(Al Marri, Ibrahem, & Nassar, 2012)	(Alaryan, 2014)	(AlSanad, 2015)	(Almutairi, 2016)	(AL-Adwani, 2016)	(Soliman, 2017)	(Al-Adwani et al., 2018)	(M. Al-Adwani & Fleming, 2019)	Number of occurrences
Poor Planning and control	✔						✔		✔	✔	✔	✔	✔	✔		✔	9
Poor Site Management	✔			✔					✔	✔	✔	✔	✔	✔		✔	9
Lack of communication and coordination	✔	✔			✔		✔		✔		✔		✔	✔	✔	✔	10
Procurement system									✔			✔	✔		✔		4
Material-related factors				✔					✔		✔		✔				4
Financial difficulties						✔		✔	✔		✔						4
Design-related causes		✔				✔		✔		✔			✔	✔			6
Change in orders/ decisions		✔				✔			✔	✔	✔	✔	✔				7
Labour shortage and productivity							✔				✔	✔					3
Conflicts			✔									✔	✔				3
Contractor-related issues	✔					✔			✔			✔		✔			5
Subcontractor-related issues	✔								✔			✔	✔				4
Weather							✔				✔						2
Others						✔						✔			✔		3

Table 9 demonstrates that the top five causes of the time and cost overruns are a lack of communication and coordination, poor planning and control, poor site management, changes to orders or decisions, and design-related causes. Al-Reshaid et al. (2005) believed that time and cost overruns could be mitigated to a huge range, if not removed, by paying attention to the pre-construction phases of projects. The pre-construction period consists of three main phases, which are (Al-Reshaid et al., 2005):

1. Planning (pre-design).

2. Design.

3. Tendering and award.

Al Tabtabai (2002) indicated that the executive process is extremely slow and the flow of information among all parties involved in the project is ineffective. Consequently, he recommended that project management methods and processes should be better implemented in the conceptual and detailed planning phases of projects and the decision-making process and information flow improved among all project stakeholders.

Table 10: Recommendations for mitigating risks in the construction industry in Kuwait as found in previous studies.

No.	Previous Studies	Challenges/ Problems	Recommendations
1	(Al Tabtabai, 2002)	Delay	A better application of project management techniques and procedures being taken at both conceptual and detailed planning phases of projects. In order to achieve the established plans and avoid future crisis with contractors, selection of contractors or sub-contractors should be bound to project size, time limit, quality required etc. The employees need to be empowered trained, trusted, and accountable for their decisions. Improving the decision-making process and the flow of information among all project stakeholders.
2	(H. Al-Tabtabai, 2003)	Delay	Develop an interactive Web-based Project Pre-Design Phase Information (P3I) System.
3	(H. M. Al-Tabtabai & Thomas, 2004)	Delay and Cost overrun	This paper presents the application of a decision-making methodology, the Analytical Hierarchy Process (AHP), to conflict management.
4	(P. A. Koushki & Kartam, 2004)	Delay	N/A
5	(Al-Reshaid, Kartam, Tewari, & Al-Bader, 2005)	Delay and Cost overrun	This paper presents an innovative control concept, which focuses on specific proactive methodology and is therefore highly recommended for implementation during the pre-construction phases. This professional methodology known as Project Control System (PCS). Web-base Management System.
6	(P. Koushki, Al-Rashid, & Kartam, 2005)	Delay and Cost overrun	The client should ensure adequate and available source of finance, perform a pre-construction planning of project tasks and resource needs, allocate sufficient time and money on the design phase. If cost-effective hire an independent supervising engineer to monitor the progress of the work and ensure timely delivery of materials, and finally select a competent consultant and reliable contractor to carry out the work
7	(Al Zubaidi & Al Otaibi, 2008)	Delay	N/A
8	(Al-Humaidi & Tan, 2009)	Construction Accidents	There is a need to change current legislation and control strategies in construction and building sites to more rigorous legislations and control practices to enhance construction safety level in Kuwait.
9	(Soliman, 2010)	Delay	N/A
10	(Al Marri, Ibrahem, & Nassar, 2012)	Delay	N/A
11	(Al-Humaidi, 2013)	Contract Disputes	The concept of arbitration as an alternative dispute resolution method .
12	(Alaryan, 2014)	Cost overrun	The most six common control measures are: checking and reviewing the contract documents, reviewing design before change approval, the change order must be negotiated by knowledgeable persons, the scope of change orders must be clearly made, appropriate approval in writing must be handed, and the good tools to control the occurrence of change including the areas of concern in monthly reports and meetings.
13	(AL-Adwani, 2016)	Delay	N/A
14	(Almutairi, 2016)	Delay	A periodical evaluation of the contractors should be carried out by a special pre-qualification committee within Kuwait construction industry and the relevant government ministries in Kuwait or by the project management firms hired by Kuwait. The contractors and subcontractors should be selected based on the size of the project, time limit of the project and quality of work required. The tenders should be awarded based on the capabilities and past performance of the contractors. Professional Construction Management (CM) practises should be applied in order to build the spirit of teamwork and professional trust in the contractual parties in the construction project. The time schedule of material delivery to the construction site needs to be developed so as to reduce the lack or shortage of materials as the construction work is in progress. The staff with appropriate experience should be appointed to lead the technical and management aspects of the project. Enough engineers, technicians, foremen and planning managers are necessary in order to ensure effectiveness of the work as the responsibilities is shared between them based on the specialization. The late payments by the owner to the contactors should be avoided by ensuring that the contractors are paid the progress payment on time. Qualifid consultants. There is a need for the human resources in the construction industry to be trained and the craftsmen classified. The construction engineers should be trained so as to have adequate management skills such as time and cost control, scheduling, information systems and management of human resources should be given to the key stakeholders in the industry to improve the performance in each section and reduce delays.
15	(Soliman, 2017a)	Delay	The study showed that communication tools in governmental project in Kuwait needed to be more efficient by improving filling system, enhance progress meeting procedure and legally acceptance of using new communication tools which are highly available in Kuwait state. To increase meeting efficiency, it is recommended to prepare a clear and predefined common agenda that contains progress, cost, quality reports, subcontractors' status and problems discussion especially the occurred delay or anticipated delay.
16	(SOLIMAN, 2017b)	Delay	The recommendations need governmental motivation to change its procedure of project delivery system for both contractor and consultants. Changing order procedure and function should be revised by governmental agencies. It is highly recommend revising and updating out of dated general conditions documents. In addition to recommend upgrading all planning skills for all project users.
17	(AlSanad, 2017)	Delay and Cost overrun	A mega project due to its size and critical nature necessitates expert management in order to minimise risk occurrence
18	(Al-Adwani et al., 2018)	Delays	The government or the public sector should encourage the adoption of mitigation strategies such as the integration of Lean Construction and Building Information Modelling (BIM)
19	(M. Al-Adwani & Fleming, 2019)	Delay and Cost overrun	The implementation of advanced Project Management approaches to improve the industry's performance such as Lean Construction and BIM

Table 10 presents recommendations on how challenges in the Kuwaiti construction industry could be addressed, according to the findings in previous studies. Al Tabtabai (2002) recommended improving the application of project management methods and techniques, as well as enhancing the decision-making process and the flow of information among all project stakeholders. While Al-Tabtabai and Thomas (2004) discussed the Analytical Hierarchy Process (AHP) as the application of a decision-making methodology to conflict management. Al-Tabtabai (2003) suggested the development of an interactive Web-based Information Support System (P3I) in order to help engineers and administrators enhance management of the pre-design phase of construction projects in the public sector. Al-Reshaid et al. (2005) stated that a professional methodology, known as Project Control System (PCS) which is a web-based management system, that focuses on the pre-construction phases of construction projects could eliminate time and cost overruns. Additionally, Almutairi (2016b) suggested that, in order to minimise delays in construction projects and improve collaboration and commitment between all stakeholders, professional Construction Management (CM) practises should be implemented. Soliman (2017a) emphasises the need for communication methods to be more efficient in the Kuwaiti government projects by improving the filing system and enhancing progress meeting procedures. He encourages the government to change its project delivery system proceedings for both contractors and consultants and to develop all planning skills for all project parties. AlSanad (2017) pointed out that, in order to avoid risks, large projects need experts in project management due to their size and critical nature. However, adopting advanced project management strategies, such as Lean Construction (LC) and Building Information Modelling (BIM), will have a positive impact on the performance of the industry (Al-Adwani et al., 2018). According to Al-Adwani and Fleming (2019), the implementation of LC and BIM approaches in this industry will help to overcome construction challenges such as delays, inappropriate project management practices, and a lack of collaboration and communication between project stakeholders. Hence, this could be an appropriate way to improve performance and productivity in the construction industry in Kuwait.

After systematically reviewing literature on the challenges facing the construction industry in Kuwait, 19 studies were found and 14 of these provided suggestions to resolve issues. However, a knowledge gap was found on Lean Construction and Building Information Modelling in the Kuwaiti industry, with only two studies referring to these approaches to improve the industry without reference to its proper implementation. Although these studies suggested improving the information system and project management practices, Al-Adwani and Fleming (2019) indicated that there is a significant lack of awareness and knowledge of Lean principles and a lack of implementation of BIM applications in the construction industry in Kuwait. Additionally, they argued that the implementation of BIM in Kuwait's construction industry is inappropriate, and there is a major misunderstanding of its purpose. Consequently, this research will focus on solving the challenges facing this industry to improve public projects in the construction industry in Kuwait by adopting Lean Construction and BIM to mitigate the challenges found.

2.4 Lean Production

Lean production is a western term for Toyota Production System (TPS). It is a systematic way to minimise waste and add value for customers. The philosophy of Toyota Production System was developed by Eiji Toyoda and Taiichi Ohno towards the end of World War II due to the inability of mass production systems to meet customer needs. Therefore, the Toyota Production System was designed in the 1950s to fulfil customers' requirements (Dennis, 2015). TPS is an integrated management system that not only focuses on reducing waste and meeting customers' needs, it also considers employees as a team, respects them, and encourages them to cooperate and solve problems together and consider continuous improvement (Liker, 2004). The term "*Lean Production*" derived from TPS and was first introduced by Womack, Jones, and Roos (1990) in their book "*The Machine That Changed The World*".

Womack and Jones (2003) believed that Lean Thinking is the answer for Muda (waste). The benefits behind adopting Lean Thinking are that "it provides a way to specify value, line up value-creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively" (Womack &

Jones, 2003, p. 15). Five principles of Lean Thinking can be drawn from the previous discourse and could be defined as follow:

1. Value

"Value can only be defined by the ultimate customer. And it's only meaningful when expressed in terms of a specific product which meets the customer's needs at a specific price at a specific time" (Womack & Jones, 2003, p. 16).

2. Value Stream

Womack and Jones (2003) identified the value stream as a set of all the activities necessary to design, demand, and deliver a particular product, from idea to launch, demand to supply, and from raw materials into a final product delivered to the customer.

3. Flow

The flow in Lean principles is determined as the *"*progressive achievement of tasks along the value stream so that a product proceeds from design to launch, order to delivery and raw materials into the hands of the customer with no stoppages, scrap or backflows*"* (Womack & Jones, 2003, p. 348)

4. Pull

Womack and Jones also defined the pull principle, as a system of flow manufacture and dispatch orders from downstream to upstream, where nothing is produced form the upstream resource until the customer shows an indication of need.

5. Perfection

Perfection is the fifth and the final principle of Lean which was defined again as the thorough elimination of waste (Muda) in which all actions along a value stream add value.

2.5 Lean Waste

Lean thinking aims to remove waste from work processes. Waste is defined as an activity or an operation that adds no value to the client (Skhmot, 2017). The term waste, or Muda, was introduced by Taiichi Ohno, the Chief Engineer at Toyota (Liker, 2004). Figure 7 shows the eight types of Muda.

Figure 7: The 8 Types of Lean Waste (Skhmot, 2017)

Additionally, Liker (2004) described each type of Lean waste, as follows:

1. Overproduction

Overproduction occurs when a product or component of a product is manufactured before being requested or demanded. It is one of the most severe types of waste because it generates other types of waste such as overstaffing, storage and transportation charges because of excess inventory. For instance, when items such as reports or phone calls are made without demand from a client, these are non-value adding activities in the eyes of the customer.

2. Waiting (time on hand)

Lost goods, unexpected planning accidents and unusable lines lead to wasted time during or between operations. The waste of waiting involves employers waiting on material or equipment and unused equipment. The waiting time is often due to uneven production stations and can lead to increased inventory and overproduction. For example, in the workplace, waiting waste could include: waiting for email responses, pending files waiting for review, ineffective meetings, and waiting for the PC to load or update a program (Skhmot, 2017).

3. Unnecessary transport or conveyance

Carrying work in process (WIP) long distances results in the generation of wasteful transportation of materials, partially completed elements or completed products into or out of storage or between operations. Waste in transportation comprises the unnecessary movement of personnel, tools, supplies, equipment or items. The excessive movement of materials can damage products and cause defects. Also, the excessive movement of individuals and tools can cause unnecessary work. This is a phase that obstructs the added value of the client.

4. Over processing or incorrect processing

Taking needless steps to process components. Treatment is ineffective due to poor tool and product design, the production of excessive movement and generation of defects. Waste is caused when delivering higher-quality products than required.

Skhmot (2017) pointed out that this is a form of waste that is quite clear and easy to remove. It happens when a product goes through unnecessary stages that accordingly adds no value, leaving the client unwilling to pay for it.

5. Excess inventory

Sometimes it is hard to think about excess inventory as waste. This refers to the collection or accumulation of materials or products during any phase of the process. Excess raw materials, work in process (WIP), or finished goods leading to time wastage (longer time periods), obsolescence, damaged goods, shipping and storing expenses and delay. Excess inventory can be generated by over-purchasing, overproducing work in process (WIP), or manufacturing more products than the client wants. Additionally, excess inventory conceals problems such as production imbalances, delayed supplier deliveries, deficiencies, equipment downtime and long setup times.

6. Unnecessary movement

Excessive movement of any kind that is unnecessary to sufficiently achieve any task is classified as waste. For instance, any useless movement of personnel while performing their duties such as the search for, access to, or accumulation of parts or tools etc., leading to overwork and tiredness, at which point product processing support will not be possible (Bosca, 2012).

7. Defects

The production of defective pieces during the process which requires additional work or re-work is a waste of time and effort. Skhmot (2017) indicated that defects appear when the product is not suitable for use. This usually results in product rework or scrapping. Both outcomes are wasteful, adding extra costs to processes without providing any value to the customer.

8. Unused employee creativity

This denotes a waste of time, ideas, talents, improvements, and learning opportunities. It occurs when companies isolate the responsibility of management from workforces. It refers to the waste of unused people skills and ingenuity.

2.5.1.1 Waste in Construction

In construction, waste is found everywhere, and minimising it will have a significant impact on the process efficiency of this industry (Sowards, 2007). Koskela, Owen, and Dave (2010) indicated that construction waste is a result of re-work and non-added value activities such as waiting, transporting, examining, and missing data. For instance, personnel spend a considerable amount of time on material processing, preparation, waiting, re-work and activities without any added value (Josephson & Saukkoriipi, 2007). Mollasalehi, Fleming, Talebi, and Underwood (2016) identified types of waste found in construction projects, which are waiting, defects, unnecessary movement, and excess inventory. They also investigated the root causes of such waste and provided brief clarification of how they would contribute to waste generation, as shown in Table 11.

Table 11: Root Cause of Waste in Construction (Mollasalehi et al., 2016)

Root cause of waste	Construction Waste				Comments
	Waiting	Defects	Unnecessary movement	Excess inventory	
Change orders	*	*	*	*	Change orders would make one task to be done several times. This might have negative impacts on the construction site. Additionally, change orders in the construction would affect the productivity of labour as well as the efficiency of the work
Decision making	*	*	*	*	Insufficient design decision making at the wrong time would result in producing major types of waste. Also poor decision making will impact on the construction quality.
Lack of information exchange	*	*			Lack of information exchange will make tasks or project team wait for the information to be shared. Also, if information won't be shared at the right time this might result in redoing tasks. Moreover, lack of information exchange might result in receiving wrong information by project team which will result in rework, waiting and reducing the productivity of work and workers.
Poor communication	*	*	*		Poor communication is relatively influence by late involvement of construction management team to give sufficient insight during design stage. This will result in many change orders and poor design decision making which have negative impacts on the project. Additionally, late involvement of project team as a

On the other hand, it has been found that the integration of Lean construction and BIM has a huge impact on the early design of the project, which minimises waste at this stage. According to Formoso, Isatto, and Hirota (1999) there are three principles of waste elimination in the design process that reduces uncertainty, waiting time, and the effort needed in information transfer. Uncertainty at the design phase could be one of the major reasons for re-work. This can be minimised by focusing more on the clear identification of project constraints and internal and external customer needs. This includes a reduction in waiting time by properly analysing design tasks so that they can be planned correctly, as well as allowing information to be transferred in smaller batches.

Mollasalehi et al. (2016) pointed out that all of the above principles could be fulfilled by adopting Lean and BIM approaches. They argued that a waste elimination method in the design process will address several challenges in the construction industry, such as delays, cost overruns, collaboration and communication, health and safety, and deficiency of information exchange. Since all project data is available in a BIM model, it could be collaboratively shared amongst the project team and the effort in transferring information reduced. Consequently, the waste of waiting, unnecessary movement, defects, and excess inventory would be eliminated (Mollasalehi et al., 2016).

A study by Mollasalehi et al. (2016) revealed that the disposal of such waste in construction has several benefits to the design process from the viewpoint of Lean construction and BIM, which enhances the workflow, improves the design quality, reduces the workload, generates value, and saves time. Likewise, Liker (2004) believes that improved quality, lower cost and shorter delivery times are attainable, simply by minimising waste and increasing flow.

2.6 Lean Construction

Research has shown that the adoption of Lean philosophy and its tools in the construction industry help to address uncertainty and difficulty in this industry, consequently making it more efficient (Ahuja, Sawhney, & Arif, 2014). This adoption of Lean Principles aims to deliver promised value to the customer without the normal wastage that usually occurs during construction works on a project site (LCI, 2016).

Lean is a philosophy of production management to deliver a project (Howell & Ballard, 1998) that focuses on changing the conventional project delivery process in order to reduce waste and attain maximum value for the customer (Ahuja, Sawhney, & Arif, 2017). Lean thinking is an innovative approach to manage construction (Howell & Ballard, 1998). Although it was created in the manufacturing industry, Howell and Ballard (1998) believed that the purposes of Lean philosophy determine the control of dynamic projects. Koskela (1992) described Lean Construction as a technique to design production systems to reduce the waste of materials, time, and effort and generate the maximum possible amount of value. Lean construction is derived from Lean production principles and practices for improving productivity and efficiency and eliminating waste. Egan (1998) and Howell & Koskela (2000) agreed that project management has become inadequate and needs to be developed by adopting successful management approaches from manufacturing, specifically theories from production management that have proven their efficiency. They argued that adding workflow management and the creation and delivery of value to activities, Lean Construction is the most appropriate method to improve project management. However, it is hard to adopt Lean Principles in the construction industry due to its fragmented nature and different processes. Also, each project is different from the next meaning it is impossible to standardize (Howell, 1999). Unlike manufacturing, construction projects are generally executed on site, therefore, the off-site construction and prefabricated units have slowly increased recently (Ballard & Arbulu, 2004; Brockmann & Birkholz, 2006). Two studies were mentioned in the *BIM Handbook* regarding BIM implementation on projects where prefabricated elements have been extensively used. The prefabricated elements, mentioned by Ballard and Arbulu (2004, p. 2), are "HVAC ductwork, custom piping, pipe supports, precast concrete, electrical switchgear, reinforcing steel, structural steel and building envelope facades". Eastman, Teicholz, Sacks, and Liston (2011) stated that Lean Construction methods involve cautious coordination between the main contractor and suppliers to confirm that work can be completed when the required supplies are ready on-site. From the perspective of detailed design for the manufacture and supply by subcontractors of prefabricated elements, BIM produces an accurate model of the design and material resources required for each part of the work. It delivers the fundamental better planning and scheduling of subcontractors in order to ensure the just-in-time (JIT) access of materials and resources (Eastman, 2011).

Aziz and Hafez (2013) claimed that numerous studies have been conducted by construction specialists and researchers to improve traditional construction management and deliver best value to clients with actual profits. They also indicated that consequently, Lean Construction tools have successfully been integrated and adopted to modest and complicated construction projects.

Koskela (1992) was the first to introduce Lean Construction principles derived from the manufacturing industry. These were as follows:

1. Minimizing non-value activities.
2. Achieving the client's requirements
3. Reducing variability
4. Reducing cycle times
5. Simplifying by minimizing the number of steps, parts, and linkages
6. Increasing flexibility in deliverables
7. Increasing the transparency of the process
8. Sustaining control through the entire process
9. Creating continuous improvement into the process
10. Balancing flow improvement with conversion improvement
11. Benchmarking

However, Womack and Jones (2003) have summarized these 11 Lean principles into five fundamental principles, which are value, value stream, flow, pull and perfection. Figure 8 illustrates how Lean principles could be achieved in the Construction Industry.

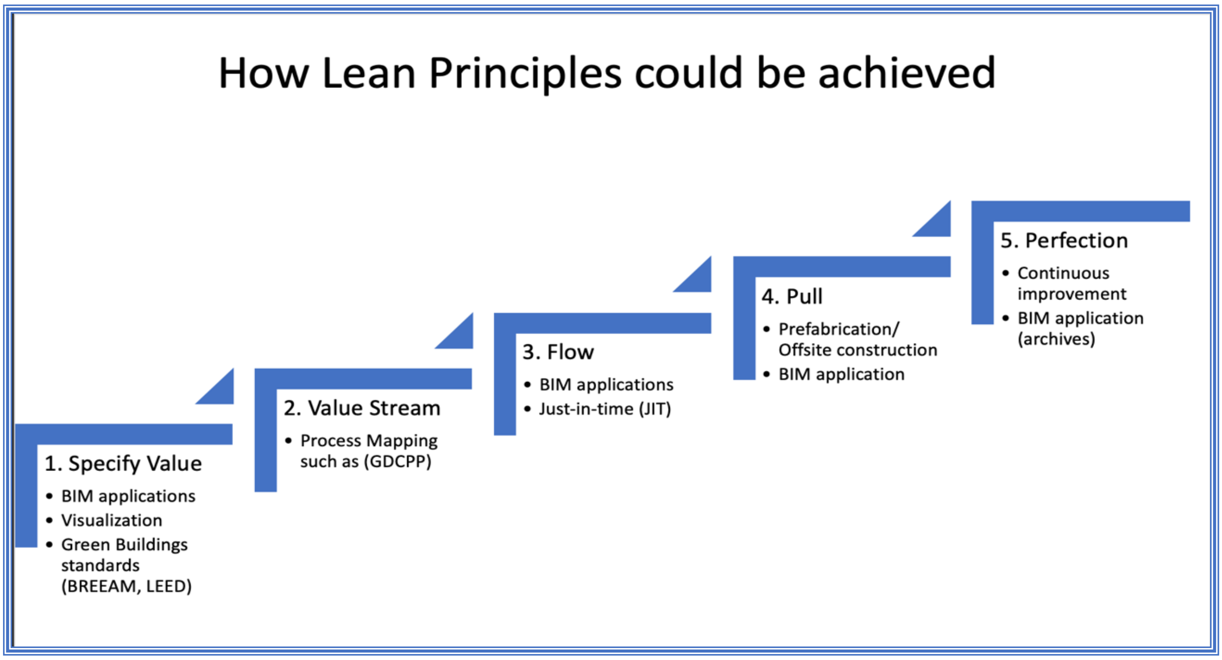


Figure 8: How to Achieve Lean Principles in Construction

Moreover, Sacks, Koskela, Dave, and Owen (2010) summarized Lean Construction Principles area into four principal areas, which are flow process, value generation process, problem solving, and developing partners. These principals have broken down into sub-principals as shown in Figure 9.

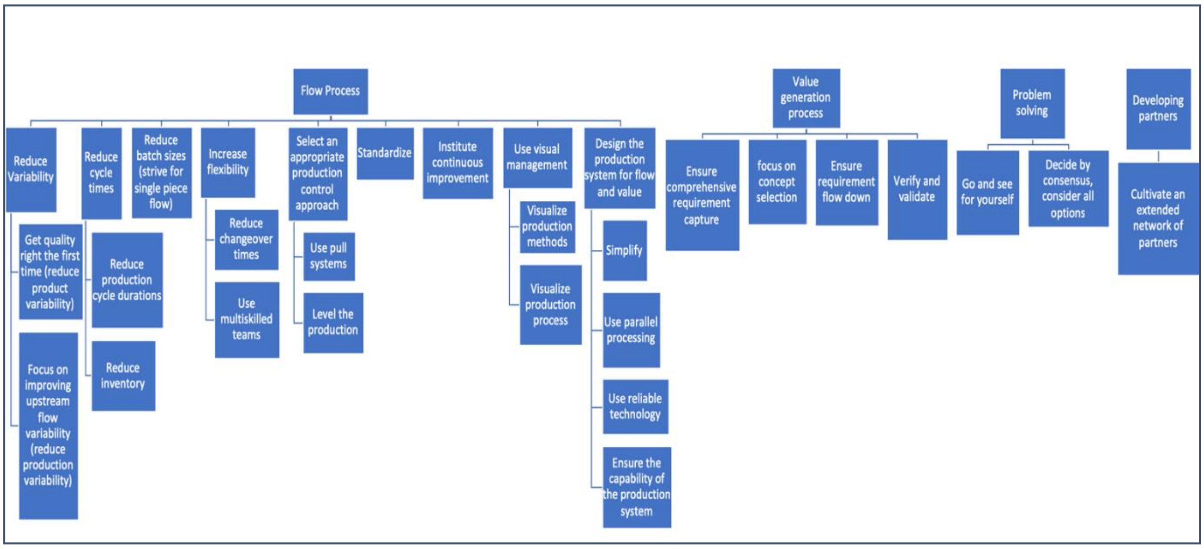


Figure 9: Lean Construction Principles

The author believes that Lean thinking could be achieved by using new project management approaches, such as the Generic Design and Construction Process Protocol (Kagioglou, Aouad, Cooper, & Hinks, 1998) which acts as a guidance or blueprint for the successful delivery of a project. Since there is a lack of process protocol to utilize BIM applications, exploiting new technologies to design, produce and monitor the project using a BIM approach will be investigated.

2.7 Lean Construction in the Middle East

After reviewing relevant literature about Lean Construction in the Middle East region, 13 studies were found. Seven studies were conducted in Saudi Arabia, while two studies were carried out in both Lebanon and the United Arab Emirates. In contrast, one piece of research was found in Turkey and Egypt. Table 12 illustrates these studies including the type of project, paper, research and the purpose of conducting it.

Table 12: Lean Construction Studies in the Middle East Region

No.	Reference	Country	Type of Project	Type of Paper	Research type	Purpose of the study/ conclusion
1	(A. O. AlSehaimi, Tzortzopoulos, & Koskela, 2009)	Saudi Arabia	Construction Projects	Research paper	Action Research	For this study **Last Planner System** has been used to improve two construction projects in KSA
2	(A. Alsehaimi, 2011)	Saudi Arabia	Building Projects	PhD Thesis	Action Research	**Last Planner System** was used to improve the construction planning and control process
3	(Tezel & Nielsen, 2012)	Turkey	Construction Projects	Research paper	A questionnaire-based research methodology	This paper aims to preduct the lean conformance levels of Turkish contractors
4	(Aziz & Hafez, 2013)	Egypt	Construction Projects	Journal paper	Secondary research	Using **Last Planner System** as a Lean Construction technique to minimise waste and enhance the construction management practices in various aspects.
5	(O. AlSehaimi, Tzortzopoulos Fazenda, & Koskela, 2014)	Saudi Arabia	Construction Projects	Research paper	Action Research	The purpose of this paper to evaluate the effectiveness of implementing Last Planner System (LPS) to improve construction planning practice and enhance site management in KSA
6	(Kanafani, 2015)	UAE	Construction Projects	Master's Thesis	Mixed Methods	The main objective of this paper is to investigate the relevance of barriers documented in literature to UAE's construction industry.
7	(Awada, Lakkis, Doughan, & Hamzeh, 2016)	Lebanon	Construction Projects	Conference Paper	A questionnaire-based research methodology	This paper examines the impact of implementing lean concepts on reducing work accidents in the construction industry in Lebaon.
8	(Hamzeh, Kallassy, Lahoud, & Azar, 2016)	Lebanon	Large scale projects	Conference Paper	Case Study	This paper presents a reflection on the first implementation of lean principles in general and the LPS in particular on a large scale project in Lebanon
9	(Mohamed, 2016)	Saudi Arabia	Construction Projects	PhD Thesis	Action Research	The research aim is to develop an innovative framework and assessment tool that facilitates the use of Lean Construction, a method that is considered new to the field, as a more efficient method of minimising the risks of Mega-Construction projects in the KSA
10	(J. G. Sarhan, Olanipekun, & Xia, 2016)	Saudi Arabia	Construction Projects	Conference Paper	A questionnaire-based research methodology	This paper aims to identify and evaluate the critical success factors for the implementation of lean construction in KSA
11	(J. G. Sarhan, Xia, Fawzia, & Karim, 2017)	Saudi Arabia	N/A	Research paper	A questionnaire-based research methodology	This study investigates the current state of lean construction implementation in the construction industry in the KSA.
12	(Small, Al Hamouri, & Al Hamouri, 2017)	UAE, Dubai	N/A	Conference Paper	Secondary research	The purpose of this investigation is to understand the barriers to implementation of lean construction principles to identify practical approaches for the implementation and promotion of lean within the UAE construction industry.
13	(J. Sarhan, Xia, Fawzia, Karim, & Olanipekun, 2018)	Saudi Arabia	N/A	Research paper	A questionnaire-based research methodology	The purpose of this paper is to identify the barriers to implementing lean construction in the KSA.

Lean construction has proven its efficiency by enhancing productivity in the construction industry around the world. Alsehaimi (2011) succeeded in improving two construction projects in Saudi Arabia by enhancing construction management practice through the application of Lean Construction to these projects. According to AlSehaimi et al. (2009), implementing Lean Construction techniques, such as the Last Planner System (LPS), in the construction industry in Saudi Arabia had a significant impact. This has positively reflected on the industry by improving site management practices and construction planning. Additionally, they noticed that LPS reduces the duration of structural works in projects, which is a great improvement on existing project delivery. In addition, Aziz and Hafez (2013) suggested the use of Last Planner System as a Lean Construction tool to minimise waste and enhance construction management practices in Egypt.

Despite implementing Lean Construction in few countries in the Middle East such as Saudi Arabia, Turkey, UAE, and Lebanon, research on the challenges in the Kuwaiti construction industry shows neither evidence of adopting Lean principles nor the application of Building Information Modelling. This confirms a significant lack of awareness, knowledge, and implementation of Lean principles and BIM in Kuwait.

2.8 Building Information Modelling (BIM)

Recently, Building Information Modelling has been widely implemented in many AEC companies globally (Nanajkar & Gao, 2014). According to NBS (2016), BIM is the future of project information because the awareness of BIM is nearly universal, so it is expected that within five years all countries will adopt this technology.

Building Information Modelling (BIM) has been defined by Vanlande, Nicolle, and Cruz (2008, p. 3) as the "*process of generating, storing, managing, exchanging, and sharing building information in an interoperable and reusable way*". Additionally, Eastman et al. (2011, p. 586) states that Building Information Modelling is *"a verb or adjective phrase to describe tools, processes and technologies that are facilitated by digital, machine*-readable *documentation about a building, its performance, its planning, its construction and later its operation".* In more detail, Underwood (2009, p. 16) describes BIM as:

> *"A model of information about a building that comprises, complete and sufficient information to support all lifecycle processes and which can be interpreted directly by computer applications. It comprises information about the building itself as well as its components, and comprises information about properties such as function, shape, material and processes for the building life cycle".*

According to the National Building Information Modelling Standard (NBIMS) (NIBS, 2007, p. 6), BIM is:

> *"An improved planning, design, construction, operation, and maintenance process using a standardized machine-readable information model for each facility, new or old, which contains all appropriate information created or gathered about that facility in a format useable by all throughout its lifecycle".*

Furthermore, Building Information Modelling is known as:

> *"... a modelling technology and associated set of processes to produce, communicate, and analyse building models, it is the acronym of 'Building Information Modelling', reflecting and emphasizing the process aspect, and not of 'Building Information Model'. The objects of BIM processes are building models, or BIM models"* (Sacks, Eastman, Lee, & Teicholz, 2018, p. 14).

Sacks et al. (2018) describe the characteristics of building models as follows:

- Constructing components represented by digital representations (objects) that transfer calculable graphics and data characteristics that classify them to software applications, along with parametric regulations that allow for intelligent processing.
- Elements that include data describing how they behave, as needed for analyses and work

processes, such as take-off quantity, specification, and energy analysis.

- Reliable and non-duplicated data, such as changes in component data, are embodied in all component views and assemblies that are part of it.

According to Sacks et al. (2018, p. 14), the NBIMS initiative classified the Building Information Model in three ways:

- as a product
- as an IT-enabled, open standards-based deliverable, and a collaborative process
- as a facility lifecycle management requirement

Azhar (2011) indicated that BIM helps designers and engineers to visualize what will be built in a simulated environment and detect possible design, construction or operational problems. In addition, BIM epitomises a retreat from traditional two-dimensional design applications through the combination of 3D graphical Modelling, 4D time Modelling and 5D cost Modelling meaning that prototypes are sophisticated (Deutsch, 2011).

Moreover, BIM allows automatic quantification and the creation of schedules, which will broadly eliminate the demand for manual launches of constructions during calculations (Deutsch, 2011; Woo, 2006). Likewise, the design of information is correlated; thus, the modification of one component immediately updates anything affected by the change (Sylvester & Dietrich, 2010).

2.8.1 Building Information Modelling Functionality/Applications:

Building Information Modelling is "*a process for manufacturing and managing information models on a construction project across the project lifecycle*" (Shaikh et al., 2017, p. 1785). This produces a digital description of all aspects of the built model, which is considered one of the main outputs. BIM is described as a combination of interrelating codes, processes, and technologies which create an organized approach to control and manage important construction project data and information in a digital format during the building life cycle (Penttilä, 2006). According to Shaikh et al. (2017), producing this digital-rich model requires stakeholders to utilize the process in order to ensure optimum performance thereby achieving the preferred value for the overall life of the built asset. Azhar (2011) mentioned that BIM models could be used for several purposes, namely visualisation, manufacturing, code reviews, cost estimation, construction sequencing, conflicts and clash detection, forensic analysis, and facility management, as shown in Figure 10.

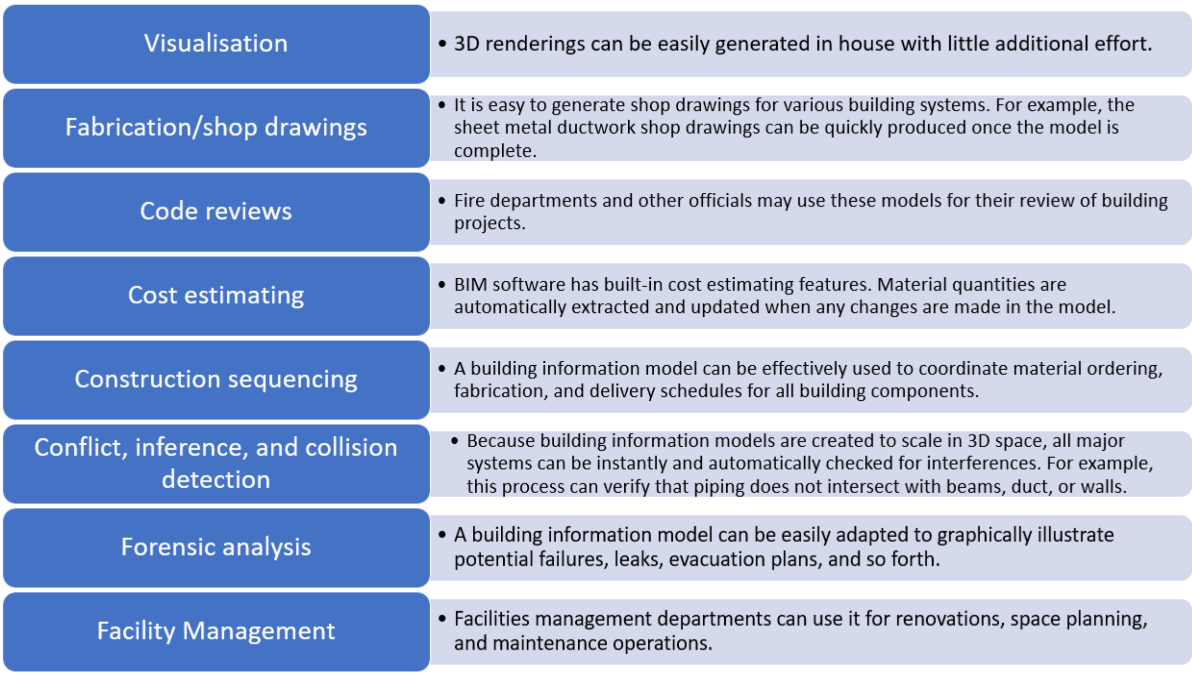


Figure 10: BIM Functions (adopted from: Azhar, 2011)

2.8.2 Benefits of BIM

Building Information Modelling technology can reinforce and enhance many business practices (Sacks et al., 2018). It is the hub of collaboration that fills the gaps between various stakeholders of a certain project. BIM is an information management process that facilitates the transfer and sharing of data, documents, and drawings between all project parties. Figure 11 illustrates the information exchange in the traditional approach compared to Building Information Modelling.

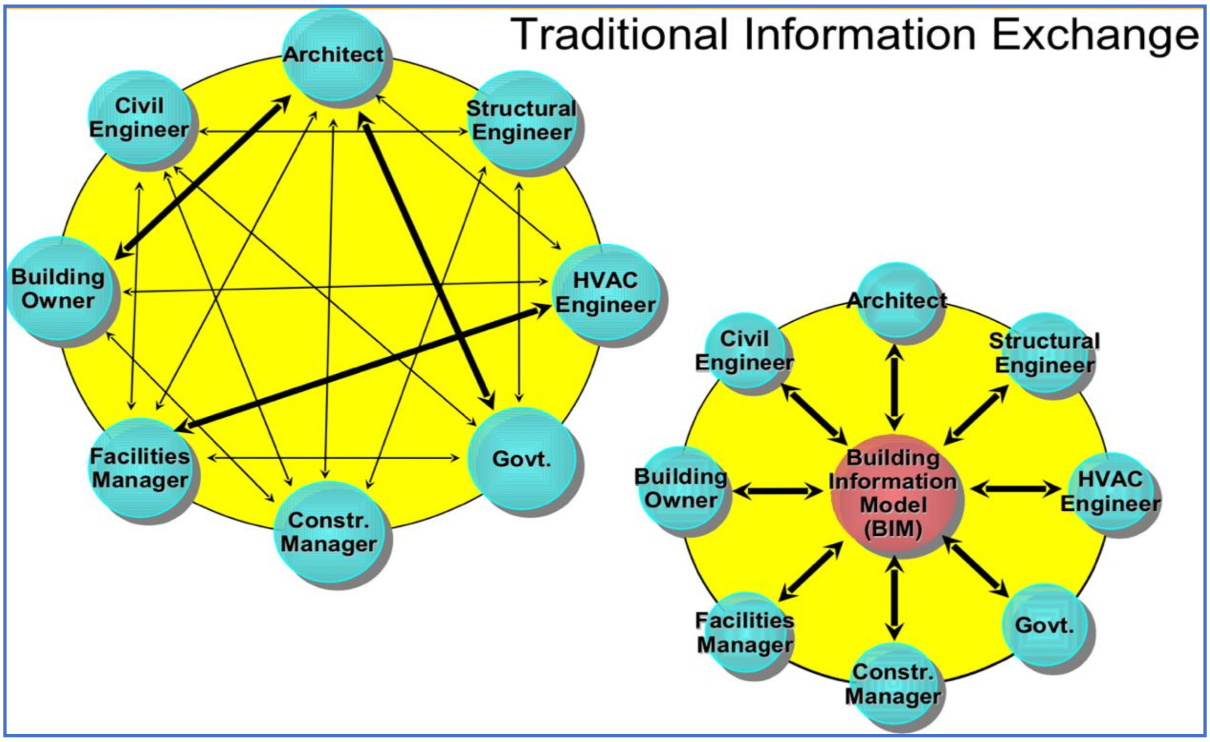


Figure 11: Information Exchange in Traditional Approach compared to BIM (U. NIBS, 2012)

There are numerous benefits associated with the implementation of BIM for all project specialties. These benefits include enhanced visualization, improved coordination between all project parties, better integration of construction drawings (Wang & Leite, 2014), technical advancement, interoperability capabilities, early capturing of building information, utilisation during the construction lifecycle, integrated procurement, enhanced budget control mechanisms, decreased clashes, and project team benefits (Ghaffarianhoseini et al., 2017). For instance, BIM has the ability to detect multidisciplinary conflicts in graphics in order to reduce mistakes, maintain design structure, control quality and accelerate communication (Al-Yami & Sanni-Anibire, 2019). Figure 12 illustrates the way that BIM technology and its associated processes get to the core building design and construction processes and the ways they react to the increasing pressures of greater complexity, quicker development and boosted sustainability while minimising the cost of the project and its subsequent usage (Eastman, 2011).

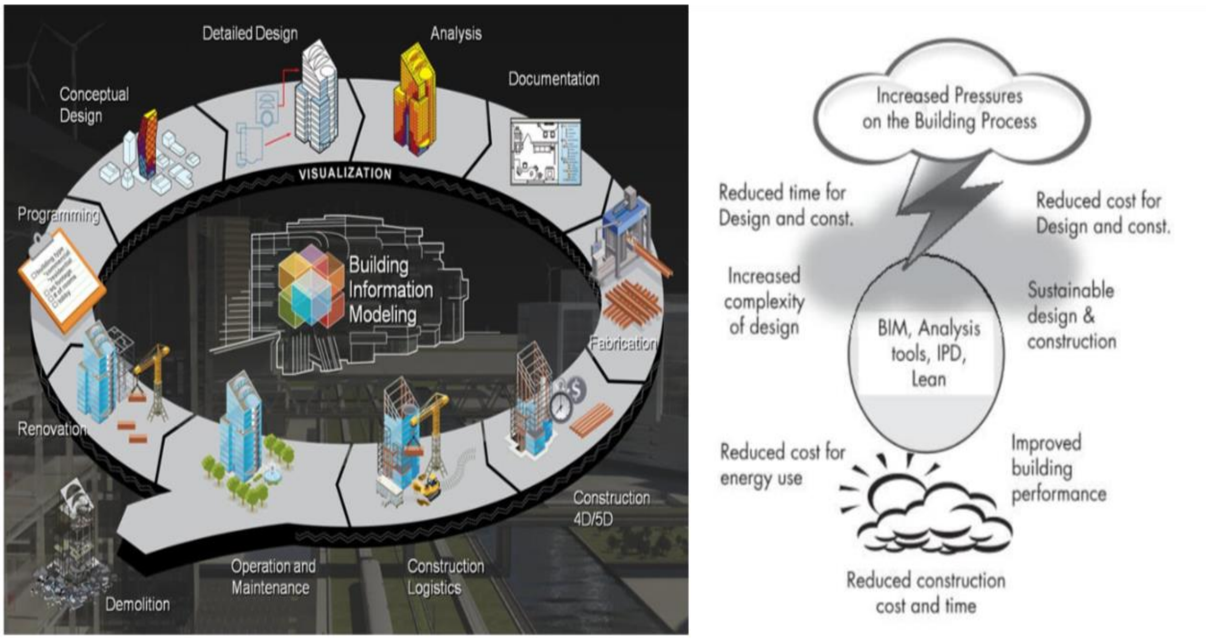


Figure 12: Building Information Modelling Process

However, the construction industry has long sought to overcome the aforementioned challenges and boost construction output. Azhar (2011) argued that Building Information Modelling is key to attaining these established aims. Several studies have been conducted on BIM's benefits (Azhar, 2011; Ghaffarianhoseini et al., 2017; Lu, Fung, Peng, Liang, & Rowlinson, 2014; Migilinskas, Popov, Juocevicius, & Ustinovichius, 2013). For instance, according to Stanford University's Centre for Integrated Facilities Engineering the advantages of implementing BIM across 32 major projects were follows (Moud, 2013):

- Project time dropped by 7%
- Up to 10% of the contract value saved by detecting clashes
- The accuracy of the budget estimates increased by 3%
- The preparation of budget assessment time decreased by 80%
- Up to 40% was discharged from unbudgeted change

There are several benefits and drivers for adopting BIM in the construction industry, which are listed in Table 13 (Eadie, Odeyinka, Browne, McKeown, & Yohanis, 2013).

Table 13: Benefits and drivers for adopting BIM in the construction industry (Source: Eadie, Odeyinka, Browne, McKeown, & Yohanis, 2013).

BIM Benefits/ Drivers	Reference
• Faster and more effective processes • Better design • Controlled whole-life costs and environmental data • Better production quality • Automated assembly • Better customer service • Lifecycle Data	(CRC Construction Innovation, 2007).
• Clash detection • Cost savings through reduced re-work • Improve design quality • Accurate construction sequencing • Improve built output quality • Desire for innovation • Competitive pressure • Government pressure • Improve capacity to provide whole life value to client • Streamline design activities • Time savings • Cost savings through reduced (Request for Information) RFI's • Improve communication to operatives • Facilitate increased pre-fabrication • Client pressure • Automation of schedule/register generation • Design health and safety into the construction process • Facilitate facilities management activities	(Eadie, Odeyinka, Browne, McKeown, & Yohanis, 2013)
• Enhance communication and collaboration • Process Standardisation achievement • Reliability in specification and regulations • Productivity in assets • Better perspective and innovative strategy • Fewer labour costs	(Farr & Piroozfar, 2014)
• Effective communication • Collaboration coordination practice • Collaboration coordination tools • Reliability in BIM technologies • Sharing data effective methods • Common data environment • Track information • Collaboration and commitment • Leadership with shared goals • Roles and responsibilities allocation • Collaboration willingness • Sharing information trust • Relationship with client • Problem solving • Clear collaboration plan	(Eissa Alreshidi, Mourshed, & Rezgui, 2017; Migilinskas et al., 2013)

Sacks, Koskela, et al. (2010) mentioned four BIM implementation benefits: visualization of model, collaboration in design and construction, rapid generation and evaluation of construction plan alternatives, and MEP clash detection. They also provided a clear explanation for each, as shown in Table 14.

Table 14: BIM Implementation Benefits

BIM benefits	**Description**
Visualization of model	To evaluate the functional and aesthetic aspects. This will improve the stakeholder's participation through the production of 3D designs rendering that are accessible to them.
Collaboration in design and construction	There are internal and external collaboration. Internal collaboration involves various users within one organisation or specialty modify the same model simultaneously, where the external collaboration consists of multiple users who view integrated or separated multidiscipline models simultaneously to coordinate the design.
Rapid generation and evaluation of construction plan alternatives	Many commercial software are available for 4D visualisation of construction timetables. Construction tasks and modelling of dependencies and prerequisites (such as completion of previous tasks, space, information, safety reviews, crews, materials, equipment, etc.) can be generated automatically by exploitation libraries of construction methods, thus, plans can be modified and analysed within hours.
Mechanical Electrical Plumbing (MEP) clash detection	MEP systems are highly critical on technically challenging projects such as hospitals and pharmaceutical industries. In order to successfully complete the project, it is important to determine the routing and the spatial preparations of the MEP systems before the construction phase. Architects and engineers normally create a schematic drawing of the MEP system routing and the main contractor depends on his specialist sub-contractors to find the accurate dimensions of the systems considering the required specifications by the architects and engineers. The failure to determine the spatial dimensions of MEP systems and to verify possible clashes between different MEP systems before construction can lead to much rework and can lead to many problems such as re-work, delays, and cost overrun.

Eastman et al. (2011) pointed out that advantages of implementing BIM covered the whole lifecycle of a project, starting from the pre-construction to the post-construction phases, as shown in Table 15.

Table 15: BIM Benefits

Project Phases	BIM benefits
Pre – Construction	• Concept, Feasibility and Design benefits • Increased Building Performance and Quality
Design	• Earlier and more accurate visualisation of a design • Automatic Low-Level Corrections when changes are made to design • Generate Accurate and Consistent 2D drawings at any stage of the design • Earlier collaboration of multiple design disciplines • Easily check against the design intent • Exact cost estimates during the design stage • Improve energy efficiency and sustainability
Construction and Fabrication	• Synchronize design and construction planning • Discover design errors and omissions before construction (Clash Detection) • React quickly to design or site problems • Use design model as basis for fabricated components • Better Implementation and Lean Construction Techniques • Synchronise procurement with design and construction
Post – Construction	• Better manage and operate facilities • Integrate with facility operation and management systems

In the pre-construction stage, BIM facilitates the planning and economic feasibility of the project, thereby increasing the performance and quality of the building. For the design phase, the earlier capturing of the design through BIM helps to achieve: quick and more accurate design visualisations; automatic low-level modifications when variations are made to the design; easy and rapid creation of accurate and consistent 2D drawings at any phase of the design; earlier involvement and collaboration of various design disciplines; straightforward checks against the design plan; precise cost estimates during the design stage, and enhanced energy efficacy and sustainability. In the construction and manufacturing phase, BIM allows for the synchronisation of design and construction planning, detection of errors and interactions prior to construction, solving of problems in design or on-site, use of the design model as a basis for manufactured units or components, and facilitation of the application of Lean

Construction techniques. During the post-construction phase, it assists with facility management and operation, as well as the integration of design with facility management systems (Eastman et al., 2011).

Moreover, BIM profits all project stakeholders, and its key benefits include: green performance, predictable planning, reducing risks, reduced optional costs, increased quality and value, and reduced delivery costs in construction projects. It also promotes better communication in order to provide greater collaboration and coordination between project parties, as shown in Figure 13 (BSI, 2016).

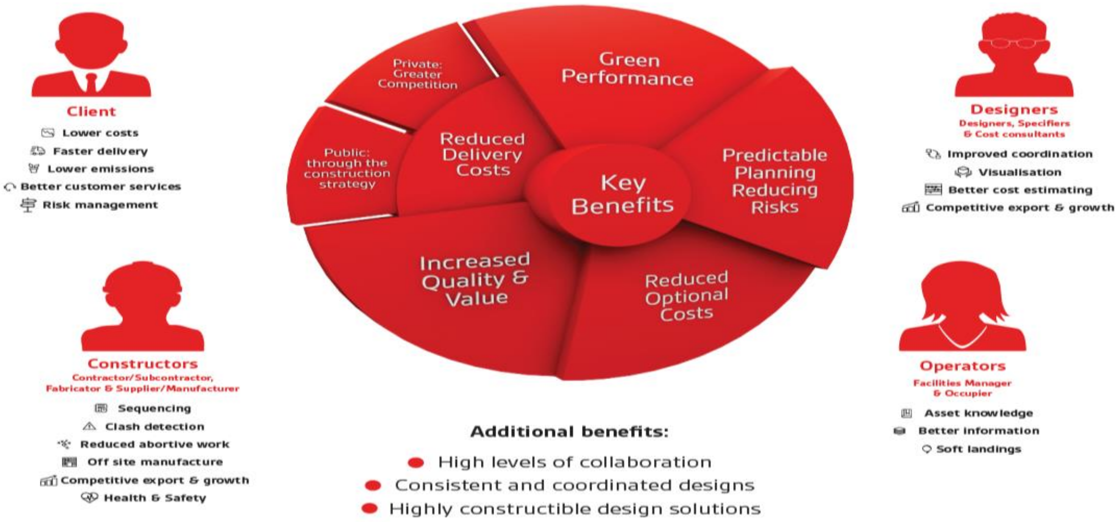


Figure 13: BIM implementation benefits for all parties

Figure 14: BIM benefits

In summary, Building Information Modelling (BIM) technology improves the construction industry by providing better quality data, a collaborative design environment, transparency, virtual modelling and virtualisation, prefabrication, a coordinated approach, mitigation to changed orders and data loss (see Figure 14). According to Azhar (2011), the average return on BIM investment for the projects under study was 634%, which clearly shows its potential economic benefits.

2.8.3 Challenges of BIM adoption:

The application of BIM inevitably changes the way in which current construction practice works. Its successful implementation necessitates full collaboration and integration among project stakeholders (Fred, 2016). Gu and London (2010) mentioned that, by adopting BIM in companies with no experience of BIM, there must be structural changes and the creation of new functions, such as a BIM Manager.

On the other hand, this huge change comes at a price, meaning there are many challenges and threats associated with BIM implementation. According to the survey conducted by the National Building Specification (NBS), there are five significant challenges to BIM implementation within the construction industry. These barriers are: a lack of client demand, fewer benefits for small projects, high cost and a lack of BIM specialists (Lymath, 2014). In GCC countries, a study explored the challenges of implementing BIM in construction projects, and the results revealed that the main risks are associated with organisational, technical, governmental, legal, and environmental challenges (Umar, 2021). For example, the lack of written procedures, the lack of knowledge and awareness, and the need to re-engineer many construction projects for a successful transition towards BIM are the main obstacles to implementing BIM in Saudi Arabia (Al-Yami & Sanni-Anibire, 2019; Aljobaly & Banawi, 2019).

Moreover, several studies have investigated the challenges to implementing BIM in the construction industry (Aibinu & Venkatesh, 2013; Alreshidi, Mourshed, & Rezgui, 2014; Arayici et al., 2011; Azhar, 2011; Bernstein & Pittman, 2004; Björk & Laakso, 2010; Criminale & Langar, 2017; Demian & Walters, 2014; Eissa Alreshidi, Mourshed, & Rezgui, 2017; Ganah & John, 2014; Isikdag & Zlatanova, 2009; Smith Dana & Tardif, 2009; Thompson & Miner, 2006; Udom, 2012), as shown in Table 16. These challenges have been classified into six categories: social organisational, financial, technical, contractual, legal, and process. For instance, social organisational challenges include: resistance to change, a lack of confidence and understanding of new technologies, a lack of knowledge and training in BIM, and a shortage of BIM experts. It has been found that BIM implementation costs; moreover, the cost of BIM training plus limited project budgets are the main financial risks behind its adoption. Furthermore, it has been mentioned that the maturity of BIM-based technologies, massive data input/output, massive data and limited data storage, interoperability issues, and a lack of mechanisms for the sharing, notification, and tracking of data are the main technical issues associated with BIM adoption. In contrast, the lack of ownership of BIM data, a lack of BIM contractual document standards, and risk allocation were cited as contractual and legal BIM challenges to the industry. Finally, the lack of national BIM standards, unclear reliability roles, and the complexity of BIM were categorised as process-related challenges when implementing BIM in the construction industry.

Table 16: BIM Challenges from the Literature

Categories	BIM challenges	References
Social-organisational	• Resistance to change • Lack of trust in and apprehension towards new technology • Lack of BIM understanding • Variations in practitioner's skills • Lack of BIM training • Lack of motivation • Client's awareness • Adoption of traditional practices and standards • Avoiding/hiding potential risks and liability for mistakes • Appropriate/efficiently trained staff • Time needed for hiring/training people to use BIM • learning curve, and lack of senior support	(Aibinu & Venkatesh, 2013; E Alreshidi, Mourshed, & Rezgui, 2014; Eissa Alreshidi et al., 2017; Arayici et al., 2011; Azhar, 2011; Bernstein & Pittman, 2004; Björk & Laakso, 2010; Criminale & Langar, 2017; Demian & Walters, 2014; Ganah & John, 2014; Isikdag & Zlatanova, 2009; Smith Dana & Tardif, 2009; Thompson & Miner, 2006; Udom, 2012)
Financial	• BIM adoption cost • Personal Indemnity Insurance (PII) is not covered • BIM training cost • Limited budget • Expensive human-based services costs	
Technical	• Maturity of BIM-based technologies • Interoperability issues • Issues with existing BIM modelling and collaboration tools • Massive data inputs/outputs • Massive data and limited data storage • Limited accessibility and access rights • Lack of sharing mechanisms • Lack of data tracking, checking and versioning control mechanisms • Difficulties coordinating large BIM models • Lack of notification mechanisms	
Contractual	• Contractors benefits from confusion • BIM contracts are not yet mature • Lack of BIM-related aspects in current contracts • Contracts need to accommodate changes in BIM collaborative environment • No standard for Contractual BIM document	
Legal	• BIM models ownership: intellectual property and copyright concerns • Liability for wrong or incomplete data • Lack of legal considerations in existing BIM contracts • Lack of legal framework for adopting collaborative BIM • PII does not cover legal aspects of collaborative work • Copyright protection for ownership of data • Determining who owns data/ components used • Risk allocation issues • Privacy threats	
Process	• Lack of national Standards • No official standard or process to evaluate the use of BIM • Complexity of BIM • Requires more time for high detail model for stakeholders • Customers do not know how to use BIM models/ do not implement • Compatibility issues between software • Who is responsible for maintaining and updating model? • Difficult to determine when and who made what error • Who is responsible for/manages data entry? • Process problems	

2.8.4 The UK Government Strategy for Implementing BIM

2.8.4.1 BIM Maturity Levels

The UK government has adopted a unique strategy that describes the qualifications of the designers and the design team by assessing the BIM process they implement against the diagram that outlines four BIM process maturity levels (Sacks, Gurevich, & Shrestha, 2016).

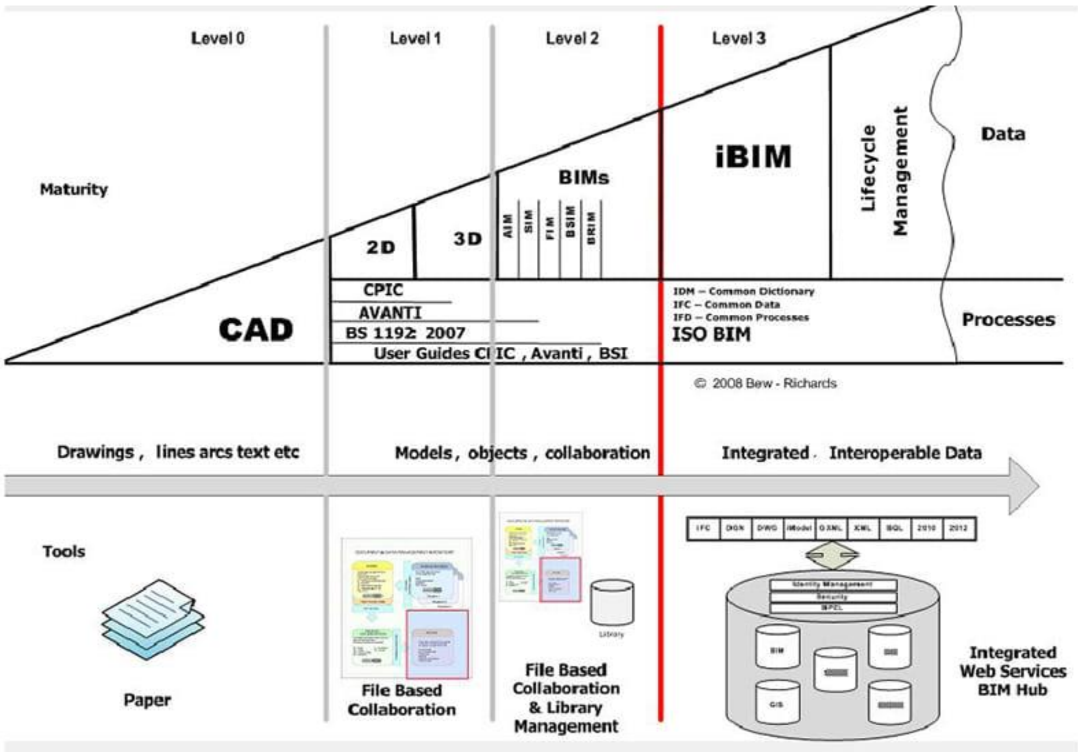


Figure 15: BIM maturity levels 0-3 (B. BSI, 2013)

As shown in Figure 15, the four levels are as follows (McPartland, 2014; Sacks et al., 2016):

Level 0

This is the simplest stage, and denotes no collaboration (unmanaged CAD). It is essentially the use of Computer Aided Design (AutoCAD) to create drawings and drawn elements using IT software (project information). Information is produced and distributed via papers and printouts, digitally via PDF, or a combination of both. It is the first step forward from generating information manually. Conversely, Levels 1 to 3 deal with varying degrees of modelling, collaboration and ultimately the exchange of fully integrated, interoperable information.

Level 1

This is called "Lonely BIM"; it includes several basic 3D elements and is the beginning of BIM modelling. It is managed CAD in a 2D or 3D format with a collaborative tool that provides a common data environment (CDE) with a unified process to data structure and format. There is no integration between finance and cost management packages, each of which operates independently in a separate program to produce commercial data. This typically comprises a mixture of 3D CAD for concept work, and 2D for the drafting of statutory approval documentation and production information. At Level 1, the progression from CAD to the creation of 2D data sets is followed by non-unified 3D models.

Level 2

Level 2 BIM is differentiated by collaborative implementation and needs a process of information exchange that is specific to a project and synchronised between different systems and project teams. A managed three-dimensional environment is held in a separate BIM tool with information attached. Commercial data is managed by business project management and planning software and combined in special interfaces or bespoke middleware. Level 2 sees the progression to Building Information Models and the grouping of those models between various parties in the project. The federation is within a single shared online area recognised as a Common Data Environment (CDE). In general, Level 2 is defined as "file-based collaboration and library management".

Level 3

Level 3 is considered to be the future of BIM and referred to as iBIM according to Fred (2016). Level 3 enables the interrelated digital design of various components which form a built environment, and reinforce the increased delivery of smart cities, services and grids (Mason & Knott, 2016; Ward, 2016). It visualises an integrated project information model, held and entirely developed in a common data environment by all project parties. This model can then be delivered to the owner for use in facility management as an "Asset Information Model".

Furthermore, BIM offers possible additional dimensions including scheduling, sustainability and facility management (Eastman et al., 2011). The dimensional development relate to 4D, 5D, and 6D BIM with additional information that can be placed in models and smart objects (O'Keeffe, 2013), as illustrated in Figure 15.

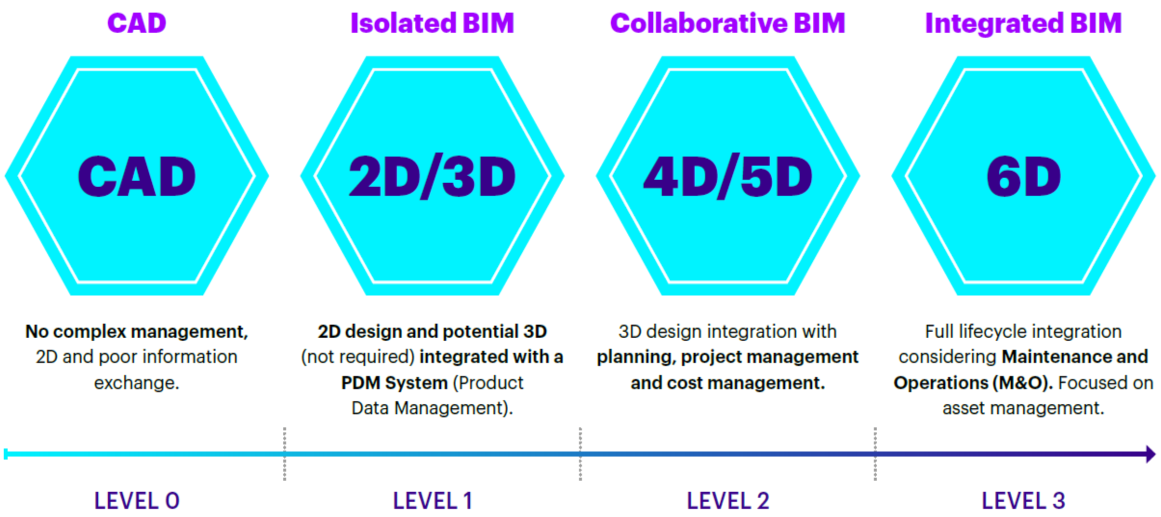


Figure 16: BIM maturity levels with BIM dimensions

These dimensions are categorised as follows (Lee et al., 2005):

- 4D BIM involves programming and scheduling information (Sulankivi, Kähkönen, Mäkelä, & Kiviniemi, 2010).
- 5D BIM involves quantity schedules and costing information (Smith, 2014).
- 6D BIM involves facility and asset management (O'Keeffe, 2013).

2.8.5 BIM in the Middle East

The researcher conducted a systematic review of literature on Building Information Modelling in the Middle East, in particular GCC, to understand the status of its implementation in this region. Table 17 presents 33 studies on Building Information Modelling found in this region.

Table 17: BIM studies in the Middle East region.

No.	Reference	Country	Research Approach	Data collection method/ approach
1	(Al Mohannadi, Arif, Aziz, & Richardson, 2013)	Qatar	Quantitative	Questionnaire survey
2	(AHMED, EMAM, & FARRELL, 2014)	Qatar	Quantitative	Survey
3	(Hamadaa, Harona, Zakiriaa, & Humadab, 2014)	Iraq	Quantitative	Quastionnaire
4	(Dawood & Vukovic, 2015)	Qatar	Qualitative	Interviews
5	(Hafeez, Chahrour, Vukovic, Dawood, & Kassem, 2015)	Qatar	Qualitative	Interviews
6	(Vukovic, Hafeez, Chahrour, Kassem, & Dawood, 2015)	Qatar	Qualitative	Interviews
7	(Abdalla, 2016)	UAE	Quantitative	Survey
8	(Aladag, Demirdögen, & Isık, 2016)	Turkey	Qualitative	Focus group discussions
9	(Balgheeth, 2016)	Saudi Arabia	Mixed Methods	Survey and interviews
10	(Gerges, Ahiakwo, Jaeger, & Asaad, 2016)	Kuwait	Qualitative	Structured interviews based on questionnaire
11	(Hafeez et al., 2016)	Qatar	Quantitative	Semi-structured interviews then Questionnaire "Qualitative survey-based research approach"
12	(Kassem et al., 2016)	Qatar	Qualitative	Interviews "Survey-based approach"
13	(Mehran, 2016)	UAE	Quantitative	Questionnaire survey
14	(Nawari & Alsaffar, 2016)	Kuwait	Quantitative	Questionnaire survey
15	(Nawari O Nawari & Alsaffar, 2017)	Kuwait	Qualitative	Case study
16	(Abdulfattah, Khalafallah, & Kartam, 2017)	Kuwait	Quantitative	Questionnaire survey
17	(AL-Btoush & Haron, 2017)	Jordan	Mixed Methods	Questionnaire & Semi-structured interviews
18	(Alenazi & Adamu, 2017)	Saudi Arabia	Qualitative	Case study
19	(Barakeh & Almarri, 2017)	UAE	Quantitative	Questionnaire survey
20	(Gerges et al., 2017)	Middle East	Quantitative	Questionnaire
21	(Hatem, Abd, & Abbas, 2018)	Iraq	Quantitative	Quantitative approach "Questionnaire"
22	(Ibrahim & Komali, 2018)	Saudi Arabia	Quantitative	Quantitative approach "Survey"
23	(Almuntaser, Sanni-Anibire, & Hassanain, 2018)	Saudi Arabia	Qualitative	Qualitative case study approach
24	(Hasanain & Nawari, 2019)	Saudi Arabia	Mixed Methods	Semi-structured interviews and Online survey
25	(Aljobaly & Banawi, 2019)	Saudi Arabia	Quantitative	Questionnaire
26	(Al-Yami & Sanni-Anibire, 2019)	Saudi Arabia	Quantitative	Questionnaire Survey
27	(Elhendawi, Smith, & Elbeltagi, 2019)	Saudi Arabia	Mixed Methods	Questionnaire and Structured interviews
28	(Elhendawi, Omar, Elbeltagi, & Smith, 2019)	Saudi Arabia	Quantitative	Questionnaire
29	(Abazid, Gökçekuş, & Çelik, 2019)	Saudi Arabia	Quantitative	Questionnaire
30	(Al-Adwani & Fleming, 2019)	Kuwait	Quantitative	Questionnaire
31	(Ahmed & Asif, 2020)	Saudi Arabia	Qualitative	Case study
32	(Nemati et al., 2020)	Iran	Quantitative	Questionnaire
33	(Alattas, Kalogianni, Alzahrani, Zlatanova, & van Oosterom, 2021)	Saudi Arabia	Qualitative	Case study

Baldwin (2013) described the Building Information Modelling situation in the Middle East construction industry as follows:

1. BIM opportunities are significant, because many clients are demanding its adoption by the main contractor.
2. Locally, there is a significant lack of knowledge of BIM; therefore, they seek the expertise of international companies from their offices abroad.
3. BIM standards are not recognised, and there is no guidance or regulation; at best, they mention a set of foreign national criteria or procedural papers.
4. Confusion in the absence of methodologies and terminologies for BIM operations.
5. The development of Building Information Modelling (BIM) specifications is often inappropriate. Products without strategy, procedure or standards.
6. OpenBIM is barely on the agenda.

On the positive side, Dubai municipality decided to mandate the implementation of Building Information Modelling (BIM) for architectural and MEP works from January 2014 for all the following (Abdalla, 2016; Austyn, 2014; Mehran, 2016):

1. Buildings of 40 storeys or more.
2. Facilities or buildings that are 300,000 square feet or larger.
3. Hospitals, academies and other specialised buildings.
4. Buildings that are delivered by/through an international party.

However, BIM has not yet been mandated to all United Arab Emirates projects, while the Abu Dhabi municipality has planned to mandate it in 2019, and Ajman will follow in 2020 (Aguinaldo, 2019; Pradeep, 2020). According to Mehran (2016), there are three main challenges to implementing Building Information Modelling on all UAE construction projects, which are: the absence of BIM standards, a lack of awareness of BIM, and resistance to change. AL-Btoush and Haron (2017) believed that the lack of understanding and deficiency of general regulations on implementation are the main obstacles its implementation in Jordanian construction projects. Accordingly, Building Information Modelling could be successfully applied if such barriers and challenges are recognised, which is a fundamental necessity for the transition of BIM into the Jordanian construction industry (AL-Btoush & Haron, 2017).

2.8.6 BIM in Kuwait

Building Information Modelling (BIM) has been incorrectly introduced in Kuwait. It was introduced as software that utilises 3D in the design. BIM tools were primarily announced to students during the 2013-2014 academic year by the Department of Architecture at Kuwait University. According to Nawari and Alsaffar (2016), BIM was initially implemented in the Structural Analysis II course as a replacement for other 3D software programs, such as 3ds Max®.

Conversely, a lack of BIM implementation amongst mega-scale public construction projects in Kuwait (Al-Adwani & Fleming, 2019; Gerges et al., 2016). Gerges et al. (2016), Abdulfattah et al. (2017), and Al-Adwani & Fleming (2019) all agreed that a lack of BIM knowledge, lack of BIM training, lack of BIM experts, and misunderstanding of the BIM concept are the most significant barriers to its adoption. Additionally, a study revealed that engineers in the Kuwaiti construction industry were highly aware of these barriers (Abdulfattah et al., 2017).

On the other hand, there are many benefits to BIM adoption in the construction industry in Kuwait, which are: better communication among projects parties, improved visualisation, better design quality and conflict detection, and reduced errors and risks (Abdulfattah et al., 2017; Al-

Adwani & Fleming, 2019; Gerges et al., 2016). Table 18 represents all BIM implementation benefits and challenges experienced in the Kuwaiti construction industry.

Table 18: The benefits and challenges and of BIM implementation found in the Kuwaiti construction industry

BIM benefits/ advantages	BIM challenges/ barriers	Reference
• Better communication across stakeholders • Time saving • Clash detection • Better shop drawings • Reduce risk • Improve construction process • Increased production • Reduced project costs • Less defective work on site • Improved site layouts • Improved construction and procurement program • Improved on-site health and safety	• Lack of knowledge about BIM • Resistance to change • Lack of client demand • Time required to train new users • Cost of training new users • Cost of investing in software and equipment • Lack of BIM users • Misuse of BIM	(Gerges, Ahiakwo, Jaeger, & Asaad, 2016)
• Improved conflict detection • Better visualisation • Easier quantity take-off measures	• Lack of BIM training • Lack of skilled personnel • The concept of BIM is not well understood (misunderstanding of BIM concepts) • Time to setup BIM technology requirements • Time required to produce the models • People refusal to learn new software	(Abdulfattah, Khalafallah, & Kartam, 2017)
• Accurate construction sequencing • Improved design quality • Reduced errors and avoiding risks	• Lack of skilled personnel • Lack of knowledge about BIM	(Al-Adwani & Fleming, 2019)

Abdulfattah et al. (2017) recommended supporting BIM implementation by, for example: offering BIM courses at engineering schools, providing in-house training programs, and mandating BIM in construction contracts. It is important to consider these challenges before designing a development strategy to avoid any complications during implementation. Al-

Adwani and Fleming (2019) suggested that BIM accreditation should be driven by the government to ensure proper implementation. Therefore, the author will produce a framework or process protocol for the government (public organisations) to monitor and manage these threats as well as facilitate the proper implementation of BIM technology, thus optimizing the performance of the industry.

2.9 Lean and BIM Synergies:

Building Information Modelling (BIM) has exploited the use of new technologies and software for the construction industry, thereby facilitating the achievement of Lean Principles. A study was conducted by Rischmoller, Alarcón, and Koskela (2006) to assess the impact of Computer Advanced Visualization Tools (CAVTs), which utilized a set of Lean principles as a suppositional framework on construction projects with emphasis on generating value during the design phase. This study revealed that the application of CAVT results in waste minimization, improved flow, and better value for the client, demonstrating a strong interaction between LC principles and CAVT. Sacks, Koskela, et al. (2010) mentioned that, as CAVT and virtual design and construction (VDC) share basic principles and technologies with BIM, these concepts could be known as BIM or BIM features. In another attempt to integrate Lean Construction processes with BIM, Khanzode, Fischer, Reed, and Ballard (2006) delivered a conceptual framework to connect Virtual Design and Construction (VDC) with the Lean Project Delivery Process (LPDS). In their study, the results confirmed that the use of VDC improves the Lean project delivery process when utilized at the right stages. Sacks (2014) believed that Building Information Modelling could make construction leaner, even when Lean was not an explicit intent. The adoption of BIM and its associated technologies would reinforce and facilitate the achievement of Lean principles, such as enabling a "pull flow" mechanism by providing a visualization that reduces variability within the building process (Sacks, Koskela, et al., 2010). Also, to implement BIM, Lean needs to be implemented first, as LC focuses on the process and flow in the project and facilitates the BIM implementation plan. For instance, Fred (2016) explained how BIM helped to achieve Lean principles, which is illustrated in Table 19.

Table 19: BIM to achieve Lean principles

Lean Construction	Intersection with BIM
Elimination of wastages (time, materials, effort)	• Structural clash tests • Design alternatives to select most suitable design • Performance simulations for the most efficient energy solution
Customer Value (achieve requirements)	• Visualization of solution that ensure clear understanding of the model • Analysis for best result • Understanding between client and supplier by use of 3D models and walk throughs
Reduce cycle times	• Automated generation of changes and material schedules and quantities • Provide accurate information to Prefabrication • Visualizing of work flow to check for process conflicts (team and tasks)
Work flow	Through making detail schedules of tasks and materials delivery times
Collaboration	Ability to work concurrently on same design solution by different teams

Sacks et al. (2010) believed there is synergy between Lean Construction and BIM, which should be sufficiently articulated to optimise the construction process performance rather than use either independently. A study conducted by Dave, Koskela, Kiviniemi, Tzortzopoulos, and Owen (2013) reveals that Lean Construction and BIM are not only interactive but the cooperative interaction extends into the whole project life cycle not just in the design phase. They also determined the three Lean principles that had the closest relationship with Building Information Modelling tasks as found in their study. First, minimising waste by obtaining the desired quality first time, namely through a well-designed product and decreased product variability (mitigating the demand for modification through the final design stages). Second, through greater certainty and enhanced production flow. Finally, through a decrease in the total construction period. Montague (2016) stated that BIM is a Lean method of producing, managing, and exchanging information. He claimed that by implementing BIM, the five principles of Lean could be achieved, and the eight wastes could be eliminated. Figure 17 illustrates a loop of the five principles of Lean surrounding the eight Lean wastes in construction.

Figure 17: Lean Principles and Waste (Montague, 2016)

Therefore, Lean principles could be achieved by utilising Building Information Modelling (BIM) as a process or tool, as represented in Figure 18.

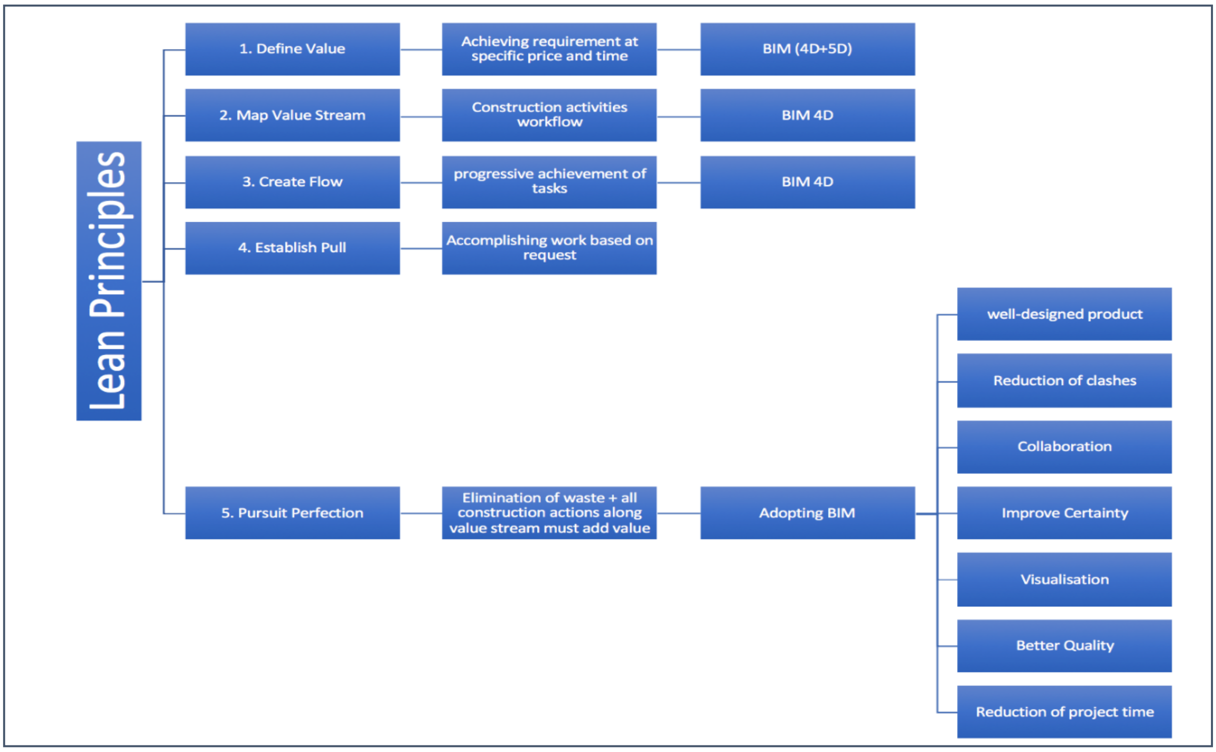


Figure 18: Lean Principles and BIM

Furthermore, a matrix of 56 intersections between Lean principles (see Table 20) and BIM functionalities (Table 21) was developed by Sacks et al. (2010) as shown in Tables 22 and 23.

Table 20: Lean Principles (Sacks et al., 2010)

Principal Area	Principle		Column key
Flow Process	Reduce variability	Get quality right the first time (reduce product variability)	A
		Focus on improving upstream flow variability (reduce production variability)	B
	Reduce cycle times	Reduce production cycle durations	C
		Reduce inventory	D
	Reduce batch sizes (strive for single piece flow)		E
	Increase flexibility	Reduce changeover times	F
		Use multiskilled teams	G
	Select an appropriate production control approach	Use pull systems	H
		Level the production	I
	Standardize		J
	Institute continuous improvement		K
	Use visual management	Visualize production methods	L
		Visualize production process	M
	Design the production system for flow and value	Simplify	N
		Use parallel processing	O
		Use only reliable technology	P
		Ensure the capability of the production system	Q
Value generation process	Ensure comprehensive requirement capture		R
	Focus on concept selection		S
	Ensure requirement flow down		T
	Verify and validate		U
Problem solving	Go and see for yourself		V
	Decide by consensus, consider all options		W
Developing partners	Cultivate an extended network of partners		X

Table 21: BIM Functionality (Sacks et al., 2010)

Stage	Functional Area and function		Row key
Design	Visualisation of form	Aesthetic and functional evaluation	1
	Repid generation of multiple design alternativs		2
	Reuse of model data for predictive analysis	Predictive analysis of performance	3
		Automated cost estimation	4
		Evaluation of conformance to program/client value	5
	Maintenance of information and design model integrity	Single information source	6
		Automated clash checking	7
	Automated generation of drawings and documents		8
Design and fabrication detailing	Collaboration in design and construction	Multiuser editing of a single discipline model	9
		Multiuser viewing of merged or separate multidiscipline models	10
Preconstruciton and construction	Rapid generation and evaluation of construction plan alternatives	Automated generation of construction tasks	11
		Construction process simulation	12
		4D visualization of construction schedules	13
	Online/electronic object-based communication	visualizations of process status	14
		Online communication of product and process information	15
		Computer-controlled fabrication	16
		Integration with project partner (supply chain) databases	17
		Provision of context for status data collection on site/off site	18

Table 22: Interaction Matrix of Lean Principles and BIM Functionalities (Sacks et al., 2010)

BIM functionality		Lean Principles																							
		Reduce variability		Reduce cycle times		Reduce batch sizes	Increase flexibility		Select an appropriate production control approach		Standardize	Institute continuous improvement	Use visual management		Design the production systems for flow and value				Ensure comprehensive requirements capture	Focus on Concept selection	Ensure requirements flow down	Verify and validate	Go and see for yourself	Decide by consensus consider all options	Cultivate an extended network of partners
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Visualisation of form	1	1,2													3				4		11	5	6	4	
Repid generation of multiple design alternativs	2	1		22									7	7		8									
Reuse of model data for predictive analysis	3	9	9	22			51												1	16		5			
	4		10	12												8				16		5			
	5	1,2	1	12															1	1	1	5			
Maintenance of information and design model integrity	6	11	11																		11				
	7	12	12	12													12								
Automated generation of drawings and documents	8	11		22	52	53											54	54							
Collaboration in design and construction	9			23						36						36									
	10	2,13		24				33											43		56	46		49	
Rapid generation and evaluation of construction plan alternatives	11	14		25	29		31								41										
	12		15	25	29					37					41					44		47			
	13	2	40	25	29						17		40	40		40						47		49	
Online/electronic object-based communication	14		29	26	30	30			34					34			42					47	48		
	15	18		26	30	30			34		38		38	34			42				45			49	
	16	19		27			32																		
	17		20	28					35								42								50
	18		21		30	30			34			39					42					47	48		

Table 23: Interaction Matrix: Explantation of Cell Contents (Sacks et al., 2010)

Index	Explanation	Evidence from practice and/ or research
1	Due to better appreciation of design at an early stage, and also due to the early functional evaluation of design against performance requirements (such as energy, acoustics, wind, thermal, etc.) the quality of the end product is higher and more consistent with design intent. This reduces variability commonly introduced by late client-initiated changes during the construction stage.	Eastman et al. 2008, p.390; Manning and Messner 2008
2	Building modelling imposes a rigor on designers in that flaws or incompletely detailed parts are easily observed or caught in clash checking or other automated checking. This improves design quality, preventing designers from “making do” (Koskela 2004a) and reducing rework in the field as a result of incomplete design.	Dehlin and Olofsson 2008; Eastman et al. 2008, p. 422
3	Building systems are becoming increasingly complex. Even trained professionals have difficulty generating accurate mental models with drawings alone. BIM simplifies the task of understanding designs, which helps construction planners deal with complex products.	Eastman et al. 2008, p.382
4	As all aspects of design are captured in a 3D model the client can easily understand; the requirements can be captured and communicated in a thorough way already during the concept development stage. This can also empower more project stakeholders to participate in design decision making.	Eastman et al. 2008, p.378; Manning and Messner 2008
5	Virtual prototyping and simulation due to the intelligence built in the model objects enable automated checking against design and building regulations, which in turn make verification and validation of the design more efficient.	Eastman et al. 2008, p. 390; Khanzode et al. 2008
6	With BIM, Gemba can be augmented because it is now possible to virtually visit the project and the worksite (Whyte 2002). With objects that contain intelligence and parametric information, problem solving is also more efficient.	Whyte 2002
7	BIM provides the ability to evaluate the impact of design changes on construction in a visual manner that is not possible with traditional 2D drawings. Rapid manipulation is a key enabler for repetition of this kind of analysis for multiple design alternatives (see also Item 40).	Eastman et al. 2008, p.378
8	It is now possible for multiskilled teams to work concurrently in order to generate various design alternatives at an early stage using integration platforms such as Navisworks, Solibri, etc., as exemplified in the Castro Valley project case study (Khemlani 2009). Also, at a later stage during manufacturing/construction; for any design change, changing the model will automatically update other relevant information such as cost estimating, project planning, production drawings, etc.	Eastman et al. 2008, p.329; Khemlani 2009
9	Testing the design against performance criteria ensures that the design is appropriate for the chosen function, reducing the variability and improving the performance of the end product.	Eastman et al. 2008, p.390
10	Automated quantity takeoff which is linked to the BIM model is more accurate as there are less chances of human error; hence, it improves flow by reducing variability. Also, changing the design at a later stage also changes the linked quantity files; this ensures that the quantities are always accurate.	Eastman et al. 2008, p. 425
11	In sets of 2D drawings and specifications, the same objects are represented in multiple places. As design progresses and changes are made, operators must maintain consistency between the multiple representations/information views. BIM removes this problem entirely by using a single representation of information from which all reports are derived automatically.	Eastman et al. 2008, p.422
12	Use of software capable of model integration (such as Solibri/Navisworks/Tekla) to merge models, identify clashes, and resolve them through iterative refinement of the different discipline specific model results in almost error free installation on site.	Eastman et al. 2008, p. 431
13	Multidisciplinary review of design and of fabrication detailing, including clash checking, enables early identification of design issues.	Eastman et al. 2008, p. 362; Khanzode et al. 2008
14	Automated task generation for planning helps avoid human errors such as omission of tasks or work stages.	Eastman et al. 2008, p. 409
15	Discrete event simulation can be used to test and improve production processes and to run virtual first-run studies which in construction are often impossible or impractical.	Eastman et al. 2008, p. 429
16	At the conceptual design stage, rapid turnaround to prepare cost estimates and other performance evaluations enables evaluation of multiple design options, including the use of multiobjective optimization procedures (such as genetic algorithms).	Eastman et al. 2008, p. 445
17	Animations of production or installation sequences can be prepared. These guide workers in how to perform work in specific contexts and are an excellent means for ensuring that standardized procedures are followed, particularly where turnover of workers from stage to stage is high, as is common in construction.	Eastman et al. 2008, p. 429
18	When up-to-date product information is available online, the opportunities for identifying conflicts and errors within short cycle times, when their impact is limited, are enhanced.	Eastman et al. 2008, p. 422

Table 23: (Continued)

Index	Explanation	Evidence from practice and/ or research
19	Direct transfer of fabrication instructions to numerically controlled machinery, such as automated steel or rebar fabrication, eliminates opportunities for human error in transcribing information.	Khanzode et al. 2008; Tekla 2009b
20	Direct delivery of information removes waiting time, thus improving flow.	Khemlani 2009
21	Provision of a model background and context for scanning bar codes or RFID tags and display of the process data on model backgrounds enable accurate reporting and rapid response to work flow problems.	Vela 2009
22	Quick turnaround of structural, thermal, and acoustic performance analyses; of cost estimation; and of evaluation of conformance to client program, all enable collaborative design, collapsing cycle times for building design, and detailing.	Eastman et al. 2008, p.386
23	Parallel processing on multiple workstations in a coordinated fashion with locking of elements edited on each machine collapses cycle times of otherwise serial design activities. Where design was previously (i.e., with CAD) performed in parallel on different parts, the time needed for integration and coordination of the different model views is removed.	Khemlani 2009
24	Model-based coordination between disciplines (including clash checking) is automated and so requires a fraction of the time needed for coordination using CAD overlays.	Eastman et al. 2008, p.422
25	All three functions serve to reduce cycle time during construction itself because they result in optimized operational schedules, with fewer conflicts.	
26	Where process status is visualized through a BIM model, such as in the KanBIM system, series of consecutive activities required to complete a building space can be performed one after the other with little delay between them. This shortens cycle time for any given space or assembly.	Sacks et al. 2010
27	Direct computer-controlled machinery fed directly from a model can help shorten cycle times by eliminating labor-intensive data entry and/or manual production, thus shortening cycle times. This does not guarantee shortened cycle times if the time gained is then wasted through batching or waiting.	Eastman et al. 2008, p. 333
28	Removal of data processing steps for ordering or renewing material deliveries, removal of time wasted before ordering, etc., improve cycle times.	Vela 2009
29	In this case the functionality can be said to increase inventory of design alternatives. This can be considered beneficial in terms of making broader selections, delaying selection of a single alternative until the last responsible moment.	Khemlani 2009
30	Online visualization and management of process can help implement production strategies designed to reduce work-in-process inventories and production batch sizes (number of spaces in process by a specific trade at any given time), as in the KanBIM approach.	Sacks et al. 2009
31	Automated generation of tasks for a given model scenario and project status drastically reduces the setup time needed for any new computation or evaluation of a construction schedule alternative from any point forward.	Eastman et al. 2008, p.345
32	For numerically controlled machinery, data entry represents setup time. Direct electronic communication of process instructions from a model essentially eliminates this setup time, making single piece runs viable.	Tekla 2009b
33	Design coordination between multiple design models using an integrated model viewer in a collaborative work environment, such as those described by Liston et al. (2001) and Khanzode et al. (2006), enables design teams to bring multidisciplinary knowledge and skills to bear in a parallel process.	Khanzode et al. 2006; Liston et al. 2001
34	Process visualization and online communication of process status are key elements in allowing production teams to prioritize their subsequent work locations in terms of their potential contribution to ensuring a continuous subsequent flow of work that completes spaces, thus implementing a pull flow. This is central to the KanBIM approach, which extends the last planner system.	Sacks et al. 2009
35	Where BIM systems are integrated with supply chain partner databases, they provide a powerful mechanism for communicating signals to pull production and delivery of materials and product design information. This also helps make the supply chain transparent.	Vela 2009
36	Multiple users working on the same model simultaneously enable sharing of the workload evenly between operators.	Not yet available
37	Discrete event simulation can reveal uneven work allocations and support assessment of work assignments to level production.	Li et al. 2009
38	Online access to production standards, product data, and company protocols helps institutionalize standard work practices by making them readily available and, within context, to work teams at the work face. This relies, however, on provision of practical means for workers to access online information.	Hewage and Ruwanpura 2009; Sacks et al. 2010; Sriprasert and Dawood 2003

Table 23: (Continued)

Index	Explanation	Evidence from practice and/ or research
39	Where BIM interfaces provide a context for real-time status reporting, measuring performance becomes accurate and feasible. Measurement of performance within a system where work is standardized and documented is central to process improvement.	Not yet available
40	BIM provides an ideal visualization environment for the project throughout the design and construction stage and enables simulation of production methods, temporary equipment, and processes. Modelling and animation of construction sequences in "4D" tools provide a unique opportunity to visualize construction processes for identifying resource conflicts in time and space and resolving constructability issues. This enables process optimization improving efficiency and safety and can help identify bottlenecks and improve flow.	Eastman et al. 2008, p. 429; Li et al. 2009
41	Detailed planning and generation of multiple fine-grained alternatives can be said to increase complexity rather than simplify management.	Not yet available
42	These applications cannot be considered mature technology.	Manning and Messner 2008
43	Where clients or end users are engaged in simultaneous reviews of different system design alternatives they can more easily identify conflicts between their requirements and the functionality the proposed systems will provide.	
44	Rapid generation of production plan alternatives can allow selection among them to be delayed (making the last responsible moment later than it would be otherwise). This can be considered to be a set-based approach to production system design and to production planning.	Kong and Li 2009
45	Online access helps to bring the most up-to-date design information to the work face (although it cannot guarantee that the design information reflects the user requirements).	Hewage and Ruwanpura 2009
46	Clash checking and solving other integration issues verify and validate product information.	Li et al. 2009
47	Visualization of proposed schedules and visualization of ongoing processes verify and validate process information.	Dehlin and Olofsson 2008
48	Where managers can "see" process status with near to real-time resolution, this may substitute for the need to see processes directly on site. However, it cannot substitute for seeing a process with one's own eyes.	Sacks et al. 2009
49	These functions can support and facilitate participatory decision making by providing more and better information to all involved and by expanding the range of options that can be considered. Of course, they cannot in and of themselves guarantee that senior management will adopt a consensus building approach.	Dehlin and Olofsson 2008
50	Integration of different companies' logistic and other information systems makes working relationships that extend beyond individual projects worthwhile and desirable.	Not yet available
51	Use and reuse of design models to set up analysis models (such as energy, acoustics, wind, thermal, etc.) reduce setup time and make it possible to run more varied and more detailed analyses.	Not yet available
52	Abuse of the ease with which drawings can be generated can lead to more versions of drawings and other information reports than are needed being prepared and printed, unnecessarily increasing drawing inventories.	Not yet available
53	Automated generation of drawings, especially shop drawings for fabrication (of steel or precast, for example), partly enables review and production to be performed in smaller batches because the information can be provided on demand. Unlike Item 52 above, this and the following item are positive interactions of automated drawing production.	Not yet available
54	Automated drawing generation improves engineering capacity when compared with 2D drafting, and it is a more reliable technology because it produces properly coordinated drawing sets.	Sacks and Barak 2008; Tekla 2009a
55	Animations of production or installation sequences can be prepared. These guide workers in how to perform work in specific contexts and are an excellent means for ensuring that standardized procedures are followed, particularly where turnover of workers from stage to stage is high, as is common in construction.	Dehlin and Olofsson 2008
56	Sharing models among all participants of a project team enhances communication at the design phase even without producing drawings, helping ensure that the requirements are understood and transmitted throughout the team and on to builders and suppliers.	Not yet available

According to Sacks et al. (2010), there are three interactions between Lean and BIM at the design stage. First, greater collaboration and communication between the project team from different disciplines allows for modification and change of design options across various software packages, such as Autodesk, Navisworks and Solibri. Together with the ability to make changes, this could straightforwardly be applied to all disciplines within a BIM model, thus highlighting the functionality of BIM in the rapid production of design options, while demonstrating how the production system design and flow of value is made via Lean (Eastman et al., 2011). Secondly, different employees can operate simultaneously with the same model which indicates that the job is shared according to the area of multiple teams. As a result, it provides high-quality work because each specialised team (structural, architecture, MEP, etc.) will conduct the design with reference to each other thus ensuring that the two drawings align. Finally, Sacks, Dave, Koskela, and Owen (2009) pointed out BIM's visualisation of the project and projection flow, which simulates the task sequences at the building site to determine possible source conflicts and clashes in day-to-day construction. This supports the goal of Lean Construction to generate a flow of tasks, while BIM resources can be assigned in a planned manner for continuous flow without the need to use or exceed resources.

Sacks et al. (2009) indicated that this matrix could help organisations understand the practical problems facing the implementation of BIM and/or Lean in their projects. They also emphasised the importance of considering BIM implementation for organisations or projects that adopt Lean principles to enhance Lean outcomes.

2.9.1 The Benefits of Integrating Lean and BIM

The rapid expansion of Lean Construction and Building Information Modelling has dramatically influenced the extremely divided construction industry. Several organisations are supporting researchers to conduct studies on these two applied research areas to improve their practices, as Lean Construction focuses on producing value for the client by minimising waste using the minimal resources, while BIM uses information technology to increase collaboration between project parties during the whole life cycle of the project (Bhatla & Leite, 2012). Therefore, the integration of these approaches can benefit the construction industry through the support and a good understanding of the philosophy of production in the construction industry (Sacks et al., 2010). BIM applications involve three main aspects, people, processes, and technology (Arayici et al., 2011). However, there is a lack of academic evidence of the BIM theory to reinforce and assure its adoption. In contrast, the basis of Lean Construction is derived from manufacturing concepts, and it is concentrated on people and process (Howell & Koskela, 2000). Mollasalehi et al. (2016) believed that Lean Construction, with its theoretical foundation, and BIM applications, with its technological potential, can be complementary to improving project efficiency. This combination of Lean Construction and BIM is illustrated in Figure 19.

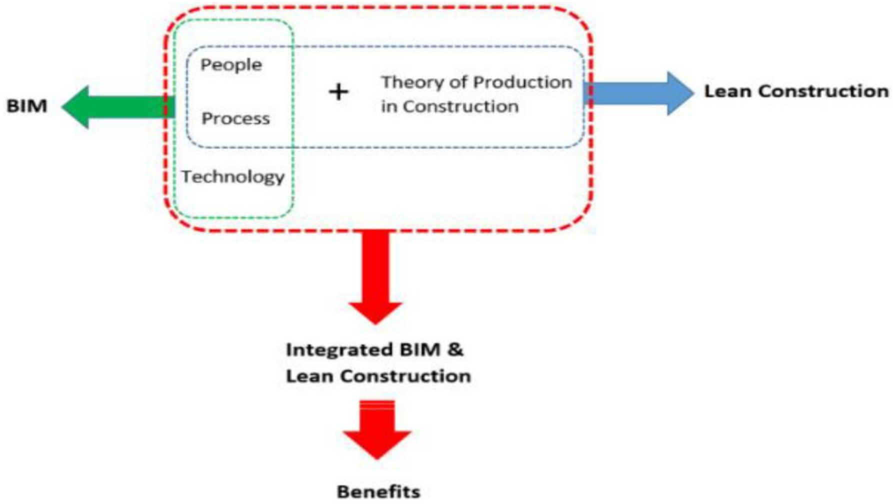


Figure 19: Integration of Lean Construction and BIM (Mollasalehi et al., 2016)

A study conducted in Sweden revealed that Lean and BIM integration during the design phase of projects have many advantages including: transparency, easy cooperation, the involvement of project information between all stakeholders, and a reduction in project waste (Moud, 2013).

In order to achieve the optimum performance of the construction industry, it is crucial to adopt new technologies because change is the only constant in this world. For instance, using BIM and offsite construction under Lean Principles will create an integrated system that could change the industry entirely.

According to Sacks et al. (2010), Lean Construction, which is the theoretical way to manage the construction projects, and Building Information Modelling, which is the transformative information technology, are the most significant advances affecting the AEC industry. Therefore, instead of using one Lean Construction tool, Building Information Modelling could be adopted to help achieve Lean thinking. BIM is an advanced system of coordination between all project's parties. Sacks et al. (2010) claimed a strong connection between Lean and Building Information Modelling. Thus, the management of the project and information could be significantly improved after implementing BIM as a software system within Lean Construction principles.

For example, BIM facilitates the implementation of off-site construction or prefabricated building systems due to its ability to provide better visualisation and project workflow, which would positively impact the construction industry in the Middle East, as the climate in this region is extremely hot, especially in Kuwait. According to AL-Qabas Newspaper, Kuwait recorded the highest temperatures in the world reaching 52.2 degrees Celsius in the shadows and 63 degrees Celsius in direct sunlight (AlShurafa, 2019). Since on-site construction will mean harsh labour conditions in summer, which is the longest season of the year, prefabricated building systems (such as concrete) could offer a solution for better performance in the industry. It will provide a more comfortable and safer environment for workers, thus, adding more value and greater quality to the project (Bataglin, Viana, Formoso, & Bulhoes, 2018). However, the implementation of these systems involves an intense information exchange between the building site and manufacturer to ensure agreement between the production of parts, logistic process, and location assembly. Building Information Modelling (BIM) can enable the sharing of information to reinforce decision-making in this kind of environment, along with the application of Lean production concepts and principles (Bataglin et al., 2018).

A study was carried out in Finland to investigate the impact of BIM and Lean Construction on design management practices in projects using BIM. It was found that several risks arose in these projects, namely: the undefined sharing of responsibilities between designers in teams, insufficient BIM instructions, a lack of BIM experience and knowledge amongst design managers, and a lack of communication between the design team (Tauriainen, Marttinen, Dave, & Koskela, 2016). Tauriainen et al. (2016) stated that using Lean management tools, such as Big Room, Knotworking, and the Last Planner System, and the appropriate implementation of BIM could offer a solution to the aforementioned problems. However, they argued that it is not necessary to apply Lean tools to solve these problems, and instead, awareness of these problems, the use of comprehensive guidance and the assignment of a competent project manager and designers in the team can have a tremendous impact on the occurrence of these complications. Moreover, Tauriainen et al. (2016) presented the following guidelines to enhance design management practices in BIM projects:

- Design project managers should be experienced in BIM, and if not, a BIM consultancy should be commissioned. The differences between the 2D CAD and BIM projects should be recognised and understood.
- A lead BIM coordinator should be assigned at the beginning of a project and should be responsible for modelling, clash detection, and model integration.
- A BIM design coordinator should be appointed as the project manager’s support.
- Instructions and working methods related to BIM should be defined at the

beginning of the project. It is recommended that common national BIM requirements and Level of Details (LODs) are adopted as much as possible.

- The lead structural engineer or modelling coordinator should produce comprehensive modelling instructions for all circulation before the provision phase.
- The entire circulation should be made strictly in accordance with the schedule in order to prevent several iterative circuits.
- Maintain a pre-scheduled design and modelling meetings to control activities, BIM contents and communications between design teams. Arranging Knotworking meetings can help to solve complicated design problems.
- Discussion meetings should be organised between design teams and project feedback should be collected upon the delivery of projects.

It can be concluded that, with proper implementation of BIM technology and by using a well-defined process that includes stakeholders, responsibilities, stages and outputs, the Lean concept can be realised. To simplify and avoid any complication, it is unnecessary to use any of the Lean tools, as the researcher believes that BIM can be a sufficient approach to obtain a Leaner process if it is applied in a structured manner.

2.10 The Benefits of Integrating Lean Principles and a BIM Approach for Sustainability

2.10.1 Introduction

Recently, construction projects have become more complex, meaning there is a strong need for proper management practices (Maylor, Vidgen, & Carver, 2008). Since the construction sector is confronting serious difficulty with regard to productivity, green management and sustainability (Commission, 2012), it requires experts to not only manage the project cost and duration but also the quality and environmental considerations (Cesare, & Isatto, 2002; Formoso, Soibelman, De Howell & Ballard, 1998).

Wong et al. (2013) and Allu & Ebohon (2015) agreed that the AEC industry is a significant contributor to carbon emissions and the discipline is relatively loose in terms of controlling and managing carbon emissions that lead to climate change. Despite the fact that the concept of "sustainability" and "green buildings" has been widely used in this industry for many years, the statistics show that the construction industry is still the main consumer of energy (Wong & Zhou, 2015). For instance, in the Indian construction industry, it was reported for approximately responsible for 24% of the total direct and indirect emissions of CO_2, and it was the greatest consumer of natural resources and energy in comparison to other industries (Parikh, Panda, Ganesh-Kumar, & Singh, 2009). Moreover, around 10% of all end-use energy in the world occurs during the fabrication of building materials (Rode, Burdett, & Soares Gonçalves, 2011). In the operation phase of a building, the consumption of energy generates 30-40% of the gross global greenhouse gas (GHG) emissions, and construction and demolition (C&D) waste in developed countries accounts for approximately 40% of all solid waste (Koeppel & Ürge-Vorsatz, 2007; Rode et al., 2011). Therefore, this section will focus on the benefits of adopting Lean Construction principles and utilizing BIM in order to achieve sustainability in terms of green buildings and sustainable process.

2.10.2 Sustainability

The construction industry has a negative effect on the earth. It is responsible for carbon dioxide emissions, along with the use of all-natural resources and energy reserves. For example, many resources, such as land cover, forests, water, and energy, have been exhausted to make room for buildings. Recently, the word sustainability has become widely recognized. Shaikh et al. (2017) said that some people see it as a twisted word, and it is commonly used interchangeably with philosophies such as environmentalism or being ‘green’. Additionally, it is commonly known as sustainable development, which Shaikh et al. (2017, p. 1785) defined as “*meeting the needs of the present generation without compromising the ability of future generations to meet their own needs*”. Therefore, sustainability concerns the linkage between humans and the earth; we all share this planet, meaning that our humanities depend on healthy living and physical systems (Shaikh et al., 2017).

2.10.3 Sustainable Construction and Green Buildings

Sustainable construction seeks to implement an effectively performing green building delivery system that aims to ensure that the project is designed, built and delivered in a cost-effective manner (Ahuja et al., 2014). Therefore, several voluntary building rating systems, such as LEED and BREEAM, have been involved to increase awareness and promote green design (Ahuja et al., 2014). Consequently, the construction industry should proceed towards sustainable development by adopting new technologies that are less resource intensive and less harmful to the environment (Spence & Mulligan, 1995).

Green building, which is also recognised as green construction or sustainable building, is the practice of constructing and using better and more resource-efficient simulations of construction, renovation, operation, maintenance, and demolition (AlSanad, 2015). AlSanad (2015) stated that this process emboldens the creation of a healthful and more ecological environment and is conducted with a high level of collaboration and coordination between all project parties, such as the design team (consultants), contractors, sub-contractors, and clients.

However, this collaboration could be achieved using Building Information Modelling, which has the ability to facilitate a more integrated design and construction process as its analysis, simulation, and communications features appear on one large platform (Eastman et al., 2011). Since BIM provides an accurate geometrical representation of building elements in a Common Data Environment (CDE) (Innovation, 2007), it positively reflects on the sustainability or environmental aspect of a project and on Lean thinking, as shown in Figure 20.

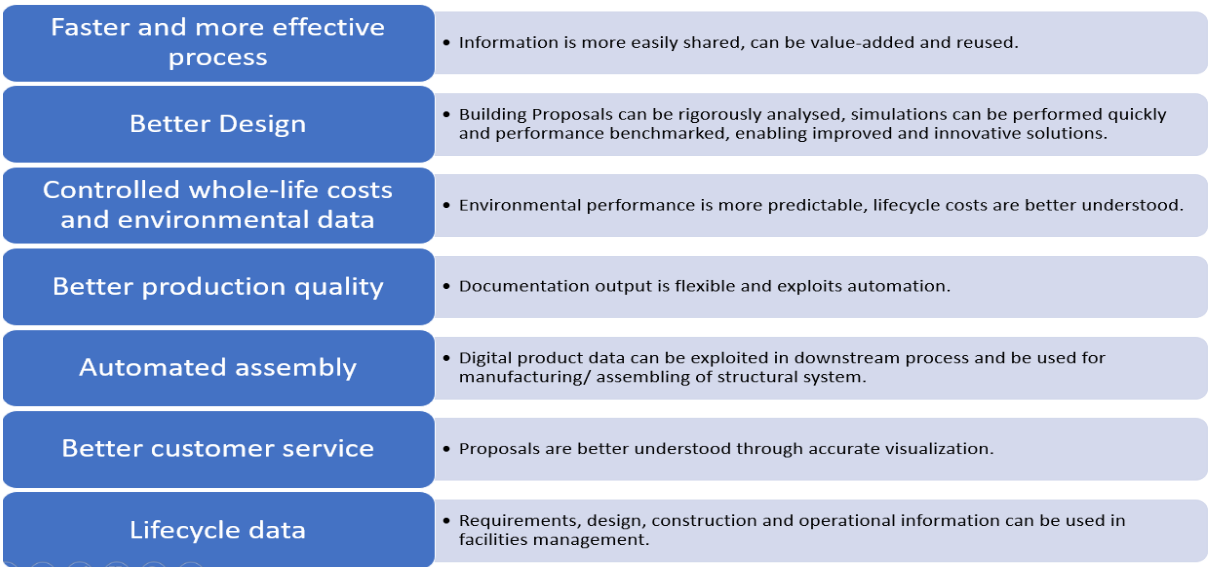


Figure 20: BIM Benefits on Sustainability and Lean thinking

Ahuja et al. (2017) emphasized the importance of energy efficiency and the usage of renewable energy, maintenance of resources, recycling, and waste minimization. They argued that the construction industry should be improved to become more efficient and sustainable by adopting Green and Lean principles to produce efficient and sustainable assets that are provided through a highly effective delivery process. Lean Construction has the potential to attain sustainability because it focuses on reducing wasted materials, movement, and effort, thus minimising environmental damage in terms of energy consumption and solid (material) waste.

Gerber, Becerik-Gerber, and Kunz (2010) pointed out that BIM can act as an enabler that facilitates Lean procedures through design to construction, operations and maintenance. The purpose of using Lean Construction is to reduce waste, improve resources and add value to the client during a continuous improvement process, while the intention of green construction is to reduce energy consumption and waste generation through effectively using resources (Ahuja et al., 2014). Figure 21 illustrates the green benefits of adopting Lean on construction projects highlighting three key aspects economic, social, and environment.

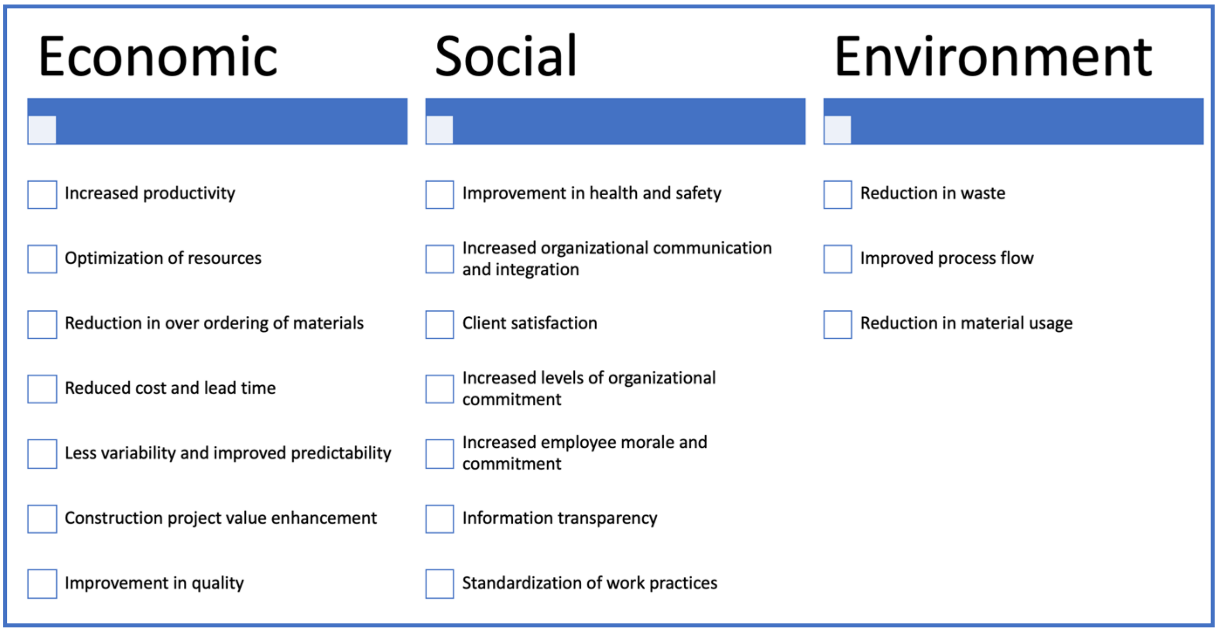


Figure 21: The Green Benefits of Adopting Lean on Construction Projects (Ahuja et al., 2017)

In terms of economic benefits, the implementation of Lean principles can increase productivity, improve resources, reduce excess material demand, reduce cost and lead time, reduce variance and improve predictability, enhance construction project value, and improve quality. Moreover, the social aspect of applying Lean will have the following effects: improving H&S, increasing organisational communication and integration, greater customer satisfaction, increasing levels of organisational commitment, increasing employee morale and commitment, information transparency, and standardising work practices. Finally, the environment benefits include: reduced waste, improved process flow, and reduced material usage (Ahuja et al., 2017).

2.10.4 BIM as an Enabler to Attain Lean and Sustainability/Green Benefits

Building Information Modelling has received considerable attention from both industry and academia (Eastman et al., 2011). The benefits of BIM include the technical development process and an advanced and integrated functioning platform that enhances productivity and sustainability for the whole project life cycle (Elmualim & Gilder, 2014). BIM data created during design and used throughout the entire project lifecycle allows for faster, more efficient, safer, less wasteful, more effective, less costly and more sustainable construction in operation, maintenance and decommissioning (Shaikh et al., 2017). Zuo and Zhao (2014) believed that with new information and communication technologies, especially BIM, has facilitated the development of green building. Building Information Modelling has changed the way of designing, engineering, building and managing construction projects through its diversity in software systems. For instance, BIM functions can facilitate sustainability by using energy analysis that helps reduce energy consumption. In addition, modelling and simulation in BIM leads to improved process productivity (Eastman, 2011).

According to Khan, Dewan, and Chowdhury (2016), three elements contribute to sustainability, namely, social, economic, and environmental. Social sustainability concerns the social well-being of people (Ahuja et al., 2017), dealing with the capability of humans to maintain a living in a way that meets their needs and those of later generations (Eastaway, 2012). Almahmoud and Doloi (2018) mentioned that social sustainability could be achieved in the construction industry by focusing on the satisfaction of its stakeholder requirements. However, BIM can enhance social sustainability in two ways. Firstly, by providing the best facility design for the comfort of a living community. BIM enables the visualization of the 3D model before the building is constructed, therefore clients can review it and share their opinion to enable the best decision making. Secondly, BIM is capable of transforming traditional practice, which is largely fragmented, into a highly collaborative environment that enhances the working relationship among the project team.

According to the National Institute of Building Science (NIBS-US), the project parties on a BIM platform must share their own views of the data with each other to create a credible foundation on which to make decisions and build a facility. Thereafter, the definition of economic sustainability is a little more difficult, as limited data is available to indicate where the green economy is developing (Gibbs & O'Neill, 2014). Ahuja et al. (2017) mentioned that this element is cost related, which fully assesses the ideal budget-use connections. Nevertheless, BIM has demonstrated that it improves the overall cost saving of the project lifecycle. For example, 6.92% of cost savings were accomplished by using a cost benefit analysis carried out in a BIM model (Lu et al., 2014). Additionally, the use of an energy simulation system in the BIM model to control the energy consumption analysis allows for more comprehensive data and an optimal design (Guo & Wei, 2016).

Finally, environmental sustainability focuses on eliminating the adverse environmental impacts of construction projects and processes to a large extent by reducing the amount of greenhouse gas emissions entering the atmosphere, thus enhancing living quality (Ahuja et al., 2017; Sassi, 2016; Shaikh et al., 2017). Bonenberg and Wei (2015) pointed out that BIM can provide an improved spatial design, especially with respect to the assessment of airflow and the overall ecosystem of the building. Furthermore, it can be used to improve energy simulation and assess the potential negative environmental effects in the context of Green Assessment (Al-Ghamdi & Bilec, 2015). For example, Hasanain and Nawari (2019) developed a new rating system for sustainability in Saudi Arabia, which is fully integrated with a BIM platform. This BIM framework has been designed to support multiple analysis functions and testing tools that can assist project team with sustainable integration initiatives in the construction industry (Hasanain & Nawari, 2019).

Sacks et al. (2010) and Mahalingam, Yadav, & Varaprasad (2015) agreed that BIM provides an efficient platform for applying Lean principles. Sacks et al (2010) investigated the positive connections between BIM and Lean, and the most important synergies recognised were the mitigation in variation through BIM implementation, which helps to cut the waste attributable to re-work. BIM provides to visualize the project at the design phase, allowing for the exploration of design alternatives. It also helps to identify clashes that eventually lead to the optimisation of design and construction. It concentrates on modelling and tracking schedules to support the reduction of cycle times.

In fact, BIM has a huge impact on the linkage between Lean and green philosophies, and acts as a catalyst (Ahuja et al., 2014). Through collaboration, integrated analysis and gathering information from specialists around the world, BIM has the potential to evaluate green buildings on different levels, and to access the information required to make sustainable choices. Basically, BIM has the ability to deliver a project faster, and in a more innovative and profitable way (Ahuja et al., 2014; Shaikh et al., 2017). Ahuja et al. (2017) showed that by adopting BIM applications in projects, its four capabilities (MEP system modelling, energy and environment analysis, constructability analysis and structural analysis) enable Lean and green construction projects. Moreover, Ahuja et al. (2014) claimed that projects that use BIM applications can integrate Lean and green more easily and add value. Intrinsically, several case studies reveal that BIM enables both Lean and green applications (Ahuja et al., 2014; Koskela et al., 2010). For instance, BIM functions, such as modelling, clash detection, quantity take-off, simulation and record model, have been determined which enable sustainability by reducing waste, increasing cost effectiveness and improving the efficiency of the construction process.

Moreover, there are many benefits of applying BIM with respect to Lean and green philosophies, which involve various stages of a project (Ahuja et al., 2014):

- At the design phase, BIM creates 3D model that could be used to visualise the design at any phase, thus enhancing sustainability by enabling rapid design modifications. In addition, BIM facilitates the production of designs without any defects, allowing for collaboration between multiple design disciplines and decreasing design mistakes. Accordingly, it enables the Lean and green desighn processes.
- By using 4D BIM, project milestones are correctly understood. BIM helps to generate construction agendas and quantity tables, which allows for effective project planning as well as the easy generation of accurate quantities at any phase of the project from the model. The adoption of Just-In-Time (JIT) technology can improve material and resource solutions, thus minimising cost, providing greater collaboration between the project team and ultimately reinforcing Lean principles. The interactions between BIM and sustainability are obvious when applying BIM analysis tools for energy and the environment. These help to assess energy consumption and environmental concerns in order to enhance the building quality. For the post-construction stage (operation and maintenance), all data concerning the installed materials are connected to the object in a BIM building model, which provides an appropriate foundation for as-built assets and systems that also contribute to the improvement of facility management systems.

- Thus, BIM advantages include: minimising the time and cost required for green design and construction, minimising the cost of energy consumption, increasing construction performance and reducing the time and cost of construction projects. Figure 22 shows the various applications of BIM that can be used to integrate Lean and green construction.

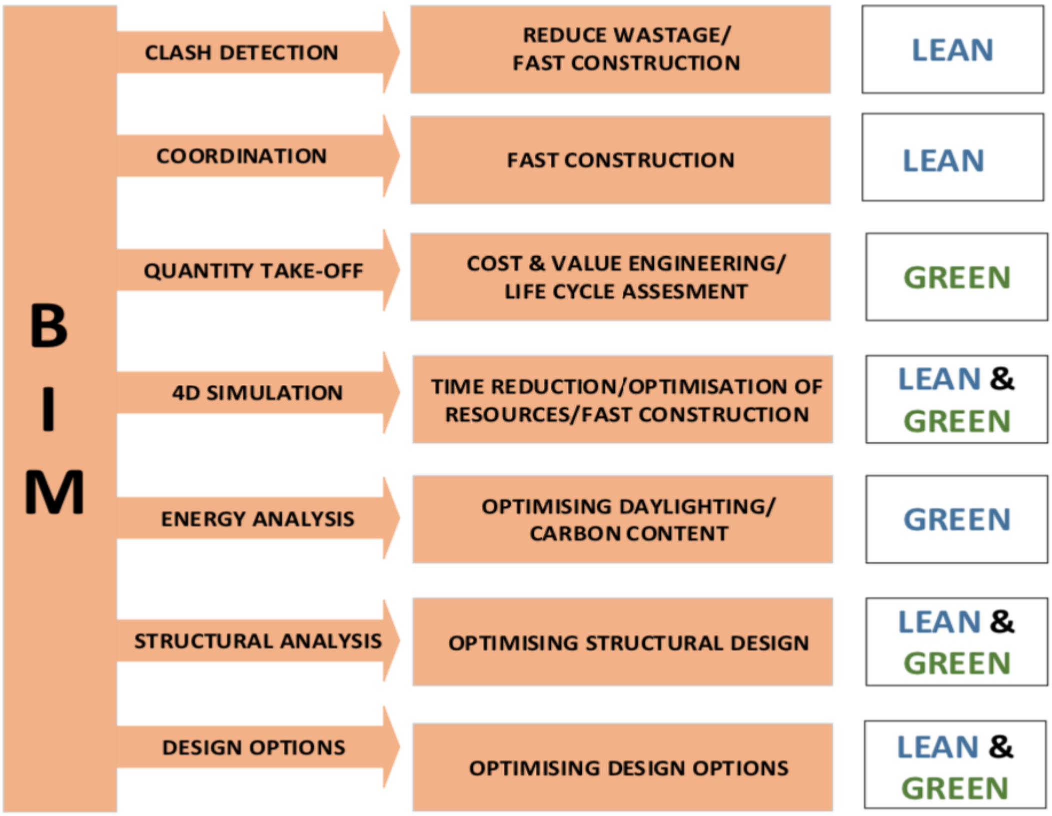


Figure 22: Various Elements of BIM leading to Lean and Green Construction (Ahuja et al., 2014)

2.11 Summary

Globally, the construction industry has suffered from several challenges, such as delays, cost overruns, and project mismanagement. It has been highlighted that the root cause for the most of these issues are poor planning and control, as well as inadequate project management practices. In Kuwait, time and cost overruns are the most common challenges in the construction industry. These issues arise from the absence of communication and coordination between authorities, poor planning and control, mismanagement of the site, and changes in orders or decisions. Recent studies have demonstrated that these issues can be mitigated by implementing advanced project management tools, such as BIM and Lean Construction. Lean Construction (LC) and Building Information Modelling (BIM) were found to be effective approaches for transforming and improving the construction industry, especially when applying them together. This is due to their synergy, where BIM is introduced as a Lean tool.

Although LC and BIM approaches are applied in different countries around the world, there is a gap in knowledge and practice when adopting LC and BIM in construction projects in Kuwait. In Kuwait, BIM was introduced as a software that uses 3D for design, which indicates a misunderstanding of the benefits of BIM technology. Yet, there are several challenges to implementing BIM in the industry that were found in the literature.

Therefore, it is important to develop a method for the effective implementation of BIM in construction projects while considering Lean principles by creating a structured approach or framework that generates a transparent workflow of activities focused on improving the industry's performance and reducing waste in the construction process. The successful implementation of these approaches can be envisioned as the development of a process framework or protocol that combines Lean philosophy with the application of BIM throughout the project lifecycle. This framework or protocol will represent a well-defined process that includes responsibilities or tasks, stakeholders, phases and deliverables. The researcher believes that this framework will improve communication and coordination between project parties by clearly defining responsibilities and objectives, and monitoring construction processes, thus facilitating the industry's transformation towards a digital and collaborative environment.

In order to develop a clear conception of what is lacking and how it can be improved, the next chapter will explore various Lean and BIM frameworks along with different construction process models.

Chapter 3: Existing Frameworks for Improving the Construction Industry

3.1 Introduction

In this chapter, the approaches and methods for improving the construction industry will be discussed. The chapter starts by reviewing existing BIM and Lean frameworks, and then examines business process management tools. Finally, construction project process frameworks and guidelines related to BIM will be explored.

3.2 Existing Lean and BIM Frameworks

This section considers existing frameworks within the literature that integrate Lean and BIM in the construction industry. Ten frameworks were found and are summarised in Table 24.

Table 24: Summary of Existing Lean-BIM Frameworks

No.	Framework Name	Purpose	Limitation	Reference
1	The Experimental Waste Framework	To determine waste in the design process by integrating Lean and BIM approaches	• There is no clear roles and responsibilities. • It was developed to use it only in the design phase. • BIM tasks not mentioned.	(Mollasalehi et al., 2016)
2	Lean-BIM Planning Framework	To manage projects and deliver evidence of the opportunities for performance improvement	• It was created for the planning phase. • There is no clear roles and responsibilities. • BIM strategy and tasks not mentioned.	(Toledo et al., 2016)
3	An integration framework of Last Planner ® System (LPS) with BIM coordination meetings	To reduce variability and add more value for customer by focusing on BIM coordination meetings.	• Simple framework just for planning BIM coordination meetings, using 3 levels of LPS: Master Schedule level, lookahead schedule level and weekly work plan level. • No clear phases, players, and deliverables (inputs and outputs) in this framework. • There is no BIM implementation strategy or BIM tasks.	(Bhatla & Leite, 2012)
4	VisiLean (software)	To facilitate the lookahead and weekly planning sessions	• It is a software created for the planning phase. • There is no clear roles, responsibilities, inputs and outputs. • BIM strategy and tasks not mentioned.	(Dave, Boddy, & Koskela, 2013)
5	KanBIM Workflow management system (software)	To control the workflow of the site by integrating process information and product information, with a direct BIM interface and built-in support for lean construction workflow	• It is a software created to control each task in the process. • There is no clear roles and responsibilities. • BIM strategy and tasks not mentioned.	(Rafael Sacks, Radosavljevic, et al., 2010)
6	IGA-BIM workflow	To deliver the Istanbul Grand Airport project on time and within budget using Lean and BIM.	• There are no clear phases or sequential operations mentioned in this framework, as well as each project party, their tasks for each project phase, the inputs and outputs of each phase are not available. • Yet, the framework was design specifically for the Istanbul Grand Airport. • BIM strategy and tasks not mentioned.	(Koseoglu et al., 2018)
7	Trilateral Collaboration Scheme	Supporting the construction industry to overcome problems of bilateral collaboration such as team communication and synergise all benefits of bilateral collaboration	• There are no clear sequential operations mentioned in this framework, as well as each project party, their tasks for each project phase, the inputs and outputs of each phase (deliverables) are not available. • BIM strategy and tasks not mentioned.	(Fakhimi, Sardroud, & Azhar, 2016)
8	Framework for integration of Lean Thinking to BIM in the PDCA of the nD visual management	This framework is a visual management for Facility Management using digital Obeya room by integrating BIM-Lean approaches.	• It was designed for the FM phase only. • It is used to apply digital Obeya room using BIM. • There is no clear roles, responsibilities, and participants. • BIM strategy and tasks not mentioned.	(Nascimento et al., 2018)
9	BIM based conceptual framework for Lean and Green integration	This BIM framework was designed to achieve Lean and Green principles, using the National Green Rating System of India (GRIHA) to evaluate the framework regarding Lean and green measurements. It is basically an assessment of the BIM framework and how to combine it with Lean and green philosophies.	• It was design based on the Indian green rating system (GRIHA) • There are no clear phases or sequential operations mentioned in this framework, as well as each project party, their tasks for each project phase, the inputs and outputs of each phase are not available. • BIM strategy and tasks not mentioned.	(Ahuja et al., 2014)
10	Conceptual framework for lean implementation in BIM-FM implementation	The purpose of this framework is to implement BIM with Lean concepts in the FM phase to reduce waste of information and time.	• It is for Facility Management phase • There are no clear phases or sequential operations mentioned in this framework, as well as each project party, their tasks for each project phase, the inputs and outputs of each phase are not available. • BIM strategy and tasks not mentioned. • The framework has not been tested yet.	(Terreno, Asadi, & Anumba, 2019)

3.2.1 Experimental Waste Framework

Mollasalehi et al. (2016) developed a framework that aimed to determine waste in the design process by integrating Lean and BIM approaches. It involved five steps, as illustrated in Figure 23, while each step is shown in Figures 24 and 25.

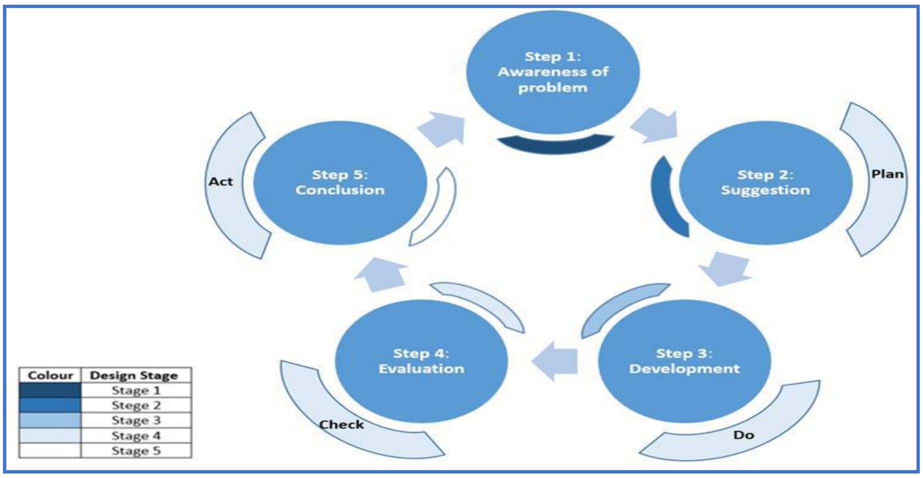


Figure 23: Experimental Waste Framework (Mollasalehi et al., 2016).

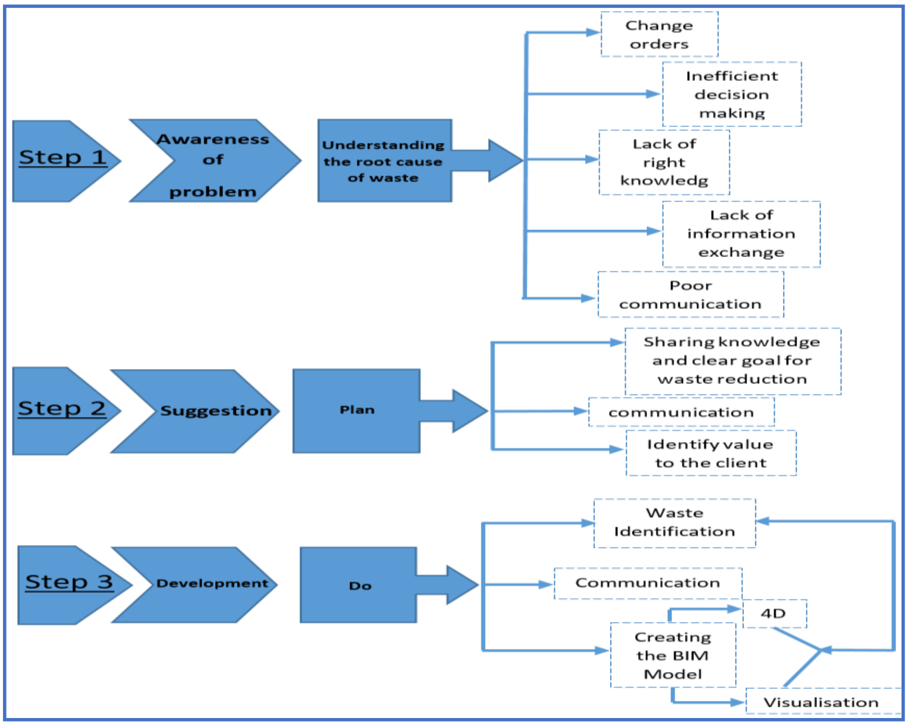


Figure 24: Steps 1 to 3 of the Framework (Mollasalehi et al., 2016).

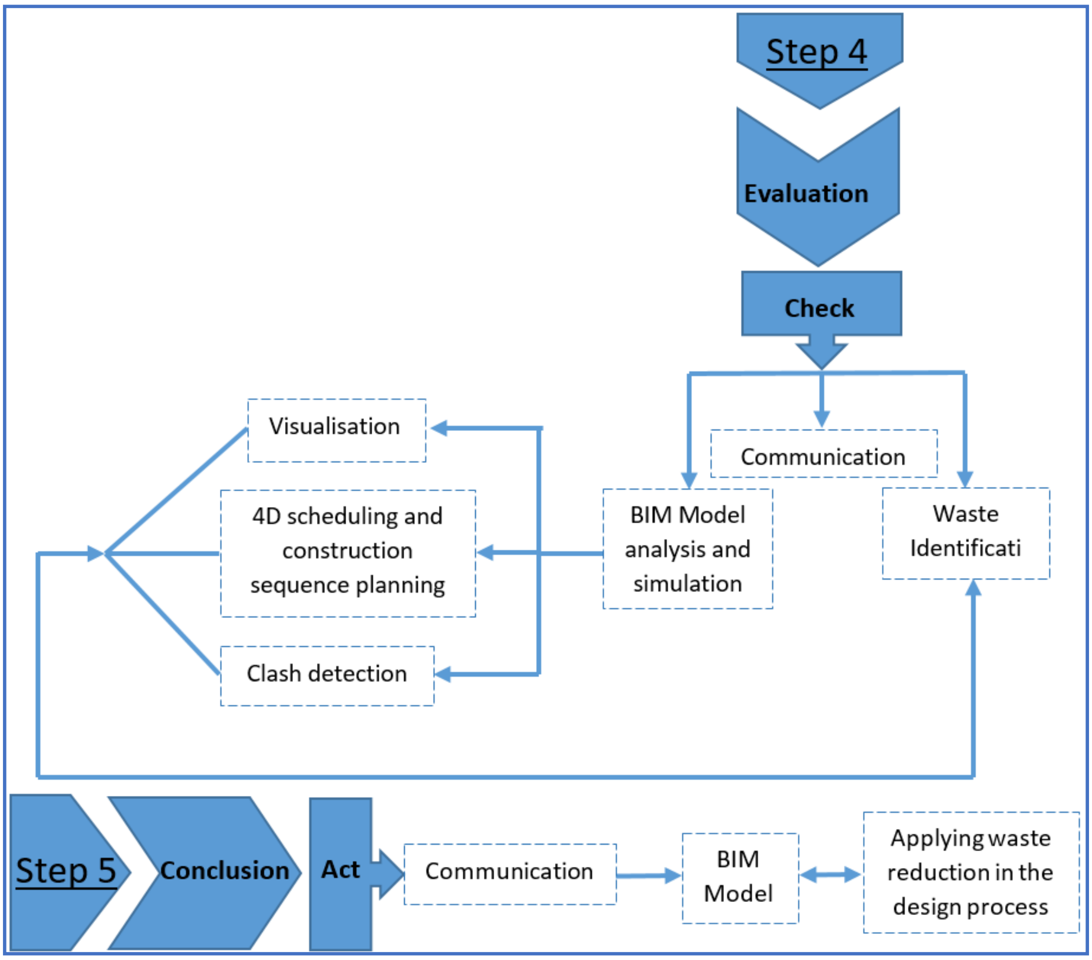


Figure 25: Steps 4 to 5 of the Framework (Mollasalehi et al., 2016).

However, the proposed framework is limited to application at the design phase. Mollasalehi et al. (2016) suggested that this framework needed further development to propose a long-term strategy where further aspects of the waste minimization method could be addressed, not only in the design phase but throughout all construction phases.

3.2.2 Lean-BIM Planning Framework

Toledo, Olivares, and González (2016) realised the gap in BIM and Lean from a practical perspective. They developed a Lean-BIM framework by integrating BIM and the Last Planner System (LPS). This framework was proposed to manage projects and deliver evidence of the opportunities for performance improvement. They compared two case studies - one using only

LPS and the other using LPS and BIM - then project information from each project was collected and analysed, and the planning processes compared. This project information involved weekly and lookahead planning meeting analysis, design requests for information (RFI), and LPS metrics. In other words, Toledo et al. (2016) intended to reveal the effect of applying BIM to facilitate the usage of LPS on the improvement of frequently used Lean project performance indexes: Percentage of Plan Completed (PPC), Reasons for Non-Compliance (RNC), and Request for Information (RFI). In both cases, they diagnosed existing challenges facing a project and prepared an enhanced proposal for project planning by using BIM and LPS which were documented using flowcharts for each planning phase (master plan, lookahead and weekly plan). Figure 26 illustrates a diagram of the framework features which were identified via the project performance improvements and existing challenges for the two case studies. Figures 27, 28, and 29 explain how the framework works.

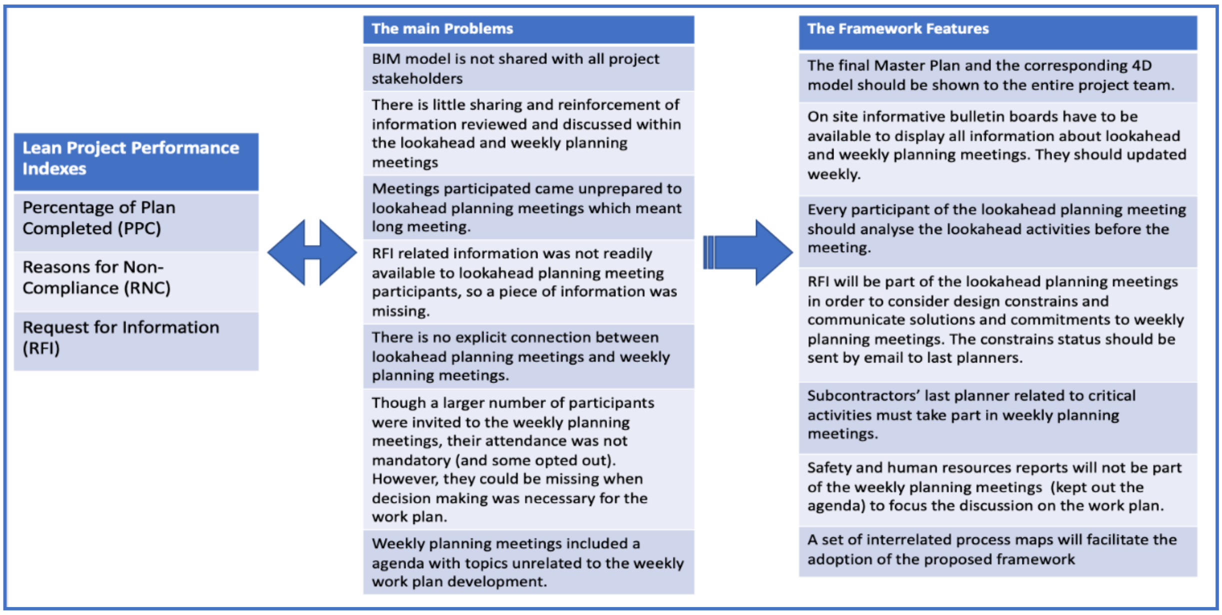


Figure 26: Diagram Illustrates How the Framework Features were Identified.

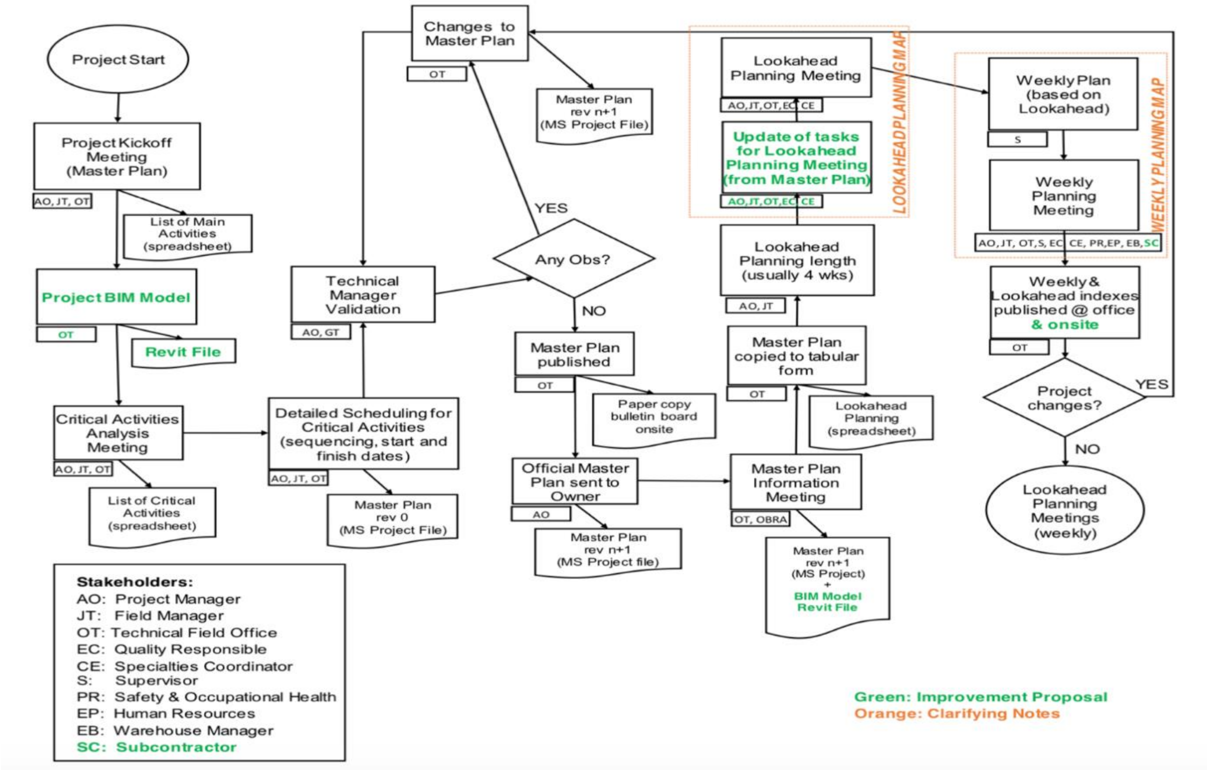


Figure 27: BIM-Lean Framework (Toledo et al., 2016)

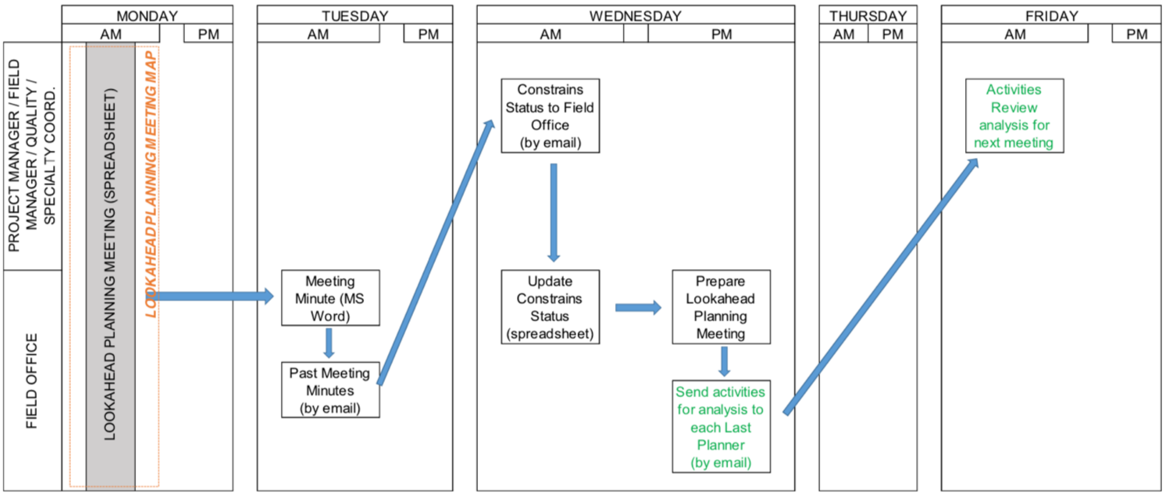


Figure 28: Lookahead Planning (Toledo et al., 2016)

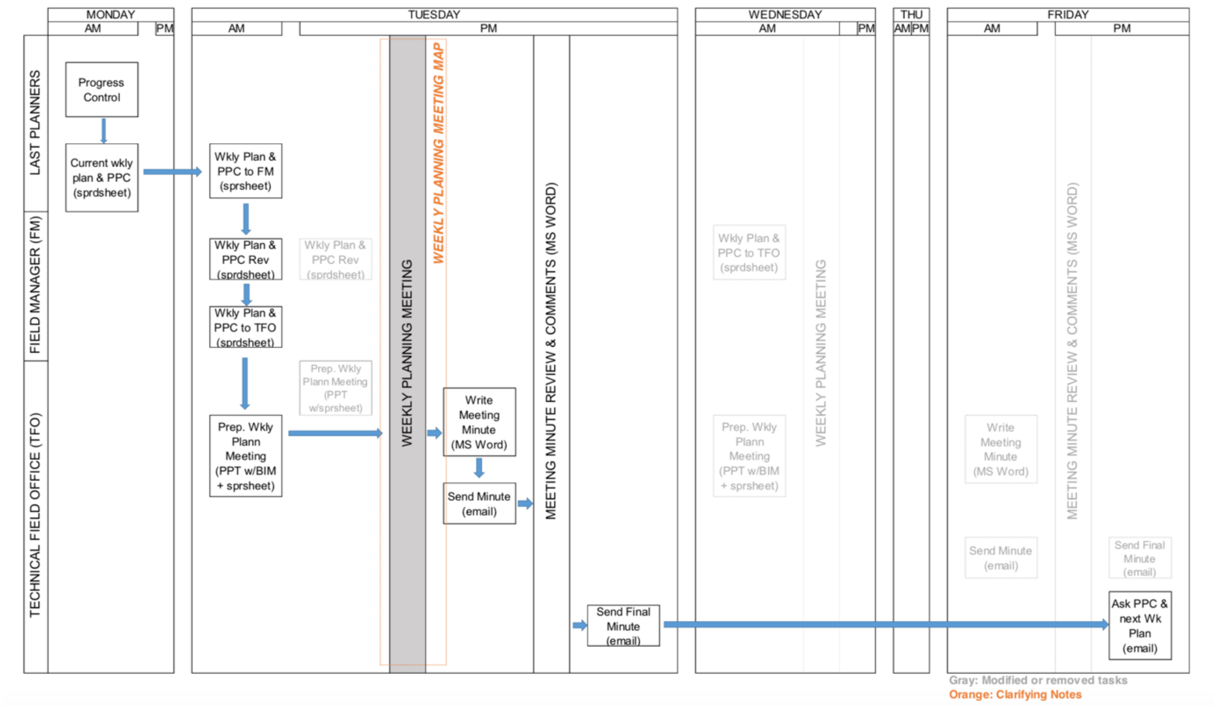


Figure 29: Weekly Planning (Toledo et al., 2016)

The results were positive. It revealed that the application of integrated LPS and BIM creates an increase in the Percentage of Plan Completed (PPC), reducing the Reasons of Non-Compliance (RNC), shortening the meeting time, and decreasing the total number of RFIs designed. As a result, this proposed framework enhances the communication of the project planning and the efficiency of project meetings (Toledo et al., 2016).

3.2.3 An Integration Framework of the Last Planner ® System (LPS) with BIM Coordination Meetings

A study by Bhatla and Leite (2012) aims to develop a framework based on LPS and BIM to reduce variability and add more value for customers. They used the case of a major renovation project at the University of Texas at Austin that had already implementing a BIM approach. Although the adoption of BIM was successful, Bhatla and Leite (2012) believed that more benefits could be attained when applying LPS with the BIM coordination meetings. Thus, they developed a framework based on LPS and BIM coordination meetings using three levels of LPS, which are the Master Schedule level, Lookahead Schedule level and Weekly Work Plan level. The purpose of the framework is to split the project into different parts and then find clashes between the different utility systems, such as mechanical, electrical, plumbing, HVAC etc., to avoid the late detection of clashes that cause re-work, leading to reduced project period. Figure 30 shows the proposed framework.

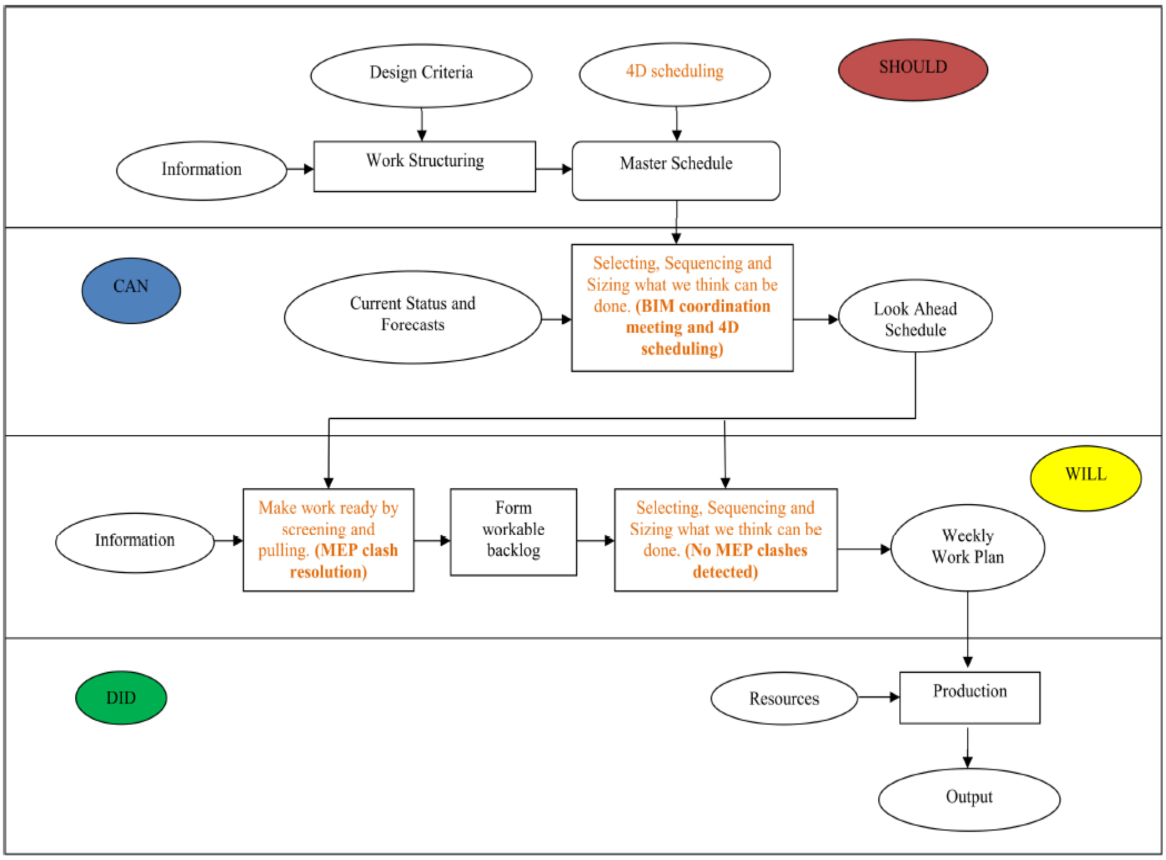


Figure 30: An integration framework of LPS with BIM coordination meetings (Bhatla & Leite, 2012)

As illustrated in Figure 30, this framework begins with LPS to establish the milestone-based master schedule for the project. This master plan is the spine of a construction project, and thus it is crucial that the reliability of this plan is high as all other plans are based on it. Bhatla and Leite (2012) pointed out that the reliability of this master plan could be improved with support from a 4D CAD model, showing the required development of the project over the schedule. This is helpful for project stakeholders in offering a better analysis of the progress of construction and a search for building alternatives to improve the workflow planning. After that, the four week lookahead plan was developed, including the extent of the BIM coordination meeting for clash detection between various project areas. This lookahead plan creates the groundwork to launch the weekly work plan, and therefore its reliability must be very high. Lastly, weekly work plans should be identified from the backlog by choosing only those activities that all constraints have been removed, and the resources and necessary information specified and purchased. However, this procedure needs to be undertaken weekly, involving all project parties. In addition, it is essential for the project team to produce a project progress report, which should be documented each week as a result of these weekly meetings. The findings of these meetings provide evidence that is highly beneficial in reducing the number of RFIs, change orders, and re-work.

3.2.4 VisiLean prototype (software)

Dave, Boddy, and Koskela (2013) developed a software called VisiLean that was based on LPS and BIM. This software required the import of the existing plan information from Primavera P6 and MS Excel and the import of the project BIM model in VisiLean, facilitating the lookahead and weekly planning sessions. Figure 31 illustrates the project workflow before and after using VisiLean.

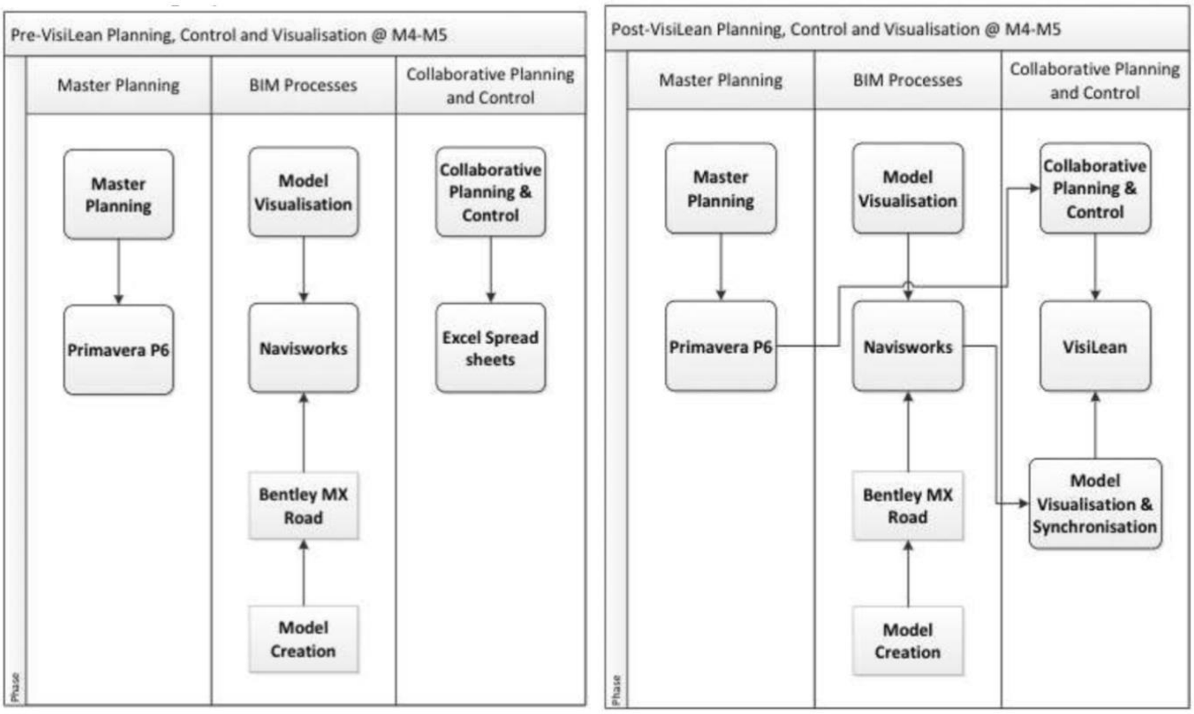


Figure 31: Before and after VisiLean workflow (Dave, Boddy, et al., 2013)

Basically, VisiLean is a software that facilitates the adoption of LPS with BIM. However, Dave, Boddy, et al. (2013) stressed the importance of developing an appropriate level of detail and structure of the construction because the presence of a BIM model is not enough for the successful use of any software system. They also emphasized that without adequate collaborative planning, such as detailed constraints analysis, the performance of VisiLean (or any similar system) would decrease.

3.2.5 KanBIM Workflow Management System (Prototype)

KanBIM™ was developed by Sacks, Barak, Belaciano, Gurevich, and Pikas (2013), as an IT application to control the workflow of the site by integrating process information and product information, with a direct BIM interface and built-in support for a Lean Construction workflow. Figure 32 shows a high-level view of the system architecture.

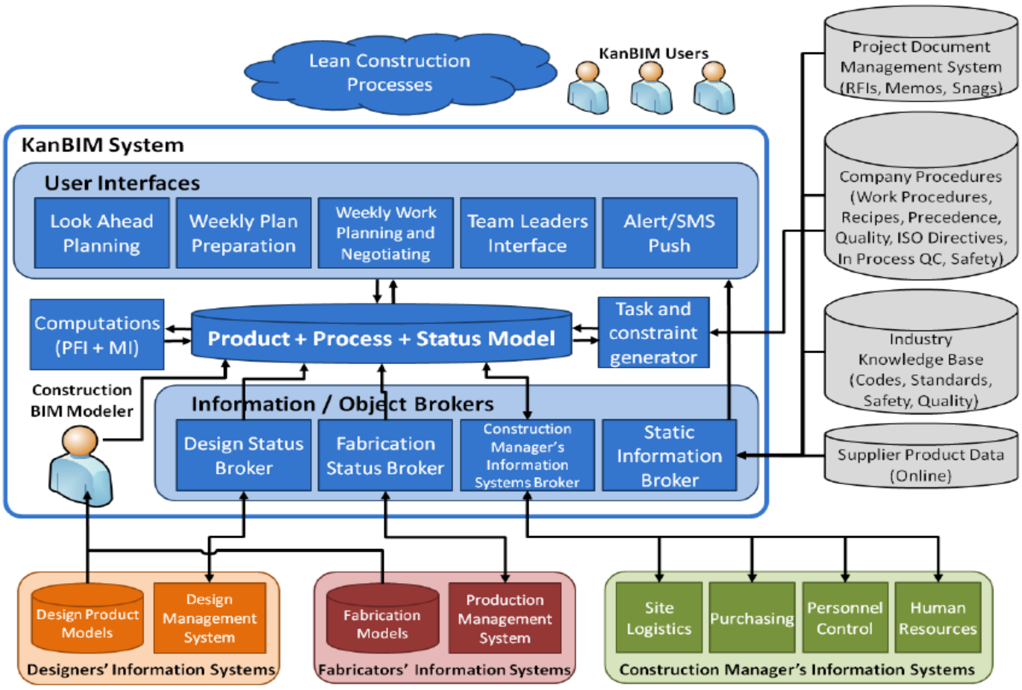


Figure 32: A high-level view of the system architecture (Sacks et al., 2013)

Similar to the previous system (VisiLean), KanBIM is also a software that exploits LPS approaches, such as Look Ahead planning, Weekly Plan, etc., with the implementation of BIM applications. Figure 33 provides a process flow model for the KanBIM system.

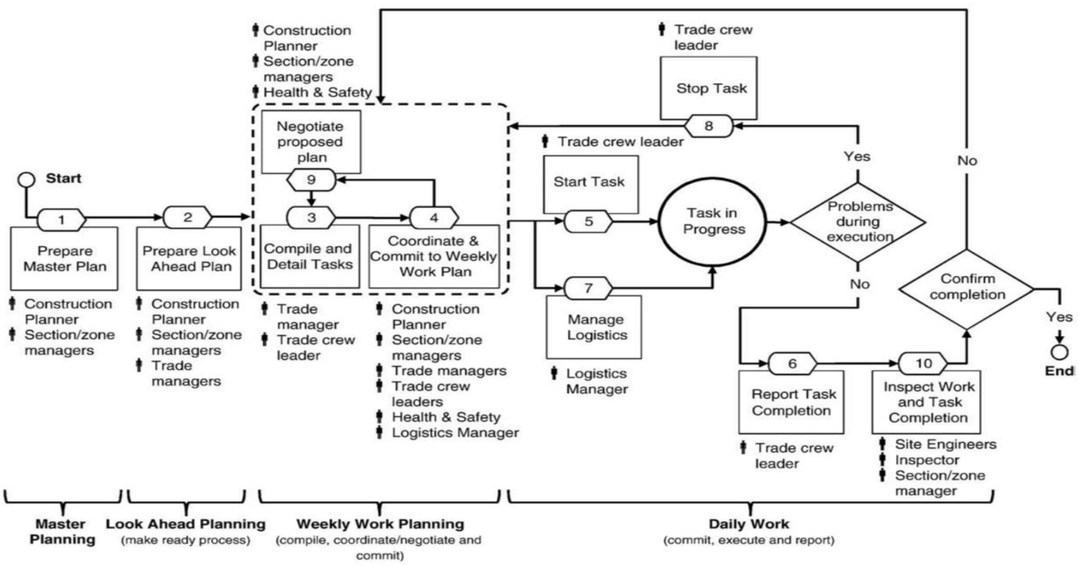


Figure 33: Process flow model for the KanBIM system (Sacks, Radosavljevic, & Barak, 2010)

According to Sacks et al. (2010), the development of the KanBIM concept was for a BIM-based Lean production management system for construction. They stated that the key contribution of the KanBIM model is that it provides a visualisation not only of the building product but of the production process. Nevertheless, there are numerous BIM applications that support this feature, so it is important to specify clear instructions for implementing BIM applications instead of designing other programs.

3.2.6 IGA-BIM Workflow + BIM-Based Project Progress Monitoring (for Istanbul Grand Airport IGA)

A study was conducted by Koseoglu et al. (2018) on the implementation of Lean and BIM in a mega-scale airport construction project in Turkey, known as Istanbul Grand Airport (IGA). The main driver for this implementation of Lean and BIM was that the project should be designed and constructed with tight deadlines and budgets and operated afterwards in an effective and efficient way. Koseoglu et al. (2018) emphasised the importance of having new roles and responsibilities for the main project stakeholders, such as architects, contractors, sub-contractors and suppliers, the identification of new contractual relationships and the re-design of the collaborative process. Therefore, the BIM department was assigned to ensure that project information required for all project parties was reached at any time. This project data was available in cloud-based data management tools that enabled the production of models and coordination of documents and related information. There were tools applied to manage the BIM workflows as shown in Figure 34.

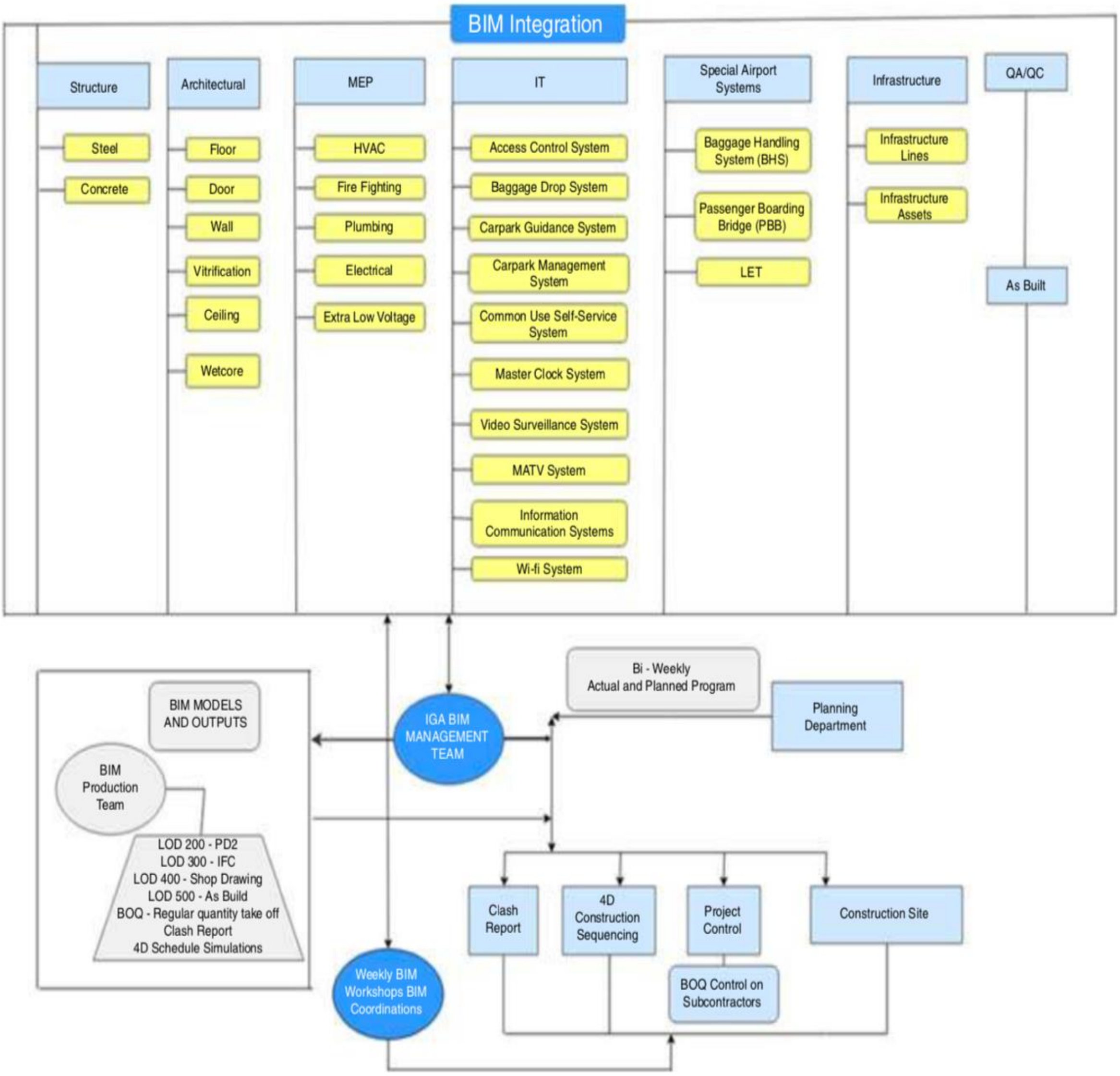


Figure 34: IGA-BIM workflow (Koseoglu et al., 2018)

In addition to the design benefits, the integration of BIM into IGA was not only limited to design management but was also expected to enhance project management with the 4D construction sequencing, 5D quantification, and construction site supervision processes. Figure 35 explains how BIM-based project progress monitoring was applied in IGA, and Figure 36 illustrates the BIM MEP-IT coordination workflow.

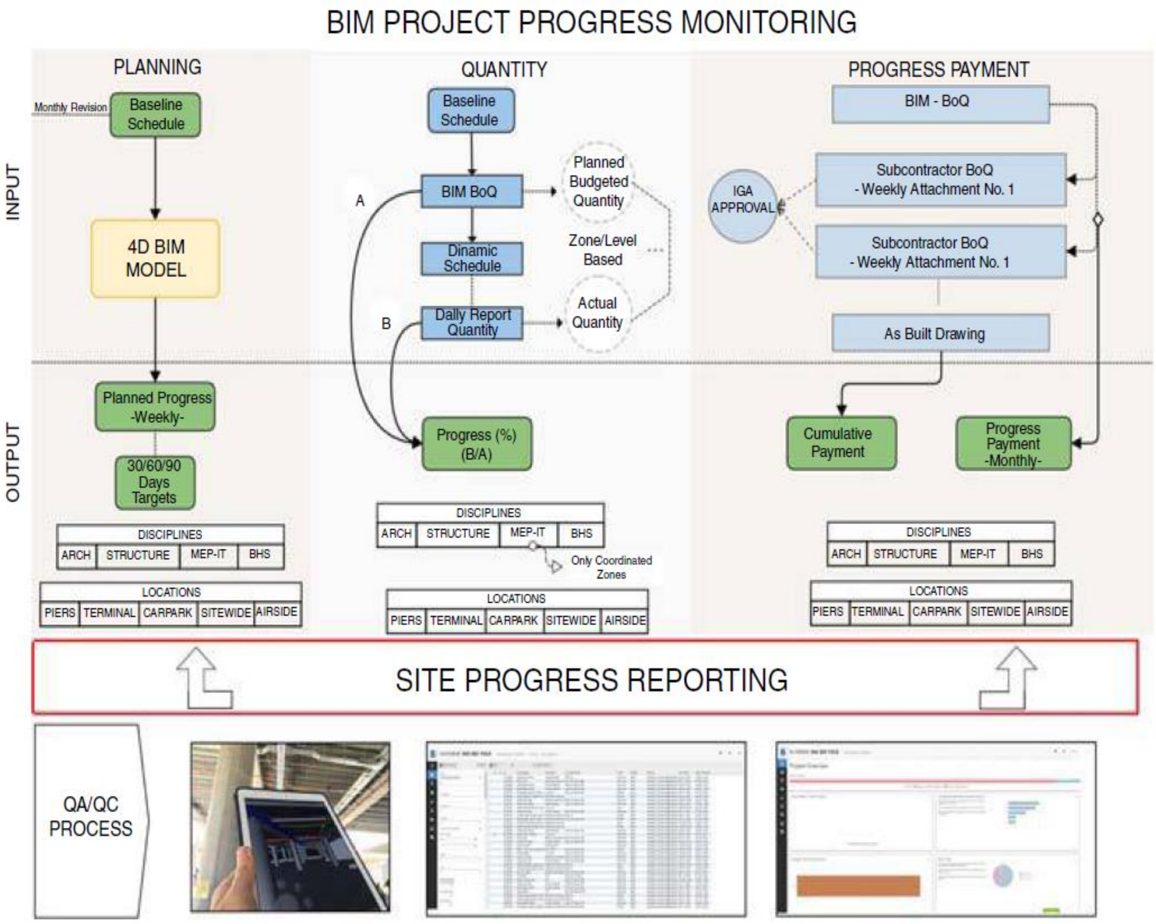


Figure 35: BIM-based project progress monitoring (Koseoglu et al., 2018)

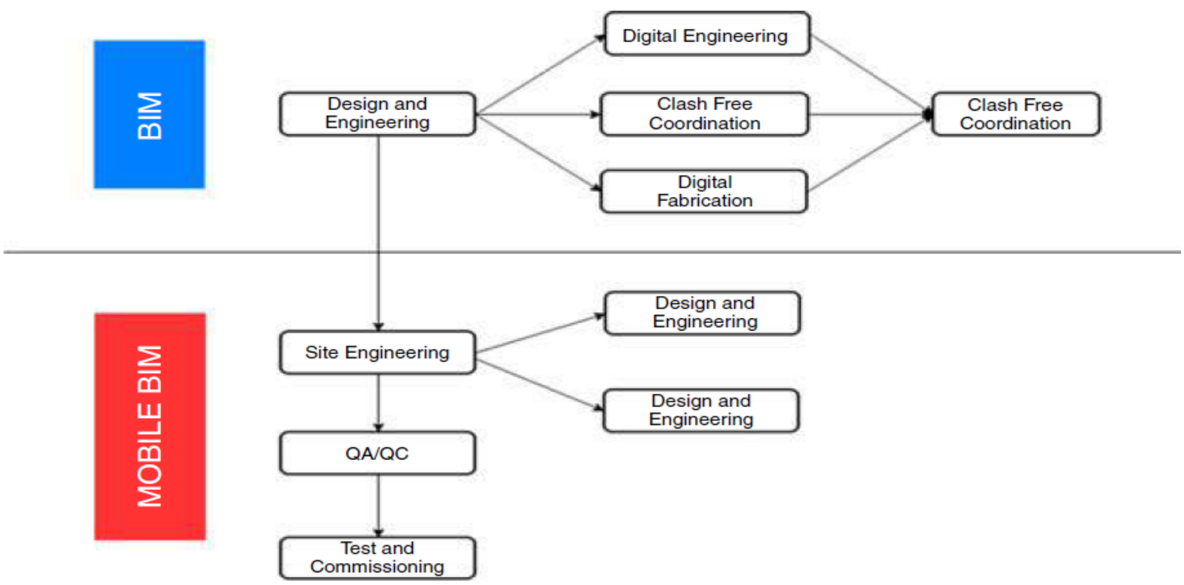


Figure 36: BIM MEP-IT coordination workflow (Koseoglu et al., 2018)

Koseoglu et al. (2018) believed that, in order to apply BIM from the design to the FM phases (known as BIM Level 3) it is necessary to thoroughly understand and adopt Lean principles. They said that, in this phase, model deliverables extend beyond semantic object assets to contain business intelligence, LC and green principles. The result of the collaborative process is a highly detailed virtual prototype representing each of the airport elements. Koseoglu et al. (2018) said that because of this BIM implementation framework, the following Lean results were accomplished through BIM:

- Capital budget as estimated;
- Building time as scheduled;
- High predictability and accuracy;
- Hardly any defects on site;
- High productivity;
- High profit level;
- Sustainable Facility Management process.

There were some weaknesses identified in this system; there were no clear phases or sequential operations mentioned in the framework, as well as each project party, their tasks for each project phase, the inputs and outputs of each phase are not available. Yet, the framework was designed specifically for Istanbul Grand Airport.

In contrast, there were some useful points that could be utilized to help project parties optimise the design process by eliminating any re-work resulting from poor coordination and communication. These useful points included assigning BIM department, holding weekly workshops, and producing clash detection reports.

3.2.7 Trilateral Collaboration Scheme (LC, IPD, and BIM)

Fakhimi, Sardroud, and Azhar (2016) developed a system that focused on LC, IPD, and BIM to benefit the AEC industry, as shown in Figure 37. By adding IPD to LC and BIM approaches, it shed the light on the contractual area and collaboration between stakeholders instead of introducing an appropriate process to eliminate waste and optimise efficiency (Fakhimi et al., 2016).

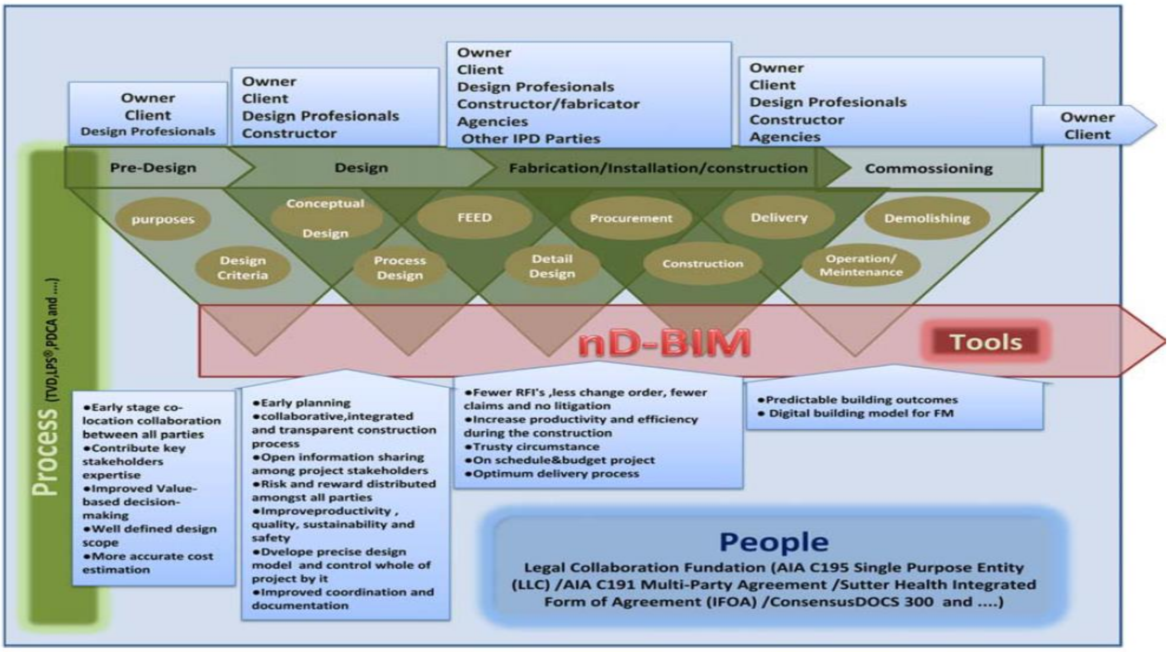


Figure 37: The Trilateral collaboration scheme (Fakhimi et al., 2016)

Fakhimi et al. (2016) claimed that this trilateral collaboration allowed a level of collaboration that not only enhanced efficiency and decreased mistakes but also allowed for the exploration of alternative methods and a growth of market opportunities. This scheme was expected to support the construction industry by overcoming the problems of bilateral collaboration, such as team communication, and supporting the synergy of all advantages associated with bilateral collaboration.

In contrast, the author believes that BIM and IPD are two sides of a same coin. Since the focus of this study is optimising the performance of AEC practice by eliminating waste and added value for the client, the efficiency of the processes will be the focal point. In complex projects, there is an essential need for a comprehensive approach to allow for the successful management of design and construction data through accurate modelling, collaboration and integration during the project lifecycle including different project disciplines (Koseoglu et al., 2018).

3.2.8 Framework for Integration of Lean Thinking to BIM in the PDCA of the nD Visual Management

An empirical study was conducted by Nascimento et al. (2018) to improve Facility Management (FM) in the construction projects. The focus of this study was on BIM and Lean approaches, with the digital Obeya room being applied using BIM technology. The major contributions of this study, as follows:

- A conceptual framework linking the PDCA (Plan-Do-Check-Act) cycle with BIM and Lean approaches.
- Identify the most relevant BIM functions and Lean principles.
- Realistic application of the framework actions to FM.

A framework for visual management purposes was produced to enhance the decision-making process at the FM phase, thus, reducing the coordination time (see Figure 38). This framework included the standard operational procedure of a digital Obeya room, where information was uploaded to an integrated relational database and linked to multidimensional visualisation within the PDCA methodology (Nascimento et al., 2018). A workflow aimed at continuous improvement and the validation of procedures has been described, as shown in Figure 39.

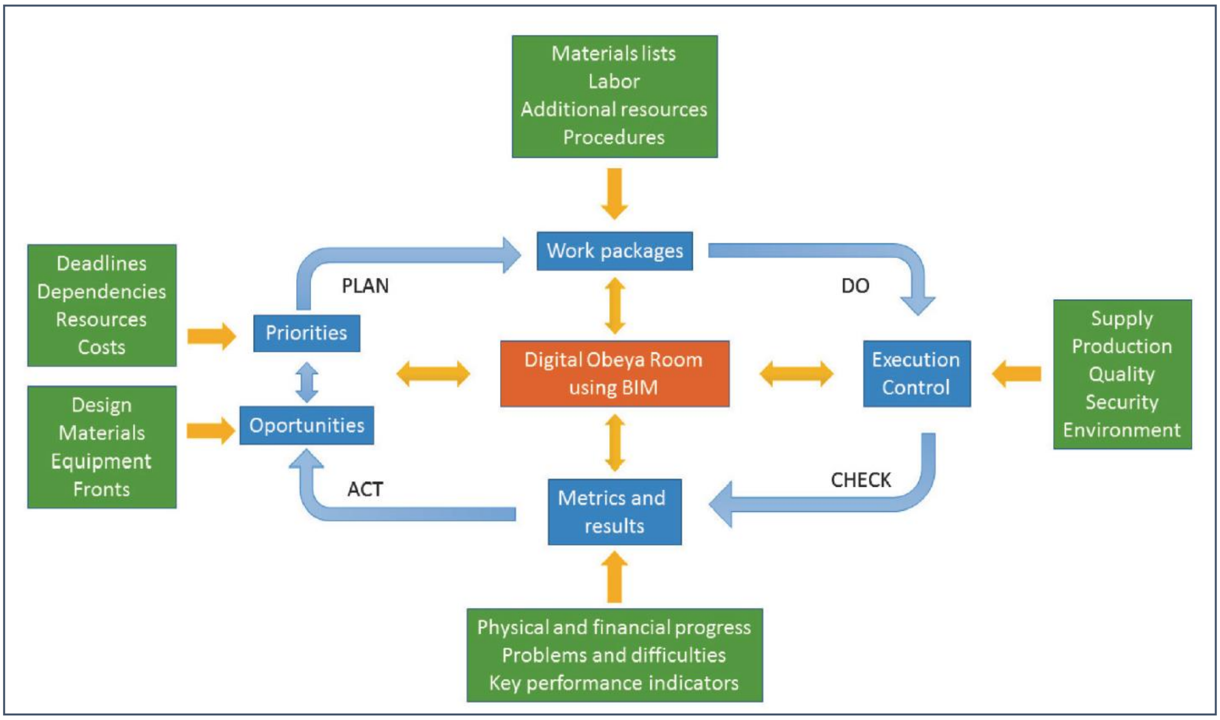


Figure 38: Framework for integration of Lean Thinking to BIM in the PDCA of the nD visual management (Nascimento et al., 2018)

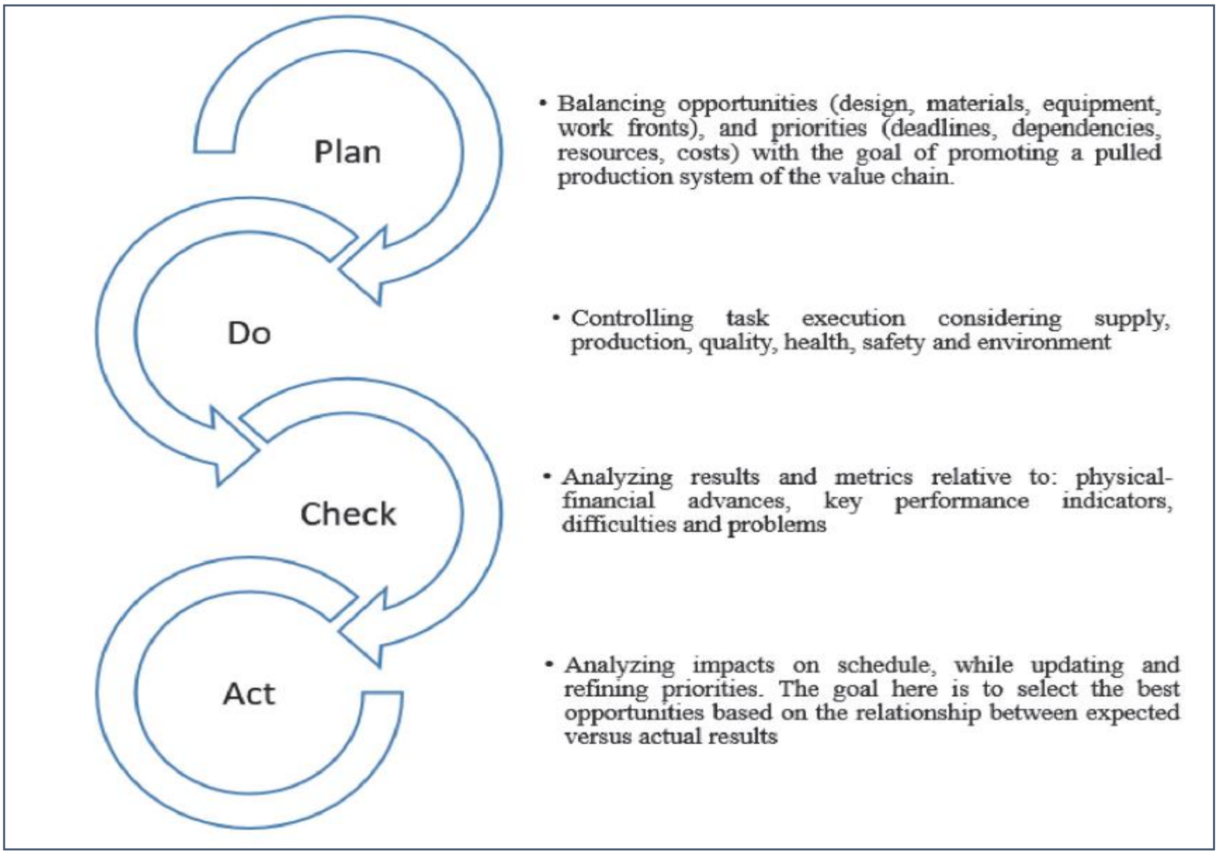


Figure 39: Standard operational procedure of Digital Obeya Room (Nascimento et al., 2018)

The standard operational procedure of digital Obeya room consists of four actions derived from Lean principles, which are plan, do, check, and act (see Figure 39).

1. Plan

   In the ‘plan’ step, opportunities (design, materials, equipment, work fronts) and priorities (deadlines, dependencies, resources, costs) will be balanced with the aim of promoting a pulled production system of the value chain.

2. Do

   In the ‘do’ step, the execution of tasks is controlled with consideration of supply, production, quality, health, safety, and environment.

3. Check

   In the ‘check’ step, results and metrics related to physical – financial advances, KPIs, difficulties and problems are analysed.

4. Act

   In the ‘act’ step, impact analysis is on schedule, with priorities updated and refined. The aim here is to identify the best opportunities based on the relationship between expected results versus actual results.

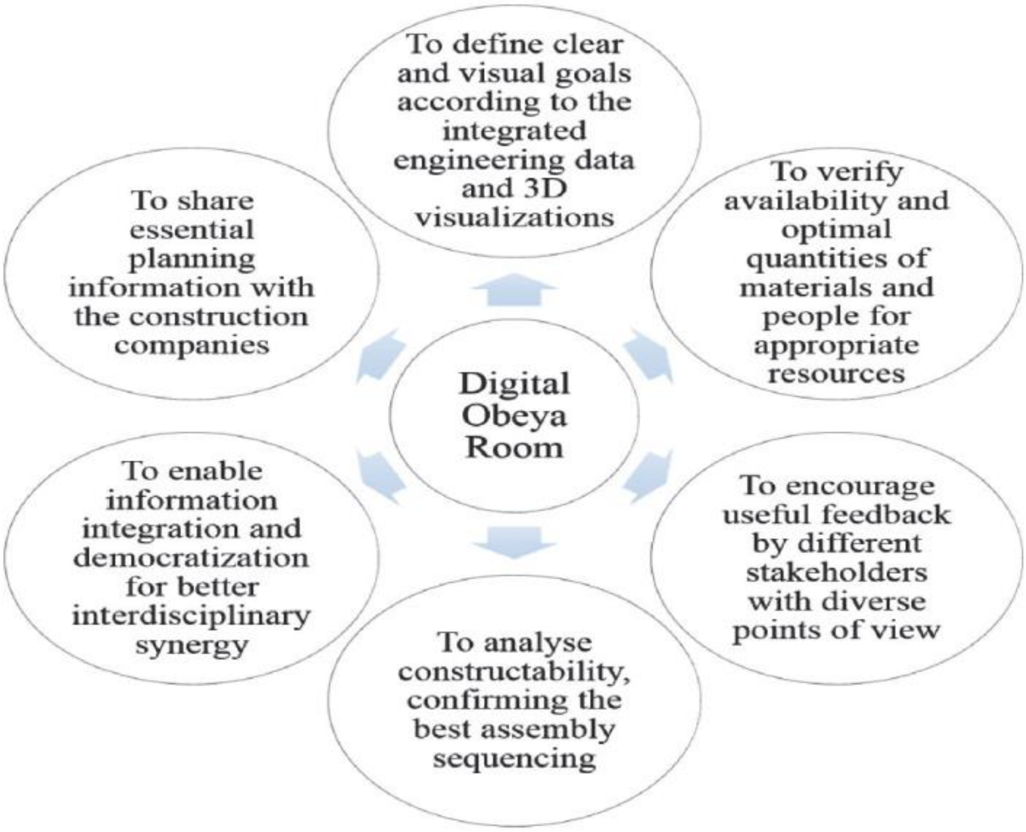


Figure 40: Guidelines in the Digital Obeya Room model (Nascimento et al., 2018)

In Figure 40, instructions are provided for the decision-making process that takes place within the Digital Obeya Room. These are as follows:

- Defining clear and visible goals according to the integrated engineering data and three-dimensional visualisations.
- Verifying the availability of optimal quantities of materials and people to obtain appropriate resources.
- Encouraging helpful feedback from different stakeholders with diverse perspectives.
- Analysing constructability, confirming the best assembly sequencing.
- Enabling information integration and democratisation for better interdisciplinary synergies.
- Exchanging basic planning information with construction companies.

According to Nascimento et al. (2018), this study has a major contribution from a pragmatic approach to the performability of maintenance planning, making the schedule more committed to the actual accomplishment of agendas and improving collaboration between stakeholders. By encouraging the use of Lean and BIM principles, it was possible to optimise the level of resources based on a pull production system and to reduce rework and waste at all stages of construction. However, the framework has several limitations; it was only designed for the FM phase by using the Obeya room with BIM technology to optimise the performance. Additionally, there is a lack of clear roles, responsibilities, and participants, as well as BIM strategy and tasks.

3.2.9 BIM Based Conceptual Framework for Lean and Green Integration

Ahuja et al. (2014) investigated the integration of BIM with Lean and green philosophies. They believed that BIM was a tool that acted as a catalyst to achieve Lean and green. Therefore, a BIM framework was developed, and the Indian National Green Rating System (GRIHA) was used to assess the framework and how Lean and Green would be achieved (see Figure 41).

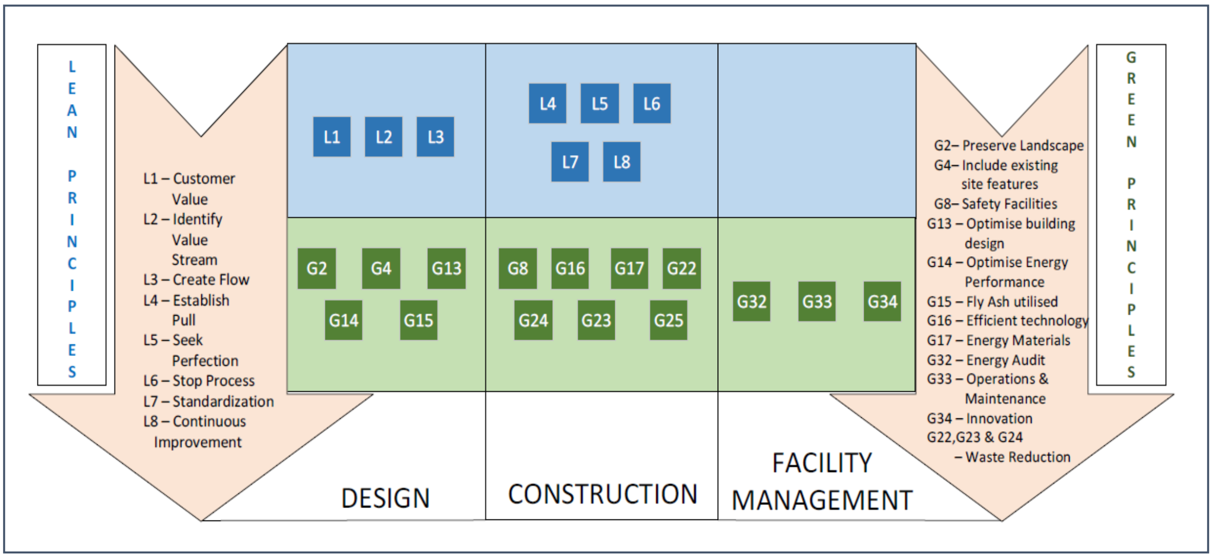


Figure 41: BIM framework (Ahuja et al., 2014)

The framework was tested and validated using three case studies. The results indicated that BIM enables the resolution of design clashes; this leads to the reduced waste of time and effort, facilitation of quantities take-offs, achievement of better billing process, and facilitation of project performance (Ahuja et al., 2014). Ahuja et al. (2014) claimed that BIM is proving to be an effective enabler in establishing the link between Lean and green. For example, clash detection and coordination in BIM helps reduce waste and enable rapid construction, thus, Lean will be achieved. Moreover, green principles, such as cost-value engineering, life cycle assessment, daylight optimisation, and carbon content, could be achieved by quantity take-off and energy analysis features in BIM technology.

3.2.10 Conceptual Framework for Lean Implementation in BIM-FM Implementation

Another study aimed at exploring the implementation of BIM in Facility Management (FM), and the potential for synergies with the Lean approach, was also conducted (Terreno, Asadi, & Anumba, 2019). It has been revealed that the existence of deficiencies and variances in information management leads to an increase in working hours and is an ongoing challenge in implementing BIM-FM. As a result, there is a need to reduce the waste of information and time by using Lean principles in BIM implementation. Thus, Terreno et al. (2019) produced a framework that employed BIM with Lean Six Sigma and Value Stream Mapping as control mechanisms, using these Lean tools to help enable better process control in the FM phase.

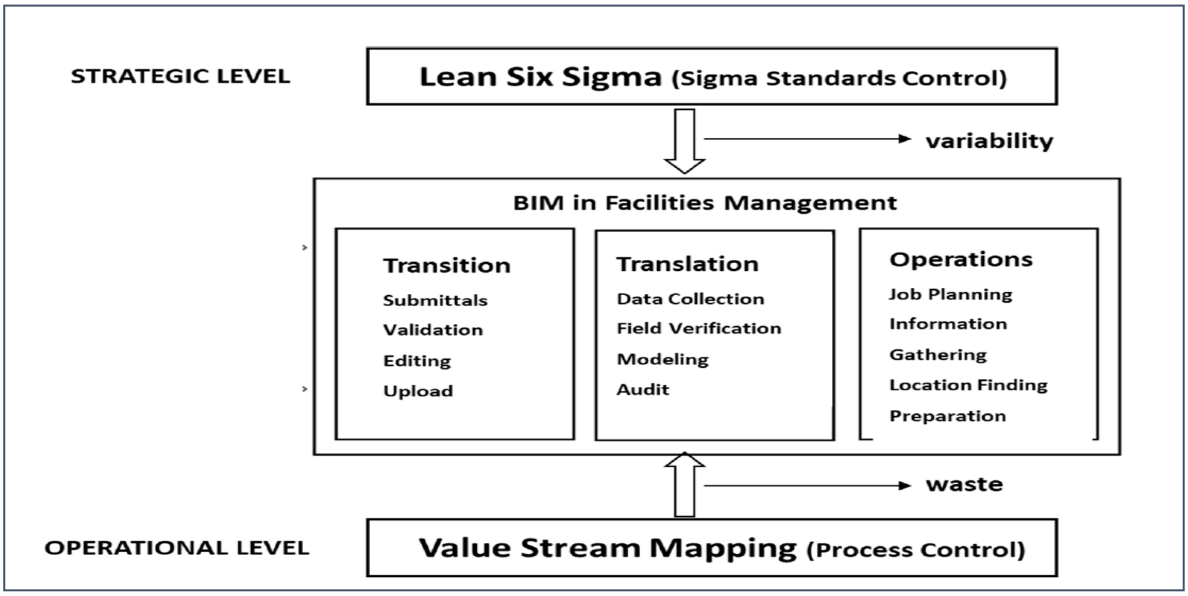


Figure 42: Conceptual framework for Lean implementation in BIM-FM implementation (Terreno et al., 2019)

As shown in Figure 42, Terreno et al. (2019) categorised the framework into three stages: transition, translation, and operations. In addition, there were two levels in the BIM framework for FM, strategic and operational levels. At the strategic level, a Lean Six Sigma approach was applied to detect and control project variation, while at the operational level, Value Stream Analysis was used to identify and eliminate waste in each process value stream. However, the framework has not been yet validated, thus, more studies in this area and strengthening of the framework are needed.

After reviewing ten relevant frameworks that integrated Lean and BIM, it appears that there is a lack of holistic approach to focus on the implementation process of BIM taking into consideration Lean Principles to optimal performance and sustainability for the whole lifecycle of a project. The researcher intended to develop a framework that facilitated BIM implementation while focusing on delivering Leaner process and sustainability.

As mentioned earlier, BIM is an enabler that facilitates Lean principles and sustainability. Therefore, there was no need for extra software or tools to achieve this. Developing a framework that used BIM applications as technology tools with the Lean thinking and that considered sustainability aspects starting from the planning phase until demolition.

Additionally, there was a lack of BIM implementation in the construction industry in Kuwait, so having clear guidance when adopting BIM is essential for successful implementation. However, developing BIM and Lean framework depends on further investigations into how BIM is used and the identification of weaknesses in this implementation as well as eliminating waste and adding value for the client by applying Lean principles and achieving sustainability.

3.3 Improvement tools of construction process

3.3.1 The Construction Problem (current issue)?

Although the models of design and construction process, such as RIBA Plan of Work (Sinclair, 2013) and The Generic Design and Construction Process Protocol (GDCPP) (Aouad, Cooper, Kagioglou, & Sexton, 1999), have been recently acknowledged, there are many forms of contract procurement (Design and Build, Management contracting, etc.), meaning these models and procurement systems are insufficient (Kagioglou et al., 1998). Kagioglou et al. (1998) explained that the construction industry is fragmented, because from project-to-project, organisational roles and responsibilities change; this is referred to as Temporary Multi-Organisations (TMO's) where the project team changes in each project and rarely works together on more than one project, which leads to confusion (Luck, 1996), and poor communication and coordination between stakeholders. As a result, the ability to learn from previous experiences is obstructed, and as Sommerville and Stocks (1996) stated, this issue effects the performance of the assembled team, and thus prevents continuous improvement.

3.3.2 Why Process?

In the United Kingdom, the construction industry has been struggling to enhance its practices (Hill, 1992; Howell, 1999). Several UK government reports have been published criticizing the industry's low performance including Simon (1944), Phillips (1950), Banwell (1964), Latham (1994), Egan (1998) and Farmer (2016). These reports indicated that the construction industry has been impeded by the following: it's fragmented nature, a lack of collaboration and communication between stakeholders, unstructured construction processes, adversarial contractual relationships, and a lack of focus on the client. Additionally, construction projects are frequently seen as volatile with regard to delivery time, cost, profitability and quality while research and development funding in this industry is commonly considered expensive compared to other industries (Egan, 1998; Fairclough, 2002). However, Latham (1994) argued that construction should learn from the manufacturing industry and adopt its innovative management strategies. In the Egan (1998) report, process modelling was proposed as an approach to improve the construction industry. Koskela (1992), Love & Gunasekaran (1996), and Kagioglou et al. (1998) stressed that, for several decades, the manufacturing sector has always been a major centre for innovation in construction. They proposed the industrialisation, digitisation, and modernisation of the construction industry by enabling prefabrication, modularisation, robotics and automated construction to conquer the challenges and issues facing the industry.

Although construction companies tend to adopt new manufacturing technologies based on the utilization of core processes to enhance the business productivity (Cooper et al., 1998), efforts are lacking in modelling processes due to the fragmented nature of the construction sector (Egan, 1998). Hence, it is important to model the entire project lifecycle process in order to streamline activities and enhance project performance.

Since Lean Construction (LC) and Building Information Modelling (BIM) are the main drivers for this research to improve the construction performance; therefore, this research will focus on developing a process protocol utilising BIM as a system to achieve Lean principles.

3.4 Process and Business Process

3.4.1.1 Process

Davenport (1994, p. 134) said that "*A process is simply structured set of activities designed to produce a specified output for a particular customer or market. It has a beginning, an end, and clearly identified inputs and outputs. A process is therefore a structure for action, for how work is done. Processes also have performance dimensions – cost, time, output quality, and customer satisfaction that can be measured and improved*". It is a series of tasks that, taken together, create a result of value to the client (Ittner & Larcker, 1997, p.523).

3.4.2 Business Process

Chang (2016, p.3) defined a business process as "*a coordinated and standardized flow of activities performed by people or machines, which can traverse functional or departmental boundaries to achieve a business objective that creates value for internal or external customers*". Al Ahbabi (2014) mentioned that the business process sequence of connected activities and operations are always associate with the company's overall plan and strategies in the successful delivery of services to clients.

3.4.3 Business Process Management:

3.4.3.1 Definition and concept:

Van Der Aalst, Ter Hofstede, and Weske (2003, p.4) defined Business Process Management (BPM) as a "*Supporting business processes using methods, techniques, and software to design, enact, control, and analyse operational processes involving humans' organisations, applications, documents and other sources of information*". BPM is a system that consolidates knowledge from information technology and management disciplines and focuses on business processes (Van Der Aalst, 2013). Neubauer (2009) describes BPM as a management system that controls business processes and proceeds with a range of coordinated activities and functions within a company to achieve a specific management objective. It is a generic approach that employs process as a basic concept for analysis and improvement purposes (Damelio, 2016; Gersch, Hewing, & Schöler, 2011).

Moreover, Weske, van der Aalst, and Verbeek (2004, p.2) demonstrate that BPM is a lifecycle approach that maintains: "*Business processes using methods, techniques, and software to design, enact, control, and analyse operational processes involving humans, organizations, applications, documents and other sources of information*". Doebeli, Fisher, Gapp, and Sanzogni (2011) describe BPM concept as a broader methodology that focuses on the process-view of a company by managing and improving each process in the business lifecycle.

In addition, the concept of BPM has developed over time and adopted different names, such as Business Process Improvement (BPI), Business Process Re-engineering (BPR), Workflow Management (WFM), Business Process Modelling, Total Quality Management (TQM), and Business Process Change (BPC) (Harrington, 1991; Huang, van der Aalst, Lu, & Duan, 2011; Motwani, Prasad, & Tata, 2005; Muehlen & Ho, 2005; Tam, Chu, & Sculli, 2001; Thomas, 1993). According to Sritharakumar (2016), these improvements were not limited to different names, but also include new values. Rosemann, De Bruin, and Hueffner (2004, p.1) outlined that "*Business Process Management (BPM) consolidates objectives and methodologies, which have been proposed in a number of approaches including Business Process Re-engineering, Business Process Innovation, Business Process Modelling and Business Process Automation/Workflow Management*".

3.4.4 Approach to Process Modelling/Process Representation:

3.4.4.1 Process Modelling

Business Process Modelling is a management concept that considered as a fundamental part of BPM. The demonstration of business processes requires a reflection from this present reality methodology to map them into process models. They are made utilizing one of a few modelling strategies based on a specific kind of business and reason for modelling. Process modelling is a fundamental segment of any BPM approach. It is simply a tool that offers ways to connect the capabilities of complex business in a structure that can be most effectively justifiable to individuals.

An essential part of BPM as a management concept is business process modelling. The modelling of business processes requires abstraction from the real-world procedures in order to map them into process models. They are created using one of several modelling techniques according to the exact type of business and purpose for modelling. The efficient design of business processes permits people to cooperate more effectively. Rosemann and vom Brocke (2014) emphasised that the aim of the process model is to capture business methods at an appropriate degree of detail to meet the intended functions. Moreover, according to Al Ahbabi

(2014), process models mirror the business tasks and their connections in an organisation; it can be utilized to analyse cost, resource use or process performance, and for automation purposes.

By promoting the implementation of BIM and Lean, the building industry will be positively influenced and enhanced through the use of process modelling. Because the utilization of BIM overreaches the preparation and designing phases, it upholds processes throughout the project lifecycle. Similarly, developing process models for BIM requires thorough examination and the collaboration of all project parties.

3.4.4.2 Process Mapping

The importance of process mapping depends on the division of main activities, which helps in monitoring and understanding the process flow; thus, any improvement can be applied once there is a transparent process line. "*Process mapping consists of constructing a model that shows the relationships between the activities, people, data and objects involved in the production of a specified output*" (Biazzo, 2002, p.42).

The reason for implementing process mapping techniques is the awareness of that such models can provide, which can offer beneficial and affordable descriptions which facilitate the improvement and redesign of business processes. One characteristic of successful change management for re-engineering companies is the use of feasible, attainable and proven methods that system engineers can routinely use to analyse and design composite-based systems (Colquhoun, 1996).

Since there are many approaches for process mapping, this study will focus on frameworks or process models that are related to construction projects. In the next section, several process models/frameworks for the construction industry will be reviewed in order to adopt the most appropriate concept to this study that can employ BIM and Lean approaches.

3.5 The Construction Process:

The construction process contains several stages and involves effort from parties' from different disciplines in order to deliver the project successfully. Generally, construction is executed in the form of one-off projects, which leads to difficulties when organising and monitoring the delivery process (Karhu, Keitilä, & Lahdenperä, 1997).

It is frequently argued that building houses and producing cars should not be compared, because each construction project is unique and based on the client's requirements. However, the stages of building a construction project are general and similar in each project, making it possible to adopt production management systems and techniques. Moreover, in the manufacturing industry, not all cars are identical, although there is a custom-made option for cars. For instance, a huge manufacturer of heavy vehicles called Scania produces customized automobiles out of a limit set of standardized components (Jongeling, 2006). Latham (1994), Egan (1998), Love & Gunasekaran (1996), and Koskela (1999) agreed that the construction industry should learn and adopt approaches from manufacturing industry in terms of process management and control. Therefore, it is important to understand the stages of construction projects in order to break the process into sub-processes and create a process model that helps to manage and monitor this procedure.

Construction is described as a process in which a client assigns a consultant (design team) to facilitate the project process. The consultant obtains a set of requirements that mean optimising results in the brief from the client, which define the main performance attributes of the required construction facility. The construction process is simplified in Figure 43.

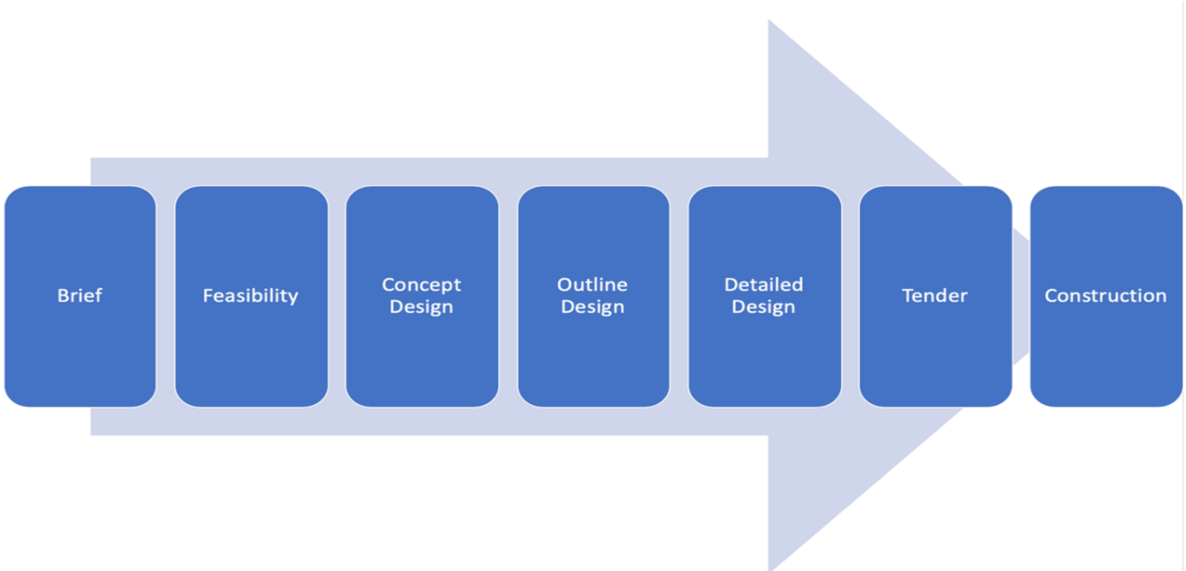


Figure 43: The construction process

Nevertheless, there are several guidance models for construction projects processes, such as the RIBA Plan of Wok and The Generic Design and Construction Process Protocol.

3.5.1 Construction Project Process Models:

3.5.1.1 RIBA Plan of Work

The RIBA Plan of Work is defined as "*The Outline Plan of Work organises the process of managing, and designing building projects and administering building contracts into a number of key Stages, which published by The Royal Institute of British Architects*" (RIBA, 2013). Developed in 1963, the RIBA Plan of Work initially aimed to organize the construction process, which includes briefing, designing, constructing and operating the building project into eight stages. Since then it has been updated and the final version emerged in 2013 (Sinclair, 2013). For more than half a century in the UK it has been the main process protocol for building design and construction process, and has influenced many countries. The RIBA Plan of Work has been a basic guideline for architects and the construction industry in general. It has offered a shared model for the organisation and project management team, and is commonly implemented as both a process plan and management system. In addition, it provides reference points at each work stage, which are used in many contracting and recruitment documents and guidelines for best practice. It has been modified and updated over time to reflect developments in the organization of the design team, regulatory systems, and modernization in procurement systems. However, these adjustments were usually gradual and interactive to variable situations rather than strategically driven (Sinclair, 2013). In 2007, the Royal Institute of British Architects (RIBA) updated their Plan of Work, with main benefits being the simplicity and clear descriptions of the stages (RIBA, 2007a). Nevertheless, it is only associated with a traditional procurement system and builds expectations about the timing of planning applications; moreover, the stages were poorly defined as shown in Figure 44 (RIBA, 2013).

Amended November 2008

RIBA Outline Plan of Work 2007

The Outline Plan of Work organises the process of managing, and designing building projects and administering building contracts into a number of key Work Stages. The sequence or content of Work Stages may vary or they may overlap to suit the procurement method (see pages 2 and 3).

RIBA Work Stages				Description of key tasks	OGC Gateways
Preparation	A	Appraisal		Identification of client's needs and objectives, business case and possible constraints on development. Preparation of feasibility studies and assessment of options to enable the client to decide whether to proceed.	1 Business justification
	B	Design Brief		Development of initial statement of requirements into the Design Brief by or on behalf of the client confirming key requirements and constraints. Identification of procurement method, procedures, organisational structure and range of consultants and others to be engaged for the project.	2 Procurement strategy
Design	C	Concept		Implementation of Design Brief and preparation of additional data. Preparation of Concept Design including outline proposals for structural and building services systems, outline specifications and preliminary cost plan. Review of procurement route.	3A Design Brief and Concept Approval
	D	Design Development		Development of concept design to include structural and building services systems, updated outline specifications and cost plan. Completion of Project Brief. *Application for detailed planning permission.*	
	E	Technical Design		Preparation of technical design(s) and specifications, sufficient to co-ordinate components and elements of the project and *information for statutory standards and construction safety.*	3B Detailed Design Approval
Pre-Construction	F	Production Information	F1	Preparation of production information in sufficient detail to enable a tender or tenders to be obtained. *Application for statutory approvals.*	
			F2	*Preparation of further information for construction required under the building contract.*	
	G	Tender Documentation		*Preparation and/or collation of tender documentation in sufficient detail to enable a tender or tenders to be obtained for the project.*	
	H	Tender Action		*Identification and evaluation of potential contractors and/or specialists for the project.* *Obtaining and appraising tenders; submission of recommendations to the client.*	3C Investment decision
Construction	J	Mobilisation		Letting the building contract, appointing the contractor. Issuing of information to the contractor. Arranging site hand over to the contractor.	
	K	Construction to Practical Completion		Administration of the building contract to Practical Completion. Provision to the contractor of further Information as and when reasonably required. Review of information provided by contractors and specialists.	4 Readiness for Service
Use	L	Post Practical Completion	L1	Administration of the building contract after Practical Completion and making final inspections.	
			L2	Assisting building user during initial occupation period.	
			L3	Review of project performance in use.	5 Benefits evaluation

The activities in *italics* may be moved to suit project requirements, ie:

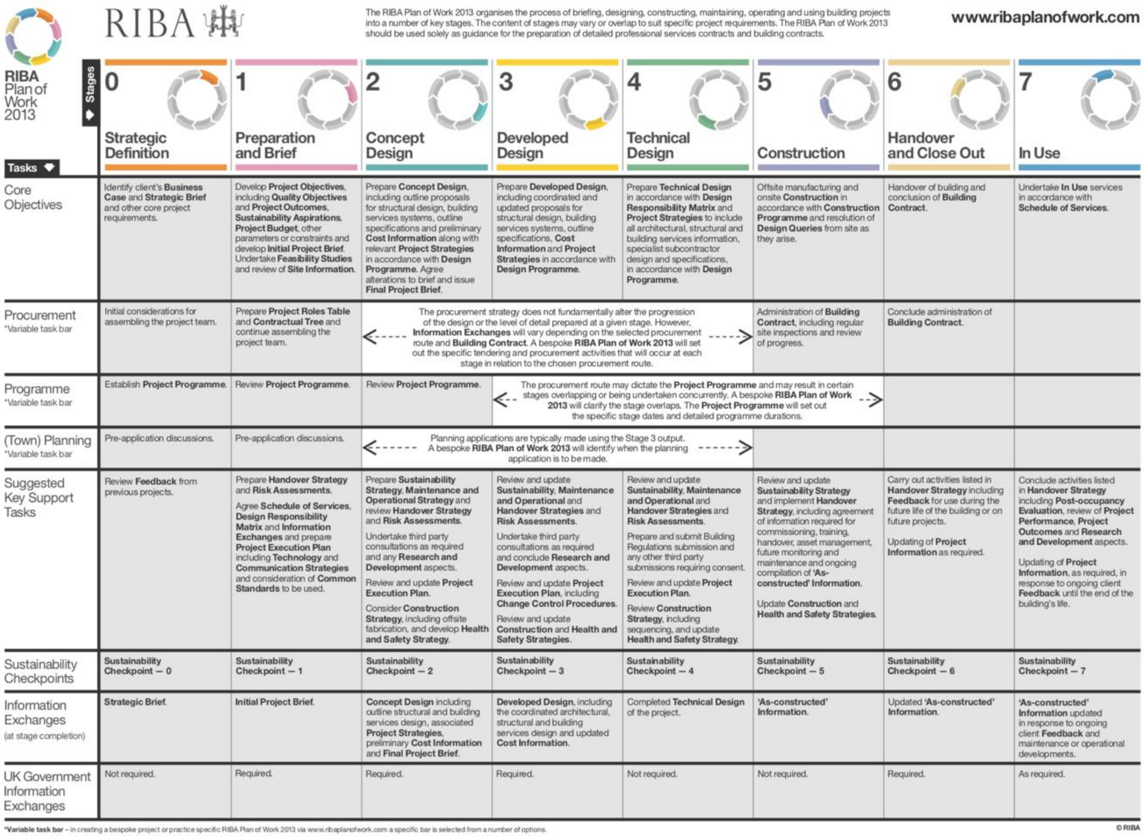
D *Application for detailed planning approval;*
E *Statutory standards and construction safety;*
F1 *Application for statutory approvals*; and
F2 *Further information for construction.*
G+H *Invitation and appraisal of tenders*

Royal Institute of British Architects — Page 1 of 3 — © RIBA 2007

Figure 44: RIBA Plan of Work (RIBA, 2007b)

In 2013, a new version of the RIBA Plan of Work was developed and released, demonstrating the overall review and development of the best business plan conducted since its inception. This new generation of RIBA contains sustainable design principles, offers a foundation to support BIM, encourages the integration of work between all project team parties, involves the construction team, and delivers flexibility to choose the most appropriate procurement route for the client. Thus, RIBA offered a significant contribution to the transformation of the construction industry in the United Kingdom which had great importance internationally (RIBA, 2013). RIBA's Plan of Work consists of eight stages: Strategic definition, preparation and brief, concept design, developed design, technical design, construction, handover and close out, and in use, as described in Figure 45.

Through this framework, the UK Government determined the need to improve the construction industry in terms of: better integration, greater efficiency, consideration of the principles of sustainability and providing an infrastructure to adopt Building Information Modelling (BIM). As a result, in 2011 and 2012 respectively, RIBA developed two versions of the Plan of Work, called Green Overlay, namely the RIBA Outline Plan of Work and a BIM Overlay to the RIBA Outline Plan of Work (Sinclair, 2012).



RIBA Plan of Work 2013

The RIBA Plan of Work 2013 organises the process of briefing, designing, constructing, maintaining, operating and using building projects into a number of key stages. The content of stages may vary or overlap to suit specific project requirements. The RIBA Plan of Work 2013 should be used solely as guidance for the preparation of detailed professional services contracts and building contracts.

www.ribaplanofwork.com

Stages / Tasks	0 Strategic Definition	1 Preparation and Brief	2 Concept Design	3 Developed Design	4 Technical Design	5 Construction	6 Handover and Close Out	7 In Use
Core Objectives	Identify client's **Business Case** and **Strategic Brief** and other core project requirements.	Develop **Project Objectives**, including **Quality Objectives** and **Project Outcomes**, **Sustainability Aspirations**, **Project Budget**, other parameters or constraints and develop **Initial Project Brief**. Undertake **Feasibility Studies** and review of **Site Information**.	Prepare **Concept Design**, including outline proposals for structural design, building services systems, outline specifications and preliminary **Cost Information** along with relevant **Project Strategies** in accordance with **Design Programme**. Agree alterations to brief and issue **Final Project Brief**.	Prepare **Developed Design**, including coordinated and updated proposals for structural design, building services systems, outline specifications, **Cost Information** and **Project Strategies** in accordance with **Design Programme**.	Prepare **Technical Design** in accordance with **Design Responsibility Matrix** and **Project Strategies** to include all architectural, structural and building services information, specialist subcontractor design and specifications, in accordance with **Design Programme**.	Offsite manufacturing and onsite **Construction** in accordance with **Construction Programme** and resolution of **Design Queries** from site as they arise.	Handover of building and conclusion of **Building Contract**.	Undertake **In Use** services in accordance with **Schedule of Services**.
Procurement *Variable task bar	Initial considerations for assembling the project team.	Prepare **Project Roles Table** and **Contractual Tree** and continue assembling the project team.	The procurement strategy does not fundamentally alter the progression of the design or the level of detail prepared at a given stage. However, **Information Exchanges** will vary depending on the selected procurement route and **Building Contract**. A bespoke **RIBA Plan of Work 2013** will set out the specific tendering and procurement activities that will occur at each stage in relation to the chosen procurement route.			Administration of **Building Contract**, including regular site inspections and review of progress.	Conclude administration of **Building Contract**.	
Programme *Variable task bar	Establish **Project Programme**.	Review **Project Programme**.	Review **Project Programme**.	The procurement route may dictate the **Project Programme** and may result in certain stages overlapping or being undertaken concurrently. A bespoke **RIBA Plan of Work 2013** will clarify the stage overlaps. The **Project Programme** will set out the specific stage dates and detailed programme durations.				
(Town) Planning *Variable task bar	Pre-application discussions.	Pre-application discussions.	Planning applications are typically made using the Stage 3 output. A bespoke **RIBA Plan of Work 2013** will identify when the planning application is to be made.					
Suggested Key Support Tasks	Review **Feedback** from previous projects.	Prepare **Handover Strategy** and **Risk Assessments**. Agree **Schedule of Services**, **Design Responsibility Matrix** and **Information Exchanges** and prepare **Project Execution Plan** including **Technology** and **Communication Strategies** and consideration of **Common Standards** to be used.	Prepare **Sustainability Strategy**, **Maintenance and Operational Strategy** and review **Handover Strategy** and **Risk Assessments**. Undertake third party consultations as required and any **Research and Development** aspects. Review and update **Project Execution Plan**. Consider **Construction Strategy**, including offsite fabrication, and develop **Health and Safety Strategy**.	Review and update **Sustainability**, **Maintenance and Operational** and **Handover Strategies** and **Risk Assessments**. Undertake third party consultations as required and conclude **Research and Development** aspects. Review and update **Project Execution Plan**, including **Change Control Procedures**. Review and update **Construction** and **Health and Safety Strategies**.	Review and update **Sustainability**, **Maintenance and Operational** and **Handover Strategies** and **Risk Assessments**. Prepare and submit Building Regulations submission and any other third party submissions requiring consent. Review and update **Project Execution Plan**. Review **Construction Strategy**, including sequencing, and update **Health and Safety Strategy**.	Review and update **Sustainability Strategy** and implement **Handover Strategy**, including agreement of information required for commissioning, training, handover, asset management, future monitoring and maintenance and ongoing compilation of **'As-constructed' Information**. Update **Construction** and **Health and Safety Strategies**.	Carry out activities listed in **Handover Strategy** including **Feedback** for use during the future life of the building or on future projects. Updating of **Project Information** as required.	Conclude activities listed in **Handover Strategy** including **Post-occupancy Evaluation**, review of **Project Performance**, **Project Outcomes** and **Research and Development** aspects. Updating of **Project Information**, as required, in response to ongoing client **Feedback** until the end of the building's life.
Sustainability Checkpoints	**Sustainability Checkpoint — 0**	**Sustainability Checkpoint — 1**	**Sustainability Checkpoint — 2**	**Sustainability Checkpoint — 3**	**Sustainability Checkpoint — 4**	**Sustainability Checkpoint — 5**	**Sustainability Checkpoint — 6**	**Sustainability Checkpoint — 7**
Information Exchanges (at stage completion)	**Strategic Brief**.	**Initial Project Brief**.	**Concept Design** including outline structural and building services design, associated **Project Strategies**, preliminary **Cost Information** and **Final Project Brief**.	**Developed Design**, including the coordinated architectural, structural and building services design and updated **Cost Information**.	Completed **Technical Design** of the project.	**'As-constructed' Information**.	Updated **'As-constructed' Information**.	**'As-constructed' Information** updated in response to ongoing client **Feedback** and maintenance or operational developments.
UK Government Information Exchanges	Not required.	Required.	Required.	Required.	Not required.	Not required.	Required.	As required.

***Variable task bar** – in creating a bespoke project or practice specific RIBA Plan of Work 2013 via www.ribaplanofwork.com a specific bar is selected from a number of options.

© RIBA

Figure 45: RIBA plan of Work stages (RIBA,2013)

In 2020, another version of the RIBA Plan of Work was released, which included the application of BIM and sustainability (RIBA, 2020). In this new release, the phases are similar to the previous version, but various procurement routes have also been embedded, taking into account some of the tasks and requirements of BIM and sustainability (see Figure 46). However, it lacks clear sequential processes and sub-processes, as well as clear roles and responsibilities of participants involved at each phase. So far, the RIBA Plan of Work for 2020 does not comply with the new BIM International standard ISO 19650 that was issued in 2019.

Nevertheless, the RIBA plan of work is not expected to be a contractual agreement. It characterises the results that the project team must accomplish at each phase, yet it does not specify who should attempt to conduct the main tasks. Project contract agreements are needed to carry clarity and consistency to the data required, who will deliver it and when it should be extricated from the design process for use in procurement or conversations with project stakeholders (RIBA, 2020).

According to RIBA (2020), there are several international plans of work that are widely used around the world, such as RIBA in the UK, ACE in Europe, AIA in USA, and APM (Global), all of which have the same purpose of providing the project team with a roadmap to enhance consistency from one stage to the next, providing necessary guidance to clients conducting maybe their first and only construction project. Although there are many international plans of work for projects, there is no clear and specific plan of work for projects submitted to engineers, contractors, and consultants in the construction industry in Kuwait. Therefore, there is no advanced framework for the design and construction process that includes all aspects (Lean, BIM, Sustainability, and roles and responsibilities for each project party) that could be applicable to the industry, especially in Kuwait. The author will consider this a starting point (or a guideline) for a new and updated framework.

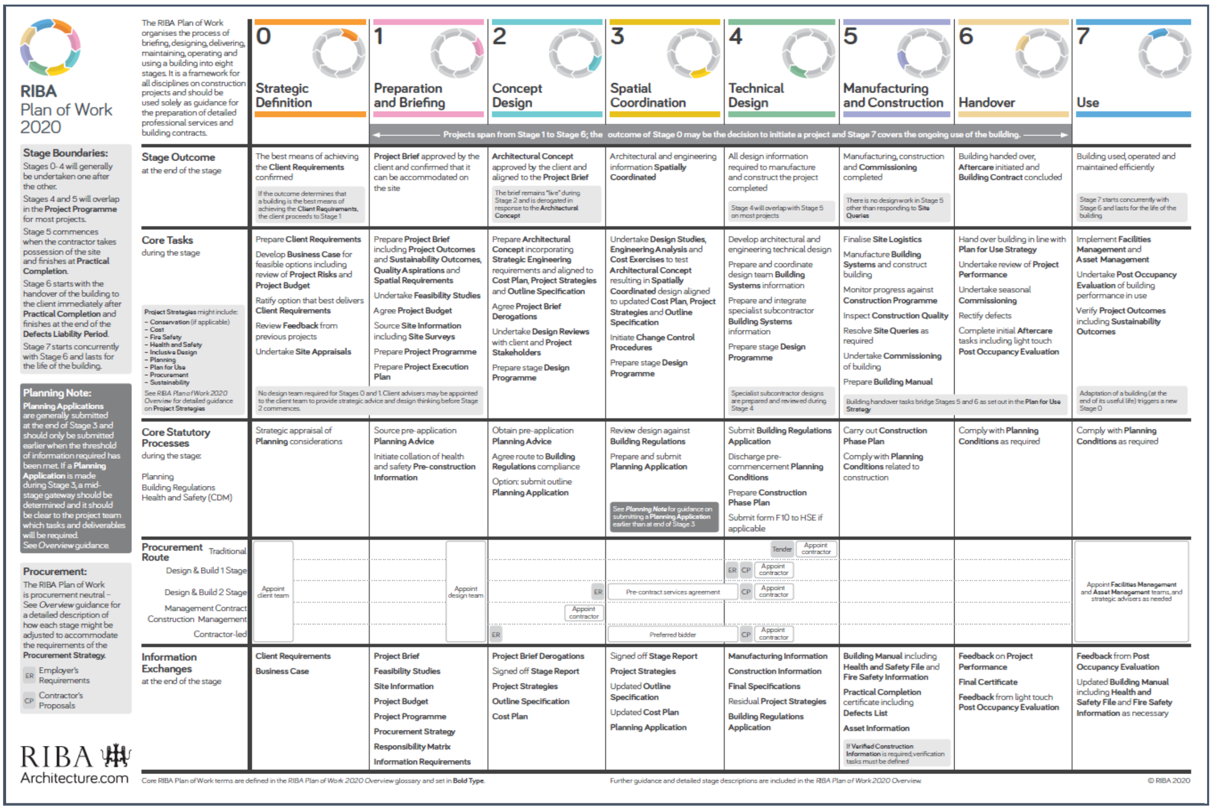


Figure 46: RIBA Plan of Work (the latest version)

3.5.1.2 The Generic Design and Construction Process Protocol (GDCPP)

The concept of the Generic Design and Construction Process Protocol (GDCPP) was inspired by the manufacturing industry. Kagioglou, Cooper, Aouad, and Sexton (2000) pointed out that this concept depends on a number of issues and insufficiencies in current construction industry practice enabling the identification of areas of improvement by studying and comparing the best practices of manufacturing project operations. To this end, the need for an appropriate model has been highlighted to address the different interests of all stakeholders involved in the construction process or to give an overall blueprint. Moreover, the design and construction processes should be part of a common process (model) that is better controlled through an integrated system (Kagioglou et al., 2000).

The Process Protocol is defined as "*a common set of definitions, documentation and procedures that will provide the basics to allow a wide range of organisations involved in a construction* *project to work together seamlessly", and purposes "to map the entire project process from the client's recognition of a need to operations and maintenance*" (Kagioglou et al., 1998). Kagioglou et al. (1998) stated that the purpose of the protocol was to offer a generic model or tool that could be adopted and applied regardless of variation in the details of a particular project, or simply put, a generic strategic management protocol.

The Generic Design and Construction Process Protocol (GDCPP) was developed by the University of Salford in 1998 to cover all phases of a construction projects, from feasibility to construction and operation (Sheath, Woolley, Cooper, Hinks, & Aouad, 1996), as shown in Figure 47. It is a high-level process map that was designed to deliver a framework to enable organisations to conduct an efficient design and construction process (Wu, Fleming, Aouad, & Cooper, 2001). The map was derived from the manufacturing industry, and in particular, Lean Philosophy. However, it was produced to mainly challenge the conventional approach of design, construction and procurement activities (Chan, Carmichael, Tzortzopoulos, & Cooper, 2004). The main objective of this process protocol was to improve design and construction processes by analysing existing building practices and adopting manufacturing practices, taking into account information technology as a support tool for model production (Kagioglou et al., 1998). According to Aouad et al. (1998), Chan et al. (2004), Kagioglou et al. (1998), Kagioglou et al. (2000) and Sheath et al. (1996), there are six key principles behind the development of the GDCPP, as follows:

- It requires a whole view of the project to encompass the entire lifecycle of the project from preparing the strategy to O&M.
- It implements the 'stage gate' method utilised in the New Product Development processes. Each process at each phase will be revised and authorised before moving to the next phase.

- It distinguishes the interdependence of tasks during the time of projects.
- It includes all project parties in every process of each phase to ensure that they get the right information at the right time. Defining project participants, their priorities, and needs allows an effective decision-making process during the lifecycle of the project.
- It supports the creation of multiple work groups at the early phases of the project where requirements for effective collaboration between project stakeholders are vital.
- It can provide feedback from each stage which implies that the success and failure of each stage can be recorded, revised and utilized throughout the process, thereby advising later stages and future projects.

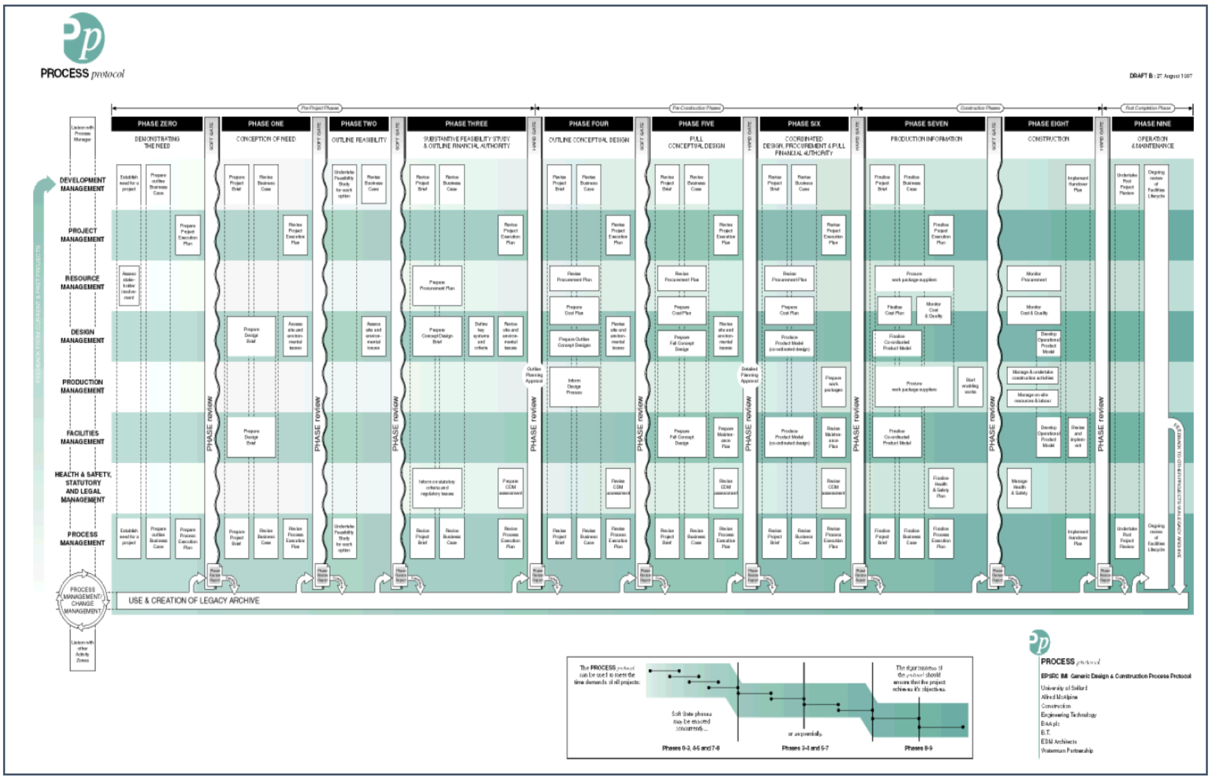


Figure 47: The GDCPP (Kagioglou et al., 1998)

As illustrated in Figure 47, the Process Protocol consists of four main stages, which are: Pre-project stage, pre-construction stage, construction stage, and post-construction stage. Furthermore, there are ten phases within these four stages (Kagioglou et al., 2000). In addition, there is an activity zone consisting of eight groups of participants involved in the stages, namely: Development management; project management; resource management; design management; production management; facility management; H&S, statutory, and legal management; and process management (Kagioglou et al., 1998).

At Stage 1, the Pre-Project Stage is equipped to explore or examine all project arrangements that will best meet the client's requirements, and to ensure that financial authority is identified to proceed with these arrangements. This stage consists of four phases, as follows:

- Phase 0: Demonstrating the Need
- Phase 1: Conception of need
- Phase 2: Outline feasibility
- Phase 3: Substantive feasibility study and outline financial authority

At Stage 2, the pre-construction stage transforms the customer's needs into a suitable project at different levels of accomplishment and ensures full financial authority to move forward. It includes three phases:

- Phase 4: Outline conceptual design
- Phase 5: Full conceptual design
- Phase 6: Coordinated design, procurement and full financial authority

At Stage 3, the construction sees the implementation of the structure, during which the final product is delivered. It consists of two phases:

- Phase 7: Production Management
- Phase 8: Construction

At the final stage (4); post-construction aims to manage the maintenance of the structure. It includes one phase, which is phase 9, operation and maintenance. Furthermore, there are several processes and sub-processes as well as outputs for each of the ten phases of this Process Protocol.

Although the GDCPP illustrated IT technology in the Process Map, BIM was not mentioned in the process protocol because it was developed prior to BIM. Thus, this research will focus on developing an updated Generic Design and Construction Process Protocol based on Lean and sustainable design principles and utilising BIM as the main platform to manage and control the process.

3.5.1.3 ISO 19650 International BIM standard:

The BIM standard ISO 19650 was developed based on the UK PAS 1192 standards; Publicly available specifications are guideline codes of practice or standards that are developed fast to fulfil the immediate needs of the industry (BSI, 2021). In 2013, the British Standards Institution published PAS 1192 part 2 standard, which included content related to the collaboration process in BIM projects including the roles and responsibilities of various stakeholders, specific naming convention templates, methodologies to facilitate effective data use/sharing and data management, graphical and non-graphical data and documents, and BIM maturity levels (BSI, 2013). Subsequently, this document was reviewed to form the existing ISO 19650 BIM standards published in 2018 (BuiltEvolve, 2021).

The ISO 19650 BIM standards were released to enable international asset owners and clients, particularly in the Middle East and Australia to recognise the benefits of BIM (Shillcock, 2019).

The ISO 19650 standard is an international standard for managing information over the entire lifecycle of a built asset using Building Information Modelling (BIM); it is also known as "*a series of international standards that define the collaborative processes for the effective management of information*" (BSI, 2019b).

BIM ISO 19650 encompasses all high-level concepts and necessities, such as the British BIM Framework and closely aligns with the existing UK 1192 standards (BSI, 2021). It includes definitions that improve communication, define quantitative and measurable targets and milestones in the BIM process, facilitate international collaboration on BIM projects, and help built environment professionals achieve more efficient and effective implementations of BIM models (BuiltEvolve, 2021).

There are positive outcomes gained from the accreditation of processes in the BIM ISO 19650, as mentioned by the UK BIM ALLIANCE. These are as follows (UKBIM Alliance, 2019, p.13):

- Clear definitions for the information required by the project or asset owner, and for the standards, approaches, processes, targets and procedures that will have control of its production and assessment.
- The quantity and quality of information produced is sufficient only to meet the specific information needs, without compromising health and safety or security.
- Efficient and effective transfer of information between project participants during the project lifecycle – particularly in projects and between project handover and asset operation.

According to BSI (2019b), BIM ISO 19650, the series consists of four documents, as follows:

- ISO 19650-1: Includes the principles, concepts, and terminology;

- ISO 19650-2: Includes delivery phase of the assets;
- ISO 19650-3: Focuses on the asset's operational phase;
- ISO 19650-5: Covers the security of information.

These reports incorporate activities, tasks, charts, and progressive approaches towards digital processes that uphold the information flow within the information management cycle; from the Project Information Model (PIM) to the Asset Information Model (AIM). The PIM and AIM are used during the asset life cycle when making decisions related to the project and asset (see Figure 48).

Key

A start of delivery phase — transfer of relevant information from AIM to PIM

B progressive development of the design intent model into the virtual construction model (see 3.3.10, Note 1 to entry)

C end of delivery phase — transfer of relevant information from PIM to AIM

Figure 48: The Generic project and asset information management lifecycle (ISO, 2018)

Therefore, the ISO 19650 documents are guidelines that define the concepts and principles of information management, make recommendations for a framework for information management, and provide a unified approach to information management. These documents apply to all types of assets and all types and sizes of organisations, regardless of the selected procurement strategy.

In BIM ISO 19650, several required deliverables or documents must be created throughout the processes at different stages of the project from various project parties, such as: Organisational Information Requirements (OIR), Project Information Requirements (PIR), Exchange Information Requirements (EIR), Asset Information Requirements (AIR), BIM Execution Plan (BEP), Responsibility Matrix (RM), Task Information Delivery Plans (TIDP), and the `Master Information Delivery Plan (MIDP).

3.5.1.3.1 Organisational Information Requirements (OIR):

Organisational Information Requirements (OIR) demonstrate the information expected to respond to or apprise high-level strategic objectives within the appointing party. OIR are the first step for all information management activities, and outline the high-level information needed by an organisation across its entire portfolio of assets and its various departments, such as human resources (HR), IT, finance, FM and production. The information requirements of all assets and departments should be modernised and embedded to help simplify the business (UB Alliance, 2019). These requirements can emerge for an assortment of reasons, which are strategic business operation, strategic asset management, portfolio planning, regulatory duties, or policy making (ISO, 2018). OIR is used to ensure the correct information is re-entered into the broader business function of the organisation to support strategic business decisions. Thus, it is an important resource for strengthening the organisation. These requirements should be established by the client or the asset owner (UB Alliance, 2019).

3.5.1.3.2 Project Information Requirements (PIR):

Similar to OIR, PIR is high-level and defines the information required for the main decision points as defined by the appointing party or client (ISO, 2018). Project Information Requirements are partially derived from OIR. They enable an understanding of the high-level information required from the client during a design and construction project (UKBIM Alliance, 2019). The UKBIM Alliance (2019) stated that PIR must be prepared by the appointing party (the client or asset owner) or their representative and must be specified within an OIR before any consultants or contractors are appointed.

3.5.1.3.3 Exchange Information Requirements (EIR):

EIR defines the administrative, commercial and technical aspects involved when producing project information. The administrative and commercial aspects must contain the information standard and the production methods and procedures that the delivery team must implement. The technical aspects of the EIR should determine those itemised parts of the information expected to answer the PIR. These needs should be expressed in such a way as to be included in the project nominations (ISO, 2018).

EIR usually must be in line with the operational events that represent the completion of some or all of the project's phases. This ensures that the correct information is delivered to the appointing party or lead appointed party in order to achieve the required tasks throughout the project (ISO, 2018; Kemp, 2020). Kemp (2020) emphasised that the EIR must be determined prior to every appointment and produced as part of the appointment process. For example, a client must produce an EIR before hiring any consultants, specialists or contractors, and the EIR must be prepared before any sub-contractor or specialists are appointed by the lead appointed party.

3.5.1.3.4 Asset Information Requirements (AIR):

AIR defines the administrative, commercial and technical aspects of producing asset information. The administrative and commercial aspects must contain the information standard, and the production methods and procedures that the delivery team has to implement. The technical aspects of the AIR should determine those itemised parts of information expected to answer the asset related OIR. These needs should be articulated in such a way that they could be incorporated into asset management arrangements to support organisational decision-making (ISO, 2018).

The AIR is generated from the OIR and produced in response to every incident triggered during the operation of the assets to ensure the correct information is delivered to the organisation and satisfies the built asset part of the OIR (ISO, 2018; Kemp, 2020). Kemp (2020) pointed out that the AIR is a significant organisational business activity to reinforce asset management, and design and construction contracts. In addition, she stressed that this report must be prepared by the appointing party (client) prior to any related appointment and led by the internal facility management team.

3.5.1.3.5 BIM Execution Plan (BEP):

The BIM Execution Plan (BEP) is an essential element of the preparation of any construction project that is implementing BIM. It described the required methods of collaboration and information exchange, including: the roles and responsibilities of project stakeholders; the software to be applied; the scope and LOD (Level of development) required of various features of the model at each phase for each design area; the management of the model itself; the quality control procedures; the object configuration, and the identification of conventions (Sacks et al., 2016).

BEP should be provided by a potential lead appointed party (designer or contractor) in their response to the bid. Kemp (2020) mentioned that there are two purposes of the BIM Execution Plan (BEP) which support the bidding, recruitment, and information delivery activities. These are as follows:

- Give evidence to the client or owner (appointing party) that the potential delivery team can manage project information in accordance with any information requirements provided to them; this is known as the “pre-contract BEP.
- Provide the delivery method that will be used to produce, manage, and share project information during the appointment together with other resources by the designer team or the contractor team (appointed party).

Consequently, even though there is only one BEP for each project, the designated party - whether designers or contractors - must provide two copies of the BEP to the client; one during the bidding phase, and the other to be updated during the appointment.

3.5.1.3.6 Responsibility Matrix (RM):

The Responsibility Matrix clearly defines the responsibility for producing the information and models for each specific phase of the project, and to the Level of Definition required. It must be developed throughout the project (The Scottish Government, 2018).

RM should be created as part of the information delivery planning process with one or more levels of detail. A Responsibility matrix should identify the following (ISO, 2018):

- Information management functions; and
- Either tasks to manage project information or assets, or information outputs as appropriate.

3.5.1.3.7 Task Information Delivery Plans (TIDP):

In the ISO 19650 part 2 (ISO, 2018), TIDP is referred to as a plan in which each team is responsible for a task (working group) must produce a plan for handing over information related to their business. It is a "*schedule of information containers and delivery dates, for a specific task team*" (BSI, 2019a, p.2). In fact, TIDP is not defined as a document, but rather as a resource that can be provided in different formats, such as: spreadsheets, project management software tools, and/ or other digital tools for management (Kemp, 2020).

3.5.1.3.8 Master Information Delivery Plans (MIDP):

MIDP is a plan that includes all relevant task information delivery plans (BSI, 2019a). According to Kemp (2020), the purpose of an MIDP is to identify the information expected for delivery by the delivery team, and this should be set against a coordinated programme that takes into account prototypes, accreditation, identified responsibilities, and review and approval periods that the lead appointed party is responsible for managing on behalf of the delivery team.

3.6 Summary

The various BIM and Lean frameworks in the construction industry were examined in this chapter. There is a lack of implementation of BIM and Lean in a structured manner as project parties, their responsibilities, tasks and outputs are identified and categorised into different phases of the project. According to Sacks et al. (2016), the attempt to implement BIM is complex; it requires the preparation of a strategy that takes into account organizational maturity, industrial capacities, regional and national policies and regulations, education, hardware and software procurement, changing contract forms and more. Besides, it is time to shift from "doing Lean" (using tools to minimize waste) to "becoming Lean" (focusing on people and problem solving) (Luckman, 2014). As a result, the researcher explored several business process management tools, in particular frameworks and process protocols for construction projects, such as the RIBA Plan of Work, the Generic Design and Construction Process Protocol, and BIM ISO 19650 (the new International BIM standard) in order to create an organised method for implementing BIM and Lean in construction projects. It is important to address client requirements, greater involvement from all project parties, and faster and more effective cycles of learning that are designed to solve problems and enhance the quality and value of the business. The researcher believes that BIM is a Lean tool because Lean principles can be achieved through the proper use of BIM. In fact, BIM requires a high level of collaboration and communication between stakeholders; thus, by creating a visible and clear process that can ease the planning and control of the project, it will improve the workflow and provide better value to the client. In order to simplify and avoid complication, Lean tools such as LPS will not be used in this research, instead, as mentioned earlier, BIM will be considered a Lean tool.

Therefore, the focus will be on achieving the better adoption of BIM processes by developing a framework or a process protocol based on BIM technology and Lean principles. The terms framework and process protocol will be used interchangeably in this study, as the basic structure upon which a system or concept is based and defines the various phases of a construction project.

Based on BIM ISO 19650 and the Process Mapping for construction projects (mentioned in this chapter), such as RIBA Plan of Work, and The Generic Design and Construction Process Protocol (GDCPP), a conceptual framework/process protocol was developed. This framework structure is derived from the GDCPP, which consists of phases, participants, processes/tasks, and deliverables (see Appendix 2). The conceptual framework or process protocol is a starting point and will be further developed during the empirical investigation.

Chapter 4: Research Design and Methodology

4.1 Introduction

The methodology presented in this chapter was implemented in order to accomplish the aim and objectives of this study. This chapter begins with an explanation of the research philosophy and approaches used in this research. This is followed by a discussion of the methodological selection, and clarification of the ways and methods to achieve the study goal and objectives. Then, the data collection and analysis procedures will be explored in order to determine the most appropriate procedures for this study. Next, the research study approach will be explained, and finally, an overview of the research design presented.

4.2 Research Philosophy and Approach

Research is "*an intensive and purposeful search for knowledge and understanding of social and physical phenomena*" (Kumar, 2008, p.1) and a systematic action to determine information, a philosophy, a concept or a purpose. A research methodology is a systematic strategy for conducting research that is designed to achieve the research aim and objectives. O'Leary (2004) believes that the research methodology outlines the techniques used to gather, investigate and explain information in order to acquire answers.

4.2.1 Research Onion

A research philosophy defines the way in which the researcher views the world, and some assumptions will reinforce the investigation process, which prompts the selection of an appropriate research methodology study. Saunders, Lewis, and Thornhill (2015) designed and developed the research onion to offer guidance to help the researchers set their research strategy. Therefore, it is important to understand each branch of philosophy in order to form a research strategy. Figure 49 illustrates the research onion and highlights the author's selection methods for this research.

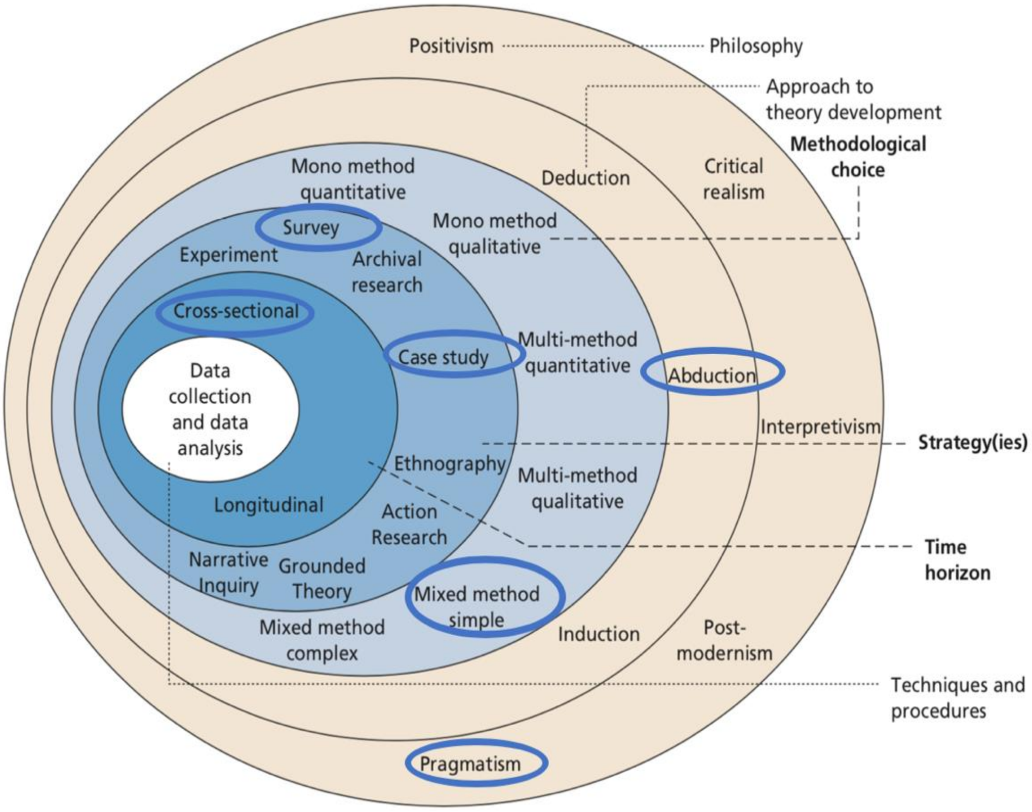


Figure 49: Research Onion and nominated methods (Saunders et al., 2015)

4.2.2 Research philosophy

A research philosophy is defined as a "*system of beliefs and assumptions about the development of knowledge*" (Saunders et al., 2015, p.124). According to Saunders et al. (2015), there are three branches of research expectations which differentiate research philosophies. These are as follows:

1. Ontology

This philosophy examines the nature of reality.

2. Epistemology

It is "*the theory of knowledge embedded in the theoretical perspective and thereby in the methodology*" (Crotty, 1998, p.3). "*Epistemology concerns assumptions about knowledge, what constitutes acceptable, valid and legitimate knowledge, and how we can communicate knowledge to others*" (Saunders et al., 2015, p.127).

3. Axiology

This branch of philosophy indicates the position of values and ethics in the research procedure. These assumptions will lead to choosing the most appropriate research philosophy in order to design the research strategy and achieve the aim and objectives of the study. The research onion is one way of presenting this, by positioning the philosophical research stance to help to design the research methodology (Hardman, 2017).

4.2.2.1 Objectivism and Subjectivism

Before positioning the philosophical stance, it is important to determine whether the researcher is taking an objectivist or subjectivist research position. Objectivism "*is an ontological position that asserts that social phenomena and their meaning have an existence that is independent of social actors*" (Bryman, 2012, p.33). Saunders et al. (2015) stated that objectivism informs the beliefs of natural science, claiming that the social reality that we examine is external to social actors. In comparison, subjectivism often informs the assumptions of the arts and humanities, which typically argue that social reality is made up of social actors' perceptions and their subsequent behaviours. Both objectivism and subjectivism have been described as polar on a continuum where they counter each other. From the three continua - or scales - of philosophy, the research paradigm for this study has been positioned, as shown in Figure 50.

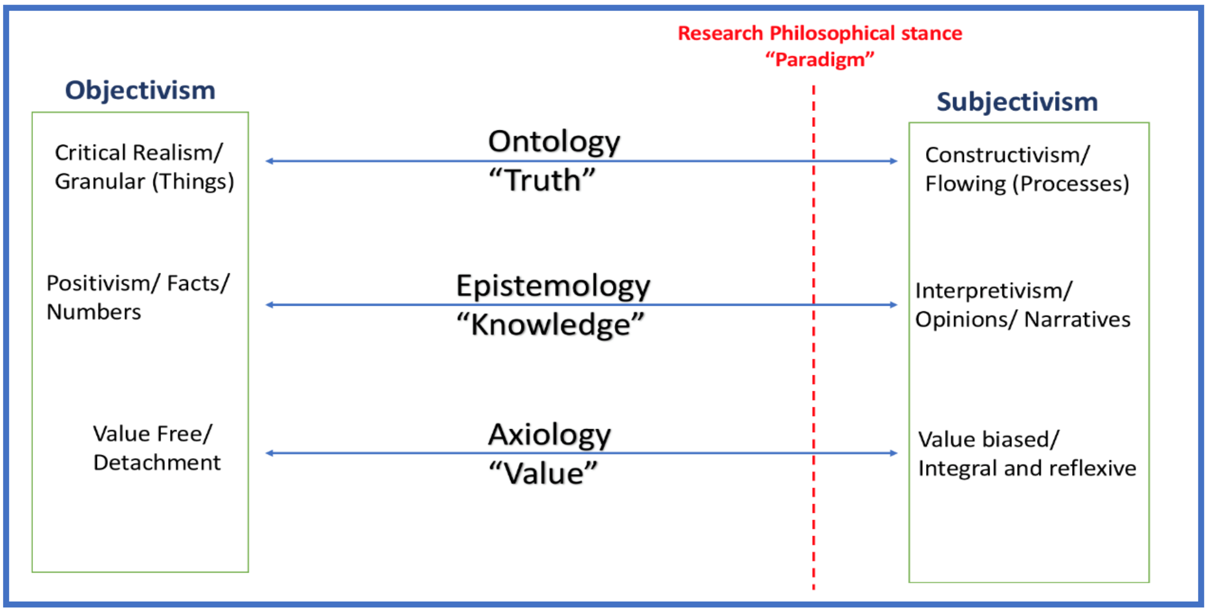


Figure 50: The Research Paradigm "Position" (adopted from Hardman, 2017; Saunders et al., 2015)

The study concerns the construction industry in Kuwait and investigates the challenges that Government projects face in this area and their ability of adopting Lean Construction and Building Information Modelling as an improvement proposal. The author aims to improve the performance of this industry by proposing a framework that contains roles and processes in order to address these risks and develop the industry. Therefore, people's opinions are important to determine these risks and evaluate the proposed improvement strategy. This research will have a significant value that will be reflected by the industry. Saunders et al. (2015) stated that the ontology of subjectivism is socially constructed, and its organisation involves flowing processes and chaos; consequently, the researcher adopts a subjectivist position in this study.

However, there are five major philosophies in business and management research. These philosophies are positivism, critical realism, interpretivism, postmodernism, and pragmatism (Saunders et al., 2015). In Table 25, a comparison between these philosophical assumptions is made. Moreover, based on the aim and objectives of the research, an appropriate philosophy has been chosen.

Table 25: A comparison between the five philosophies based on philosophy assumptions (adopted from Kelemen & Rumens, 2008; Saunders et al., 2015)

Philosophy	Description	Ontology (Nature of reality or being)	Epistemology (What constitutes acceptable knowledge)	Axiology (roles of values)	Typical methods
Positivism	Relates to the position of the natural scientist	Real, external, independent, universalism, Granular (things) Ordered	Scientific method, observable and measurable facts	Value-free research, Researcher is detached, neutral and independent of what researched	Typically deductive, highly structures, large samples, Quantitative
Critical realism	Focuses on explaining what we see and experience, in terms of the underlying structures of reality that shape the observable events	Stratified/ layered, External, independent Objective structures	Epistemological relativism, Knowledge historically situated and transient, Facts are social constructions, Historical causal explanation as contribution	Value-laden research Researcher tries to minimise bias and errors, Researcher is as objective as possible	Retroductive, in-depth historically situated, analysis of pre-existing structures and emerging agency. Range of methods and data types to fit subject matter.
Interpretivism	Focus on humans because they create meanings	Complex, rich, Socially constructed through culture and language, Multiple meanings, interpretations, realities, Flux of processes, experiences, practices	Theories and concepts too simplistic Focus on narratives, stories, perceptions and interpretations	Value-bound research Researchers are part of what is researched, subjective	Typically inductive. Small samples, in-depth investigations, Qualitative methods of analysis, but a range of data can be interpreted
Postmodernism	It emphasises the role of language and of power relations, seeking to question accepted ways of thinking and give voice to alternative marginalised views	Nominal, Complex, rich, socially constructed through power relations, Some meanings, interpretations, realities are dominated and silenced by others	Focus on absences, silences and oppressed/ repressed meanings, interpretations and voices	Value-constituted research, Researcher and research embedded in power relations Some research narratives are silenced at the expense of others	In-depth investigations of anomalies, silences and absences. Range of data types, typically Qualitative methods of analysis
Pragmatism	Pragmatism asserts that concepts are only relevant where they support action	Complex, rich, external 'Reality' is the practical consequences of ideas	'True' theories and knowledge are those that enable successful action Focus on problems, practices and relevance Problem solving and informed future practice as contribution	Value-driven research Research in initiated and sustained by researcher's doubts and beliefs	Following research problem and research question Range of methods: mixed, multiple, qualitative, quantitative, action research Emphasis on practical solutions and outcomes

After reviewing the five research philosophies, and based on the aim and objectives of this study, pragmatism was selected as the most appropriate philosophy. As Saunders et al. (2015) claimed, if the researcher concentrates on developing and enhancing their organisational practice, their study may tend towards pragmatism. They described a pragmatist's research as beginning with a problem and intending to provide practical solutions that apprise future implementation. Since the author focused on challenges to Kuwaiti construction projects and was planning to tackle these issues by producing a framework to improve the industry, the researcher tends towards pragmatism in this study.

4.2.3 Research Approach

After deciding which philosophy is the most suitable, it is necessary to pick the most appropriate approach to theory development. As shown in Figure 49, the research onion shows that there are three approaches to theory development, namely induction, deduction, and abduction. Goel and Dolan (2004) proved that thinking is a logical procedure that makes presumptions of given data. In theory, it frequently indicates the two mechanisms for thinking as the "deductive methodology" which leans upon testing a hypothesis, or "inductive methodology" that asserts another hypothesis. The deductive approach is called a "top-down" approach, which starts from the more thorough to the more specific. Figure 51 outlines the deductive and inductive workflow, and illustrates that the inductive approach workflow is counter to the deductive approach.

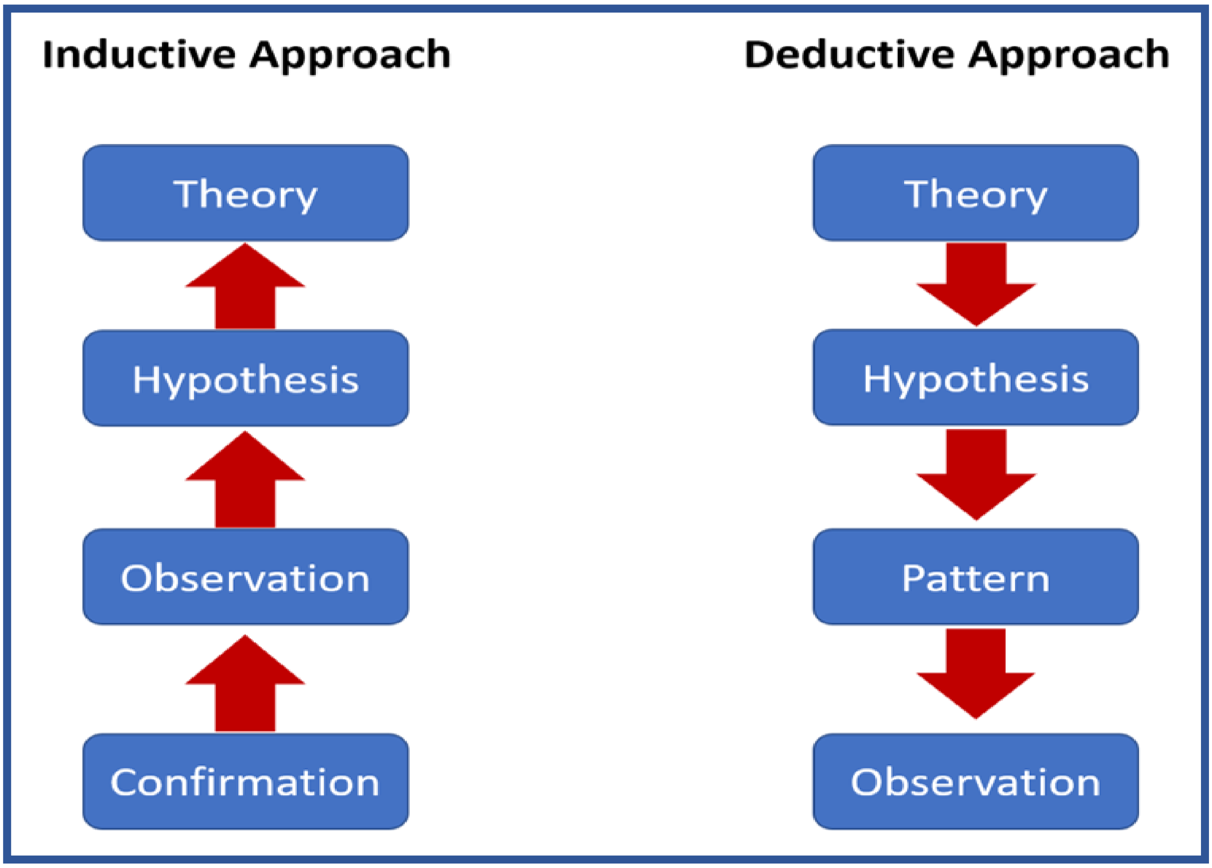


Figure 51: The steps of Deductive and Inductive adopted from (Danermark, Ekstrom, & Jakobsen, 2005; Kovács & Spens, 2005)

On the other hand, the abductive technique takes a different route, from rule to result to case. In addition, in abductive logic, the case presents a reasonable but not logically needed inference, if its estimated rule is accurate, and it can propose general rules (Danermark, Ekstrom, & Jakobsen, 2005; Kovács & Spens, 2005).

Dubois and Gadde (2002) described abductive reasoning as "theory matching" or "systematic combining" as it confirms the search for convenient theories to an experimental examination. In this method, data is gathered simultaneously to build a theory, which presents a learning loop or trend that moves back and forth between experimental and theoretical study (Dubois & Gadde, 2002; Kovács & Spens, 2005). Figure 52 explains three main approaches to theory development.

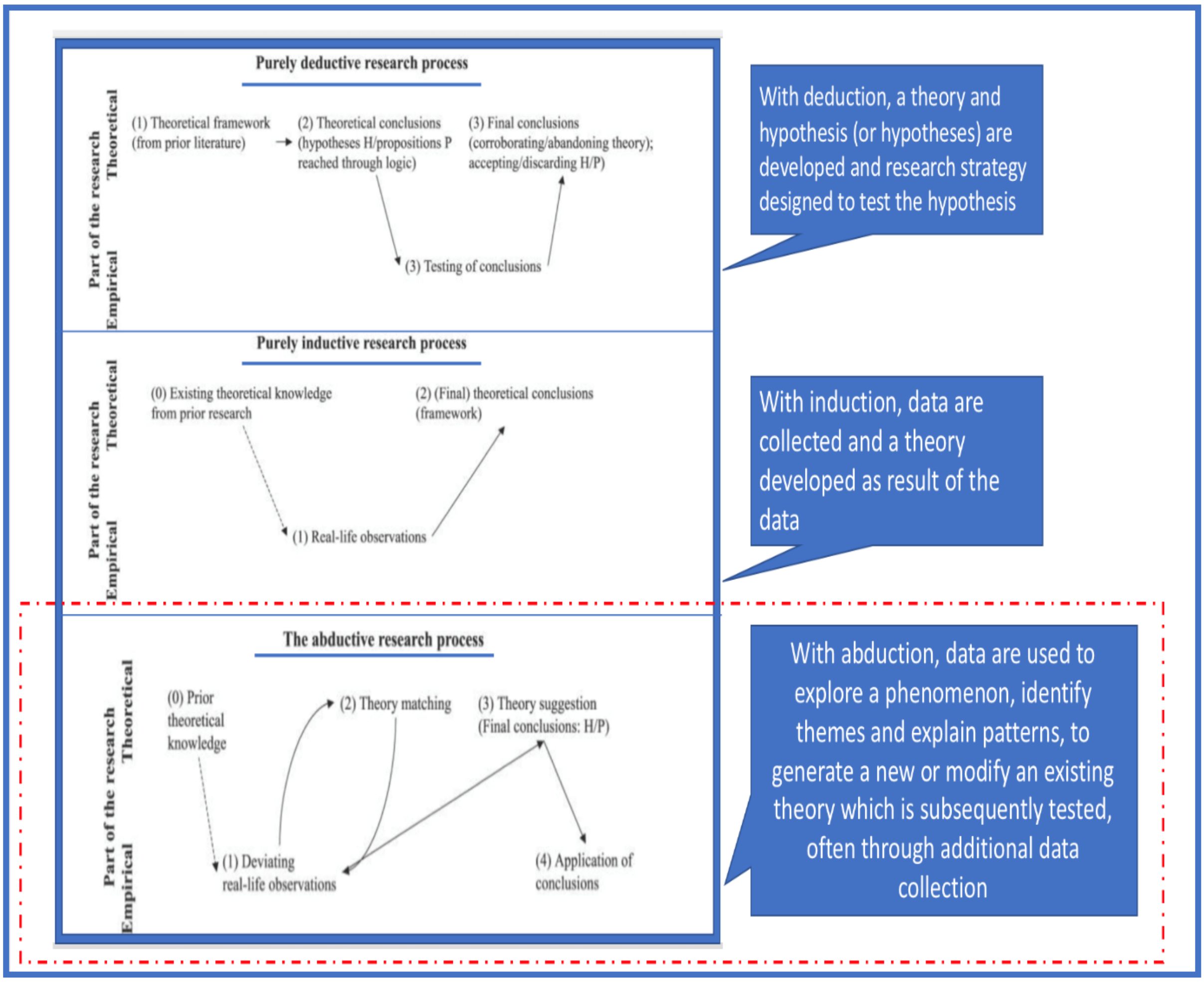


Figure 52: The three Main Approaches to theory development (Kovács & Spens, 2005; Saunders et al., 2015)

Mitchell and Education (2018) pointed out that pragmatists tend to adopt an abductive approach where they employ both deductive and inductive analysis in the same research study. Based on the research philosophy, the author chose abductive research for this study, as highlighted in Figure 52. In essence, the contribution of knowledge will be generated from existing literature on Lean Construction principles and Building Information Modelling application. Then, it will be designed and modified based on the selected context. Andreewsky and Bourcier (2000) believed that abductive research could lead to the proposal of general guidelines or strategies. So, the process for this research could be described as a cycle or a combination of both deduction and induction with the aim of generating inclusive guidelines. Accordingly, the abductive approach is more appropriate for this study.

4.3 Methodological choice

Methodology is "*the strategy, plan of action, process or design lying behind the choice and use of particular methods and linking the choice and use of methods to the desired outcomes. And the methods are the techniques or procedures used to gather and analyse data related to some research question or hypothesis*" (Crotty, 1998, p.3). Robson and McCartan (2016) indicated that there are two choices when conducting social research, namely quantitative or qualitative research.

- Quantitative research is defined as the investigation into citizens or a single matter. It inspects a theory or principle comprised of variables, computed with digits and estimated with statistical units, in order to determine if the theory is correct (Naoum, 2012).
- Qualitative research concentrates on meanings, as well as explanations and results that are described verbally or "non-numerally". There is neither numeric data nor statistical analysis (Robson & McCartan, 2016). Instead, it involves "*a subjective assessment of a situation or problem and takes the form of an opinion, view, perception or attitude towards objects. An object is referred to as an attribute, variable, factor or question*" (Naoum, 2013, p. 51).

Saunders et al. defined a third type called mixed methods research (2015, p.196):

- "Mixed methods research is the branch of multiple methods research that combines the use of quantitative and qualitative date collection techniques and analytical procedures". It is "the collection or analysis of both quantitative and qualitative data in a single study in which the data are collected concurrently or sequentially, are given a priority, and involve the integration of data at one or more stages in the process of research" (Gray, 2018, p.196). Moreover, there are several reasons for choosing a mixed methods design, as shown in Table 26.

Table 26: Reasons for using a mixed methods research design (Bryman, 2012; Saunders et al., 2015)

Reason	Explanation
Initiation	Initial use of a qualitative or quantitative methodology may be used to define the nature and scope of sequential quantitative or qualitative research. May also be used to provide contextual background and to better understand the research problem. May also help in the formulation or redrafting of research questions, interview questions and questionnaire items and the selection of samples, cases and participants.
Facilitation	During the course of the research, one method may lead to the discovery of new insights which inform and are followed up through the use of the other method.
Complementarity	Use of mixed methods may allow meanings and findings to be elaborated, enhanced, clarified, confirmed, illustrated or linked.
Interpretation	One method (e.g. qualitative) may be used to help to explain relationships between variables emerging from the other (e.g. quantitative)
Generalisability	Use of mixed methods may help to establish the generalisability of a study or its relative importance. In a similar way, the use of mixed methods may help to establish the credibility of a study or to produce more complete knowledge.
Diversity	Use of mixed methods may allow for a greater diversity of views to inform and be reflected in the study.
Problem solving	Use of an alternative method may help when the initial method reveals unexplainable results or insufficient data.
Focus	One method may be used to focus on one attribute (e.g. quantitative on macro aspects), while the other method may be used to focus on another attribute (e.g. qualitative on micro aspects).
Triangulation	Mixed methods may be used in order to combine data to ascertain if the findings from one method mutually corroborate the findings from the other method.
Confidence	Findings may be affected by the method used. Use of a single method will make it impossible to ascertain the nature of that effect. To seek to cancel out this 'method effect', it is advisable to use mixed methods. This should lead to greater confidence in your conclusions.

4.3.1 Justification for Choosing a Mixed Methods Research Design:

A mixed methods research design enables the researcher to design a single research study that answers questions about the nature of a phenomenon from the viewpoint of participants, whilst forging connections between measurable factors (Williams, 2007). It has been described as "*what seems to do to investigate, predict, explore, describe and understand the phenomenon*" (Mitchell & Education, 2018). Quantitative and qualitative research approaches are not only compatible but also complimentary, which emphasizes the need for research studies that deploy mixed methods (Johnson & Onwuegbuzie, 2004; Tashakkori & Teddlie, 2010). Saunders et al. (2015) emphasised that with abduction, data are gathered to investigate a phenomenon, categorise arguments, justify patterns, and to produce a new or adjust an existing system which is consequently verified - often through the collection of additional data. Also, pragmatists tend to adopt a mixed methods research design because they value both quantitative and qualitative research to achieve the aim of their study (Nastasi, Hitchcock, & Brown, 2010; Saunders et al., 2015). Therefore, a mixed methods research design is the most appropriate way to achieve the aim and objectives of this study. According to Table 26, a mixed methods research design will reinforce the findings of this study due to the following reasons:

1. Initiation

   The researcher uses mixed methods research to acquire a general background of the construction industry in Kuwait and reach as many participants as possible in order to understand the nature of the problem in this industry, challenges facing the industry in Kuwait, and the lack advanced project management approaches adoption (such as BIM and Lean Construction). This will help the researcher to identify cases for further investigation in order to develop an improvement-focused, BIM-driven Lean framework for the specified context.

2. Facilitation

During the research, mixed methods research may produce findings that involve new ideas and require the use of qualitative research to fulfil the research aim.

3. Complementarity

   By adopting a sequential mixed methods design, it will allow for explanations and results to be elaborated, improved, refined, assured, explained or linked.

4. Interpretation

   In this study, qualitative data will be used to help to explain relationships between variables arising from mixed (quantitative and qualitative) data.

5. Diversity

   Using mixed methods design will allow for a greater diversity of opinions to inform and be reflected in the research.

6. Problem solving

   Since the researcher aims to develop a framework to improve the performance of the construction project lifecycle in client organisations in Kuwait by applying Lean construction principles and BIM technology, the use of one method may be insufficient to produce this framework. Therefore, combining quantitative and qualitative data is more appropriate as it help to produce, evaluate, and validate the framework.

7. Focus

   The first phase of the data collection procedure, which is a mixed method, will focus on the challenges facing the construction industry in Kuwait, in particular public sector construction projects. Additionally, it will focus on the level of awareness and implementation both BIM and LC. While the second data collection phase, which involves qualitative data, will mainly focus on developing the BIM and Lean framework for this industry, besides explaining what the findings from the questionnaire.

8. Confidence

   Results might be influenced by the technique used. Using a solo method will make it impossible to ascertain the nature of that influence. To mitigate this "method influence", it is appropriate to use a mixed methods research design. This will enhance confidence in the conclusions.

4.3.2 Purpose of the Research Design Associated with the Research Methodological Choice:

The purpose of the research design (reasoning) relates to all research onion layers (shown in Figure 49). Saunders et al. (2015) discussed five purposes of the research design, as illustrated in Table 27.

Table 27: Purposes of the research design (Saunders et al., 2015)

Purpose of the research design selection	Definition	Research questions begin with	Data collection questions begin with	Use
Exploratory studies	It is a valuable means to ask open questions to discover what is happening and gain insights about a topic of interest.	They are likely to begin with 'What' or 'How'.	They also likely to start with 'What', or 'How'	An exploratory study is particularly useful if you wish to clarify your understanding of an issue, problem, or phenomenon, such as if you are unsure of its precise nature. There are a number of ways to conduct exploratory research. These include a search of the literature; interviewing 'experts' in the subject; conducting in-depth individual interviews or conducting focus group interviews. Because of their exploratory nature, these interviews are likely to be relatively unstructured and to rely on the quality of the contributions from those who participate to help guide the subsequent stage of your research.
Descriptive studies	It is to gain an accurate profile of events, persons, or situations.	They are likely begin with 'Who', 'What', 'Where', 'When', or 'How'.	Questions to gain a description of events, persons or situations will be likely to start, or include, 'Who', 'What', 'Where', 'When' or 'How'	Descriptive research may be an extension of a piece of exploratory research or a forerunner to a piece of exploratory research. Description in business and management research has a very clear place. However, it should be thought of as a means to an end rather than an end in itself. This means that if your research project utilises description it is likely to be a precursor to explanation. Such studies are known as **descripto-explanatory** studies.
Explanatory studies	It is to establish casual relationships between variables	They are likely to begin with 'Why' or 'How'	Questions that you ask during data collection will start with 'Why' or 'How'	To study a situation or a problem in order to explain the relationships between variables.
Evaluative studies	It is to find out how well something works.	They are likely to begin with 'How', or include 'What', in the form of 'To what extent'	Questions that seek an evaluative understanding, 'What', 'How' or 'Why'. As a part of this study, you may ask questions for making comparisons such as 'Which', 'When', 'Who', or 'Where'.	To evaluate something or performance and to make comparisons between events, situations, groups, places or periods. An evaluative study may produce a theoretical contribution where emphasis is placed on understanding not only 'how effective' something is, but also 'why', and then comparing this explanation to existing theory.
Combined studies	It is the combination of more than one purpose in research design.	-	-	This may be achieved by the use of mixed methods in the research design, to facilitate some combination of exploratory, descriptive, explanatory or evaluative research. Alternatively, a single method research design may be used in a way that provides scope to facilitate more than one purpose.

Saunders et al. (2015) explained that the prioritisation of quantitative or qualitative research depends on the purpose of the study. For instance, when qualitative research comes before quantitative research, it indicates an exploratory study. In contrast, in a descriptive study, quantitative research precedes qualitative research (Saunders et al., 2015). Based on the research aim and objective, there are four purposes for selecting mixed methods research and this is divided into two phases - exploratory and descriptive purposes, then explanatory and evaluative purposes.

For exploratory and descriptive reasoning, mixed methods research will first examine what was found in the literature regarding challenges facing the industry and the lack of awareness and implementation of Lean Construction and BIM. It provides a contextual background and a clear understanding of the research problem. According to Saunders et al. (2015), the survey strategy tends to be used with exploratory and descriptive research, and a questionnaire is a common method of data collection for this strategy. Therefore, a questionnaire survey will be conducted to collect both quantitative and qualitative data for the first phase of data collection. The reason for using a survey strategy for mixed research is that the questionnaire will contain some qualitative elements, although they are essentially quantitative. This questionnaire aims to explore the current situation of the construction industry in Kuwait in terms of the challenges facing this industry concerning their knowledge and awareness of Lean Construction and BIM. Moreover, it will describe the nature of the challenges in this industry, how BIM is being implemented (its maturity level, benefits, and barriers), Lean Construction and Lean waste.

However, the researcher started scoping this study with an exploratory study by systematically reviewing the literature to explore the challenges facing the construction industry in public sector construction projects in Kuwait. Additionally, finding the gap in knowledge in Lean principles, Building Information Modelling applications, and by investigating different process protocol and framework approaches to improve the performance of the construction industry in Kuwait.

In qualitative research, explanatory and evaluative studies are conducted after a questionnaire, because the selection of cases depends on the results of the first phase (questionnaire) when seeking to gain in-depth knowledge. This will help to explain and evaluate the findings for the questionnaire, as well as enable the development of an improvement framework for the construction industry in Kuwait, specifically in the public sector. Saunders et al. (2015) mentioned that semi-structured interviews can be carried out for an explanatory purpose to explain and understand the connections between variables. Similarly, semi-structured interviews can be used for an evaluative study to clarify the relationships between the standards for evaluation or effectiveness. Consequently, these studies will be carried out through semi-structured interviews along with secondary data collection such as documents. Moreover, this will validate the findings of the questionnaire and help to produce and evaluate the proposed framework. Finally, a structured interview will be conducted to verify and update the proposed process protocol/framework, and thus generate the final version. Accordingly, the aim and objectives of this research will be accomplished.

4.3.3 Research Strategy

Table 28 illustrates a summary of extant research strategies. The purpose of the research strategy is to attain the aim of the study through a plan that details how the data should be gathered.

Table 28: Research strategies (Source: Saunders et al., 2015)

Research Strategy	Definition	Research Design
1. Experiment	A form of research that owes much to the natural sciences	Quantitative Research
2. Survey	This technique is used to collect information from a large number of participants and it also uses to answer who, what, where, how much, and what number of inquiries. It tends to be used for **exploratory** and **descriptive research**. In addition, it is usually related to a **deductive research approach**. A Data collection technique includes: **Questionnaire**, Structured observation, and Structured Interviews	Quantitative Research
3. Archival and Documentary Research	It is digital data that creates online archives. It includes textual documents, visual and audio sources. **Textual document**: communications between individuals or within groups such as (email, letter, social media and blog), organisational and government sources. **Visual and audio sources:** Pictures, videos, web images	Quantitative, Qualitative, and Mixed Methods Research
4. Case Study	It is an in-depth inquiry into a topic or phenomenon within its real-life setting. A case study strategy has the capacity to generate insights from intensive and in-depth research into the study of a phenomenon in its real-life context, leading to rich, empirical descriptions and the development of theory (Dubois and Gadde 2002; Eisenhardt 1989; Eisenhardt and Graebner 2007; Ridder et al. 2014; Yin 2014). **In case studies, combination of archival records and documentation, different forms of observation, Ethnography, Interviews, Focus groups, and questionnaires.**	Quantitative, Qualitative, and Mixed Methods Research
5. Ethnography	It is used to study the culture or social world of a group.	Qualitative Research
6. Action Research	It is an emergent and iterative process of inquiry that is designed to develop solutions to real organisational problems through a participative and collaborative approach, which uses different forms of knowledge, and which will have implications for participants and the organisation beyond the research project (Coghlan 2011; Coghlan and Brannick 2014).	Qualitative Research
7. Grounded Theory	Theory that is discovered through systematic data collection	Qualitative Research
8. Narrative Inquiry	Interpreting sequence of events. It seeks to preserve chronological connections and the sequencing of events as told by the narrator (participant) to enrich understanding and aid analysis.	Qualitative Research

Based on the methodology selection (refer to the research onion, Figure 49), survey and case study strategies were selected to fulfill the research aim and objectives, as highlighted in Table 28.

A survey is a method commonly used to collect data in a quantitative form. Cohen, Manion, and Morrison (2002) claimed that the survey is an appropriate technique for gathering data when determining relationships between variables at a given time. Additionally, it is used when it is impossible to observe or test human behaviour, and to collect data regarding individuals and their thoughts, beliefs, actions, etc. (Martin & Guerin, 2006).

The researcher began by conducting a survey to collect evidence from a large number of participants and to answer research questions. It enabled participants to describe the nature of the challenges in this industry and to understand the existing situation of BIM and LC approaches and their maturity levels, benefits and barriers. In accordance with the aim and objectives of this study, the survey was used to descibe current practices, major challenges, and the awareness and application of BIM and Lean Construction in the construction industry in Kuwait. In contrast, there were some open-ended items in this survey, so it entailed a mixed methods approach. Thus, the researcher acquired a better understanding of this industry and a clear vision of the nature of the challenges and adoption of the aforementioned project management approaches. At this point, the first four objectives were achieved.

Saunders et al. (2015) stated that a case study strategy could involve multiple cases because the use of more than one case considers whether results could be duplicated across cases. Therefore, a multiple case study approach was selected to gain in-depth knowledge about the situation, to explain the relationships between variables, and develop a process protocol or framework. Indeed, an in-depth investigation can be designed in a case study to detect what is happening and why, and to understand the consequences of the condition and implications for action (Saunders et al., 2015). Since the selection of cases depends on the survey results, cases were selected with caution after analysing survey data on the basis that comparable findings were expected to be generated from each.

4.3.4 Research Time Horizon

There are two types of time horizon for research as outlined by Saunders et al. (2015) and shown in Figure 53; these are cross-sectional and longitudinal.

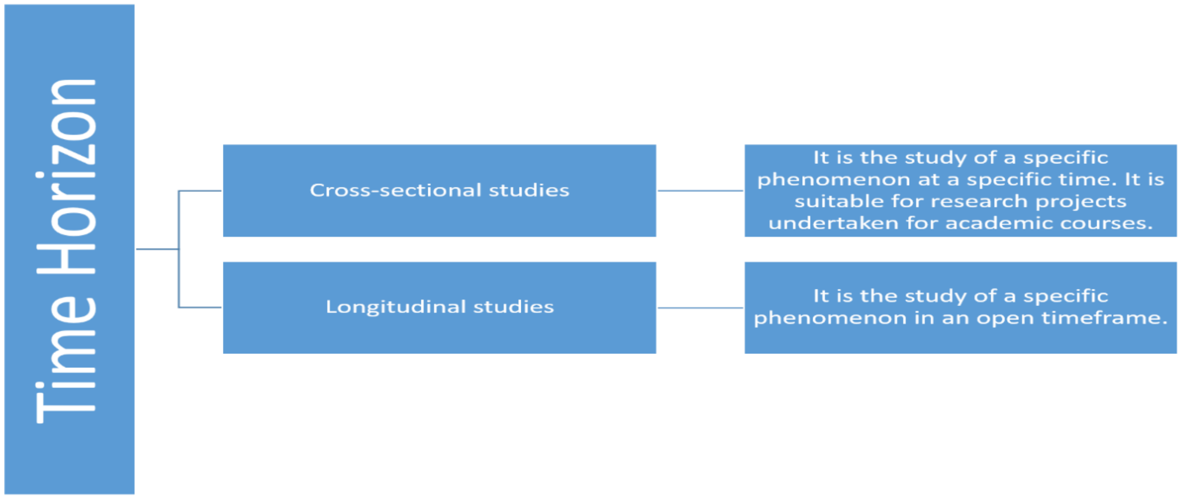


Figure 53: Research time horizon (Source: Saunders et al., 2015)

As the researcher is constrained by a limited period of time, a cross-sectional time horizon was the most appropriate choice for this study.

4.4 Data Collection and Analysis Procedures

Data collection techniques allow for a systematic selection of the best structure of both secondary data and primary data in the field of research. Data collection techniques might involve objects, humans, and phenomena as they occur in the research. Both primary and secondary data were gathered for this study. After the establishing the fundamental elements of a study concerning its philosophical stance, it is essential to understand how the selection of specific methods will accord with the research philosophy and approach. The purpose of data collection is to fulfil the aim and objectives as well as answer the research questions. There are two types of data collection - secondary data and primary data (Hox & Beoije, 2005).

Secondary data is a second-hand data (Bryman, 2012), and could be quantitative or qualitative that have been collected by other scholars for causes other than its intended use in the actual research (Ellram & Tate, 2016). There are many forms of secondary data, although the most frequently used are existing literature, census data, government statistics, financial information, organisational reports and archives (Lind, Pirttilä, Viskari, Schupp, & Kärri, 2012). Saunders et al. (2015) explained that secondary data includes documents (websites, videos, images, etc.), survey, and multiple other sources (such as industry statistics and report, etc.). This type of data provides a foundation that assists the researcher to acquire a full understanding of the subject.

In contrast, primary data are gathered for the particular research problem by employing procedures that appropriately address the research problem (Hox & Beoije, 2005). They are collected by the researcher through different methods, such as observation, questionnaire, semi-structured interview, in-depth interview and group interview (Saunders et al., 2015). In this study, primary data includes quantitative and qualitative data; these were gathered through a questionnaire follow by semi-structured interviews which aimed to answer the research questions. Finally, structured interviews were conducted to verify and update the proposed process protocol/framework. Figure 54 illustrates each data collection method and its purpose.

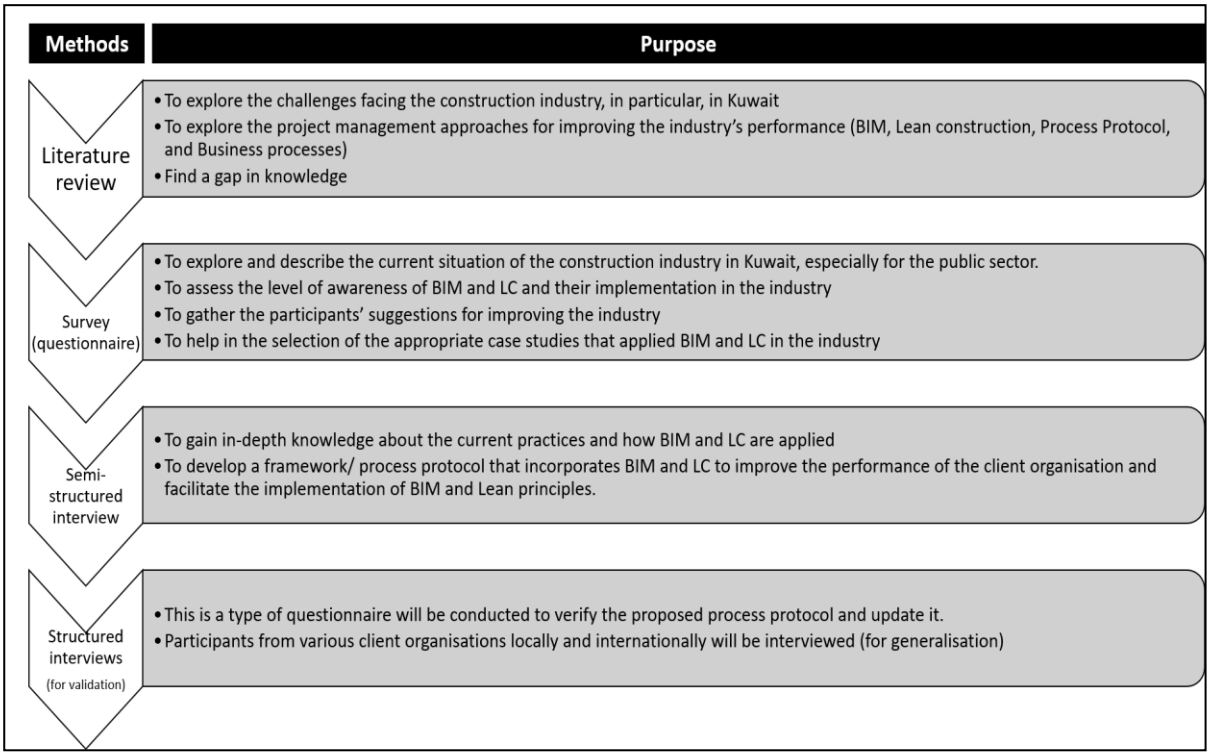


Figure 54: Methods of collecting data and its purpose

4.4.1 Sampling for Mixed Methods Research:

A sampling procedure is the process whereby the researcher determines the research location, the characteristics of participants who will provide the data, how they will be selected, and the number of participants needed to answer the research questions (Creswell & Clark, 2017). Creswell and Clark (2017) claimed that these data collection stages apply both to quantitative and qualitative research, although there are major differences in how they are normally addressed in terms of sampling size and procedure. According to Bryman (2012) and Saunders et al. (2015), there are two types of sample, probability and non-probability. A probability sample includes a simple random sample, systematic sample, stratified random sampling, and multi-stage cluster sampling. While a non-probability sample includes a quota sample, purposive sample, volunteer sample, and haphazard sample. Saunders et al. (2015) mentioned that, if the target population is known, probability sampling is typically used, while non-probability sampling means the target population is unknown. Nevertheless, a final sample size is not fixed until the study is carried out to confirm that an adequate database has been gathered to evolve an in-depth understanding, which is referred to reaching a saturation point (Creswell & Clark, 2017).

4.4.2 Data Analysis for a Mixed Methods Research Design

In a mixed methods research design, data analysis involves the separate analysis of quantitative data with quantitative techniques and qualitative data with qualitative techniques (Creswell & Clark, 2017). Creswell and Clark (2017) mentioned that there are similar procedures to analyse both quantitative and qualitative data, which are: preparing the data for analysis, exploring the data, analysing the data, representing the analysis, interpreting the analysis, and validating the data and interpretating the results.

4.4.3 The First Data Collection Procedure Phase: Quantitative Data

4.4.3.1 Questionnaire

A questionnaire was used for the first primary data collection phase of this research to collect quantitative data. The questionnaire is generally considered the main method for conducting a survey, especially for business and management research (Saunders et al., 2015). It is a relatively quick and cheap way to gather data on a particular issue from a large number of individuals and gathers answers to the same questions from all the individuals surveyed (Bryman, 2012). Gray (2018) claimed that the questionnaire method allows for more confidentiality that permits participants to express themselves freely. There are two types of questionnaire typically applied - self-completed and interview-completed. Saunders et al. (2015) described these types as follows:

- Self-completed questionnaires are normally completed by the participants and are often referred to as surveys. This type of questionnaire could be distributed to participants across the Internet (Internet questionnaire); respondents can either access the questionnaire using their web browser via a hyperlink (Web questionnaire) or straightway through a QR (quick response) code scanned into their mobile device (mobile questionnaire). Otherwise, a postal questionnaire can be mailed to respondents who return it by mail after completion; alternatively with a delivery and collection questionnaire respondents receive the questionnaire by hand and it is collected later.
- Interviewer- completed questionnaires are recorded by the interviewer who records each interviewee's answers. It includes a telephone questionnaire and face-to-face questionnaire. Telephone questionnaires are conducted using the phone, while in face-to-face questionnaires interviewers physically meet interviewee and ask questions face-to-face (structured interviews).

In this study, the purpose of the questionnaire is to understand the current situation of the construction industry performance in Kuwait and investigate the type of advanced project management approaches, such as Lean Construction and BIM, used including how they are implemented. Thus, the questionnaire will be used to explore the awareness of BIM and Lean Construction along with the main challenges facing this industry. The author was constrained by the limited time available and was obligated to stay in the UK during her studies. Thus, the Internet and digital media were more appropriate for this study. According to the Internet World Stats (IWS), 99.8% of the total population in Kuwait are internet users. As this study focuses on Kuwait, a self-completed questionnaire was selected; in particular, an Internet questionnaire was deemed the most convenient option for this phase of the research. Thus, the questionnaire was distributed online via a hyperlink to practitioners in the construction industry in Kuwait.

The author used LinkedIn (a large professional networking platform), social media and her contact list to reach as many respondents as possible. However, this helped the researcher to obtain a large sample size in a short time, while the data input was automated (Saunders et al., 2015), easy to export and converted to a compatible file for the analysis software. Moreover, it easy to complete at any time anywhere (using smartphones, laptops, PCs, etc.).

4.4.3.2 Types of Variables

Saunders et al. (2015) pointed out that it is essential to determine the theories you desire to test as relationships between variables before designing your questionnaire. Similarly, Ghauri and Grønhaug (2005) argued that the researcher should carefully review literature, discuss ideas widely, and conceptualise the research before designing the questionnaire. Specifically, researchers should have a clear idea of which relationships are most likely to exist between the variables (Saunders et al., 2015, p.444):

- A dependent variable that changes in response to change in other variables;
- An independent variable that causes changes in a dependent variable;
- A mediating variable that transmits the effect of an independent variable to a dependent variable;
- A moderating variable that affects the relationships between an independent variable and a dependent variable.

These relationships can be tested through statistical analysis of the questionnaire. According to Dillman, Smyth, and Christian (2014), there are three types of variables that could be addressed by a questionnaire:

- o Factual or demographic

Contains readily available data for the respondent and is likely to assume that the respondent is willing to disclose them and to be accurate. These variables include characteristics such as age, gender, marital status, education, occupation and income.

- Attitudes and opinions.

Involves data that participants may need to consider before answering. They are probably affected by the context in which the question was asked, capturing how participants feel about something or what they think or believe to be true or false.

- Behaviours and events

Possibly affected by context. This includes data about people's behaviours (what they did) or events (what happened in the past), what is happening now, or will happen in the future.

4.4.3.3 Designing the Questionnaire

The questionnaire was designed to address the research objectives and identify the factors impacting the performance of the construction industry in Kuwait. As the Internet questionnaire was selected for this study, there are numerous platforms to design an online questionnaire, such as SurveyMonkey, SmartSurvey, etc. However, the author chose eSurveyCreator platform to design the online survey due to its support to the University of Salford, which made it a more reliable platform. It offers a free package that includes all the features needed to design the questionnaire.

The questionnaire was designed based on the factors derived from a review of the literature. It included 29 questions and was divided into seven sections, ensuring that the questionnaire was designed in an ordered way:

- In the first section, questions focused on the respondent's profile, which included the type of industry sector they represented (client, contractor, consultant, or educational institution), their job function in this sector, years of experience, and whether they work on public projects or not.

- The second section focused on the challenges or problems facing this industry that have an impact on its performance. It was examined through using Key Performance Indicators (KPIs), which included: time, cost, waste, communication, productivity, accidents, project management practice and site management, experience and qualifications, the use of new technologies, planning and control, and the number of variations.
- In the third section, the focus was on Lean Construction, and investigated its status and application in Kuwait, whilst also examining Lean waste in construction projects.
- The fourth section was based on the implementation of Building Information Modelling (BIM), including its maturity levels, the types of adopting projects, the level of awareness and experience in BIM amongst practitioners, and BIM training.
- The next section measured the synergies between Lean Construction and BIM functions, how they could complement each other and contribute to improved performance.
- The last two sections were about the drivers and barriers to BIM implementation in the construction industry in Kuwait, as collected from the literature review. Major drivers and barriers to implementation were put in separate matrix questions and these questions were measured using a Likert Scale. Moreover, participants were asked whether adopting a BIM-driven Lean Construction Process Protocol/framework would improve the industry or not, and which party should be responsible for that implementation. Finally, participants were asked to submit their suggestions to improve the performance

of the construction industry in Kuwait, especially for the public sector. It was an open-ended question that included qualitative elements in order to gather more in-depth information.

4.4.3.4 Sampling for Questionnaire

Creswell and Clark (2017) suggested that the ideal strategy in quantitative research was probability sampling and in particular, random sampling, in which the intent is to choose a large number of people who represent the population, or part of the population based on a systematic procedure.

A sampling frame is necessary for any probability sample; without it, it is impossible to choose a probability sample when a non-probability sample can be considered instead (Saunders et al., 2015). Saunders et al. (2015, p.277) defined the sample frame as "*a complete list of all the cases in the target population from which your sample will be drawn*". Since the study focused on describing the performance of the construction industry in Kuwait, the sample frame of the questionnaire included engineers, architects, and professionals who were involved in public projects including clients, consultants, and contractors. According to the Central Statistical Bureau in Kuwait, the percentage of employees in the construction industry is 12.2% from an active population of 2,418,734 (CSB, 2015); thus, the number of people in the construction industry is around 295,085 people. Saunders et al. (2015) stated that a sample size for a 100,000 target population at a 95% confidence level is 383. Therefore, the target population that the researcher aimed to collect was around 383. However, the researcher used random sampling because it was distributed online using a professional platform called LinkedIn to reach the target population, along with the author's contacts in this field. Furthermore, the questionnaire hyperlink was distributed via email and social networking applications, such as WhatsApp Messenger, Facebook groups, etc

4.4.3.5 Pilot Survey

The questionnaire questions derived from and were designed according to the literature review findings, so it is important to test these questions before the survey. A pilot study is necessary for a self-completion questionnaire in order to clear up any ambiguity, which cannot be addressed by the interviewer who is absent (Bryman, 2012). It enables the researcher to verify that all the related topics are included, the order is accurate, vague or leading questions are recognised, the pre-codes are precise, and that any subjects which may be essential to the respondent are not neglected or forgotten (Secomb & Smith, 2011).

Thus, the researcher carried out a pilot survey with a group of colleagues and friends in this field to test and judge the difficulty and relevance of the information explored in the questionnaire questions. Moreover, a pilot study was used for the final draft of the questionnaire before it was distributed across the construction industry in Kuwait. Additionally, this draft was evaluated and validated by the researcher's supervisor. The pilot survey showed that the questionnaire could be completed in 15 minutes.

4.4.4 Presenting and Analysing Questionnaire

4.4.4.1 Types of data

It is important to understand the differences between types of data when analysing quantitative data in order to avoid any misleading information while using data analysis software that could produce little value from the data. Thus, it enables a more accurate the scale of measurement, and a greater the range of analytical techniques (Saunders et al., 2015).

According to Saunders et al. (2015), there are two types of quantitative data: categorical and numerical. Categorical data cannot be statistically measured but can be categorised into groups based on the characteristics that distinguish or describe the variable or rank order, whereas numerical data are values which are numerically counted or measured as quantities (Brown & Saunders, 2007). Table 29 illustrates the types of variable in each group.

Table 29: Types of Quantitative Data

Quantitative Data Group	Data type	Description
Categorical Data	Descriptive/ nominal Data	It is impossible to define the category numerically or to rank it
	Dichotomous Data	It is a descriptive data where there are only two categories. variable is divided into two categories, such as the variable gender being divided into female and male.
	Ranked/Ordinal Data	It is a more precise form of categorical form. It includes Rating and scale questions where a respondent is asked to rate how strongly agrees with a statement, collect ranked (ordinal) data.
Numerical Data	Interval Data	It is the difference or interval between any two data values for particular variable, but you cannot state the relative difference. For example, the Celsius temperature scale
	Ratio Data	You can calculate the relative difference or ratio between any two data values for a variable.
	Continuous Data	It is data whose values can theoretically take any value (sometimes within a restricted range) provided that you can measure them accurately enough (Dancey and Reidy 2011). Data such as furnace temperature, delivery distance and length of service are therefore continuous data.
	Discrete Data	It is data can be measured precisely. Each case takes one of a finite number of values from a scale that measures changes in discrete units. These data could be integers value (e.g. the number of mobile telephones manufactured, or customers served), on non-integer values (e.g. UK shoe size)

As highlighted in Table 29, the research uses categorical data. The questionnaire was designed based on literature and the research questions and mainly consisted of closed ended questions. These types of questions - known as forced-choice questions - offer a number of different answers from which the respondent is instructed to select. It includes six types of questions: list, category, ranking, rating, quantity and matrix (Saunders et al., 2015). The researcher used four of them, namely list, category, rating (Likert-scale), and matrix questions. The questionnaire consisted of 29 questions: ten of them were category question, 13 were list questions, five were matrix questions, and finally an open-ended question was included. However, there were few blank spaces provided in several category and matrix questions, and the only open-ended question was the last question in the questionnaire, which offered an opportunity for participants to make suggestions.

There are two types of statistics descriptive statistics and inferential statistics (Gray, 2018). Panik (2012) described each type as follows:

1. Descriptive statistics.

   The purpose is to summarise and arrange data in a readable form. At this point, tables, charts, and graphs can be constructed. Additionally, it allows for the calculation of percentages, rates of change, etc.

2. Inductive or inferential statistics.

   Applies the concept of statistical inference, i.e. deducing something about the entire dataset from examining only part of the data set.

Thus, descriptive statistics are differentiated from inferential statistics in that they aim to demonstrate what the data is, while inferential statistics attempt to draw conclusions beyond the data (Gray, 2018). Since the survey was for descriptive purposes, only descriptive statistics were used.

4.4.4.2 Presenting and Analysing Data using Descriptive Statistics

It is important to determine the variables in order to describe, explain, explore, or predict certain phenomenon (Nardi, 2018). Nardi (2018) emphasised that it is essential to run a univariate (one variable at a time) analysis and consider every element in the study in order to obtain a sense of variability in the responses before completing any further data analysis. There are several techniques to consider when presenting the univariate data of variables; these involve frequency distributions, graphs, and statistical measures (Nardi, 2018). Table 30 represents different techniques for presenting data that could be used for the questionnaire.

Table 30: Presenting Data Techniques for Questionnaire (Nardi, 2018)

Techniques for presenting univariate data	Description	Notes
Frequency Tables/ distribution	It shows how often each response (a value) was given by the respondents to each item (a variable).	Frequency tables are especially useful when a variable has a limited number of values, such as with **nominal** or **ordinal measures**.
Charts and Graphs	It is representing the findings visually with a graph or chart.	If the variable has a limited number of discrete values, as with **nominal** or **ordinal measures**, then a **bar graph** or **pie chart** can be used.
		If the data are **continuous** or **interval/ratio measures**, **histograms** and **frequency curves** (known as **frequency polygons**) are better ways of visually presenting univariate data.
Univariate Statistics	It is used to understand more about distribution of the variables in a sample. Of most importance is a measure of central tendency, which provides a quick summary of where the responses are clustered.	Depending on whether the variable is nominal, ordinal, or interval/ratio, a **mode**, **median**, or **mean** is used. These measures provide information about the distribution of a variable's values.

Based on the types of data used in the questionnaire, the author will use different ways of representing data, which are frequency tables, pie charts, bar graphs, and univariate statistics. Gray (2018) indicated that not all types of graphs are appropriate for all kinds of data; therefore, Table 31 demonstrates the appropriate use of charts and graphs for frequency data.

Table 31: Appropriate use of charts and graphs for frequency data (Gray, 2018)

	Bar chart	Pie chart	Histogram	Frequency polygon
Nominal				
Ordinal				
Interval/ Ratio				

Nominal and ordinal data were used in the questionnaire. Nardi (2018) mentioned that intensity scales, such as Likert scales, are ordinal measures; however, researchers treat intensity scales as interval/ratio measures. Consequently, bar charts or pie charts will be used for nominal data, bar charts will present the ordinal data, and for questions that use a Likert scale, a histogram or frequency polygon will be adopted.

4.4.4.3 Analysing Data using Descriptive Statistics (Univariate Statistics)

Frequency distribution is one of the most common techniques when analysing survey data and it is frequently related to the use of Likert Scales (Gray, 2018). Nardi (2018) pointed out that using the Measure of Central Tendency is an essential way to understand more about the distributions of variables in a sample. In addition, it helps to quantify the findings by using a single, representative digit (Gray, 2018). The Measure of Central Tendency includes the mean, median, and mode, which are based on whether the variable is nominal, ordinal or interval/ratio. These measures provide information on the distribution of variables. For instance, a perfect normal curve occurs when the mean, median, and mode are equal. When the mean is greater than the median, a positive skew occurs because a few high scores distort the mean away from the media, whereas a negative skew occurs when the mean is lower than the median because a few low scores minimise the mean (Nardi, 2018).

Gray (2018) claimed that it might be necessary to calculate the spread of responses around the mean to show if the mean is representative of the responses or not. Additionally, he mentioned that there are a number of ways to calculate measures of dispersion, as follows (Gray, 2018, p.623):

- The range: “the difference between the highest and the lowest scores”.
- The inter-quartile range: “the difference between the score that has a quarter of the scores below it (often known as the first quartile or the 25th percentile) and the score that has three-quarters of the score below it (the 75th percentile)”.
- The variance: “a measure of the average of the squared deviations of individual

scores from the mean".

- The standard deviation: "a measure of the extent to which responses vary from the mean and is derived by calculating the variation from the mean, squaring them, adding them and calculating the square root. Like the mean, because you are able to calculate a single figure, it allows comparisons to be made between different parts of a survey and across time periods". It is a more powerful measure of dispersion than using a range (the median) and is applicable to interval/ratio data (Nardi, 2018).

In sum, the selection of presenting and analysing data methods using descriptive statistics is varied and depends on the type of data (nominal, ordinal, and interval/ratio). Accordingly, a summary of the selected methods for presenting and analysing the questionnaire data using descriptive statistics is outlined in Table 32.

Table 32: A summary of the selected methods for presenting and analysing the questionnaire data using descriptive statistics

Data type	Presenting Data Methods	Analysing Data Methods
Nominal	Bar charts Pie charts	• **Frequency distribution/table.** • **Measure of central tendency**: by calculating the mode; it is finding the most frequently selected value for a variable.
Ordinal	Pie charts	• **Frequency distribution/table.** • **Measure of central tendency**: by calculating the mode, the median, and the percentile. • **Measures of dispersion:** by calculating the inter-quartile range and the range.
Interval/ratio	Histogram Frequency polygon	• **Frequency distribution/table** • **Measure of central tendency:** by calculating the mean (Arithmetic mean). It also can be used for ordinal scales (such as **Likert Scale**). • **Measures of dispersion:** by calculating Standard deviation.

Based on the research purpose and the types of variables selected in the questionnaire, the data analysis methods were generated using SPSS software for the descriptive statistics. For the open-ended questions**,** content analysis was used, which is a technique that includes the filtering of key ideas, words, or phrases and codes them based on a system developed by the researcher (Nardi, 2018).

4.4.5 The Second Phase of Data Collection Procedure: Qualitative Data

4.4.5.1 Case studies

The focus of this study is on the public sector in the Kuwaiti construction industry, in particular, governmental construction projects that include public facilities (such as hospitals, schools, and universities), housing, and commercial construction projects (such as Airports). There are two main government organisations that are responsible for undertaking these types of projects, which are the Ministry of Public Works (MPW), and the Public Authority for Housing Welfare (PAHW). However, the reason for choosing this sector lies in its importance; residential and public facilities projects are a fundamental right of the country's citizens, and there is a need to develop and enhance this industry to meet the new vision of Kuwait. Additionally, a government report revealed the size of the investment spending of Kuwait on development projects included in development plans until the year 2035 was up to $165 billion; this includes infrastructure projects and the establishment of residential cities, new tourist areas and a sophisticated concept that simulates European countries (Badeer, 2017).

Nevertheless, two case studies were selected based on the findings of the questionnaire. These cases included two different types of on-going construction projects implementing BIM or LC applications, and different types of procurement systems. In-depth interviews were conducted with experts from different project parties who were working on these projects. They were questioned on relevant subjects in this area including requirements and procedures applicable to BIM or Lean implementation. Data from the interviews were analysed further to find similarities in these two case studies (two projects) concerning the entire project process and the way BIM and Lean were implemented. From this, a BIM and Lean Construction framework was developed. This framework was designed for government (client) organisations in order to facilitate the implementation of BIM and Lean Construction, as well as improve the management and control of construction projects in the public sector. Finally, the framework was validated through interviews with different people to enable generalisation. This framework was expected to improve the performance of the construction industry in Kuwait, thus creating better project management practice.

4.4.5.2 Interviews

A case study strategy was selected for the second phase of this study. It is a research strategy that concentrates on understanding the dynamics present within a single scope (Amaratunga, Baldry, Sarshar, & Newton, 2002). It is an "*empirical inquiry that investigates a contemporary phenomenon in depth and within a real-world context, especially when the boundaries between phenomenon and context may not be clearly evident*" (Yin, 2014, p 43). However, the selection of cases and their criteria depend on the questionnaire findings.

In qualitative research, the role is attitude measurement based on opinions, views and perceptions measurement, and the emerging link between theory and research (Naoum, 2012). Bryman (2012) mentioned that interviews are a data collection method associated with qualitative research. There are three types of interviews, according to Saunders et al. (2015):

1. Structured interview

   Questionnaire-based where the interviewer prepares a standardised set of questions. Also, Bryman (2012) claimed that quantitative research is typically highly structured, so it is associated with structured interviews, and is supposed to create answers that can be coded and processed rapidly.

2. Semi-structured interviews

   The researcher has a list of themes and possibly some key questions to be covered, although their use may vary from interview to interview.

3. Unstructured interviews

   This type of interviews is informal. It is used to explore in depth a general area on which the research is focused.

Qualitative research can contribute to the purpose of this research, which is to improve the performance of public sector construction projects in Kuwait by developing a framework based on Lean Construction and BIM applications. This was achieved through the adoption of semi-structured interviews with experts, as semi-structured interviews focus on a particular event or experience and collaborations that are socially constructed (Gray, 2013; Mason, 2018). In order to develop a framework that includes stakeholders' roles and their processes, it was important to take the stakeholder's opinions and experience into consideration. Additionally, the researcher utilized secondary data, such as documents, which involved text materials (e.g., newspapers, emails, reports, the text of web pages, etc.) and non-text materials (e.g. audio, videos, pictures, drawings, etc.) (Saunders et al., 2015). For the framework validation, structured interviews were carried out with participants from various local and international client organisations to enable generalisation.

4.4.5.3 Sampling for Semi-structured Interviews (Qualitative Data)

In qualitative research, the researcher employs a purposive sampling strategy when choosing participants and locations that could provide the required information to understand the main phenomenon (Creswell & Clark, 2017). Regarding the sample size, the researcher needed a small number of participants to provide in-depth information about the phenomenon. Creswell and Clark (2017) mentioned that the sample size may vary from one strategy to another. For instance, the number of participants may range from 1 or 2 in a narrative study, 4 to 10 in a case study, and 20 to 30 in a grounded theory project. Additionally, the minimum sample size for semi-structured interviews is between 5-25 (Saunders et al., 2015). As individual cases were difficult to identify or reach, a sample snowball sampling (volunteer) technique was used for the semi-structured interviews.

4.4.5.4 Qualitative Data Analysis

Saunders et al. (2015) recommended that, before undertaking any analysis, it is important to prepare data by transcribing them. Table 33 shows the different types of qualitative analysis methods.

Table 33: Types of Qualitative Data Analysis (Source: Saunders et al., 2015)

No.	Types of Qualitative Analysis	Definitions
1	Thematic Analysis	It is a generic approach to analysing qualitative data. Also, it refers as a 'foundational method for qualitative analysis. The essential purpose of this approach is to search for themes, or patterns, that occur across a data set (such as series of interviews, observations, documents or websites being analysed). It is a standalone analytical technique.
2	Template Analysis	Similar to thematic, but a researcher codes a proportion of the data items before developing an initial list of coding and themes. It is a standalone analytical technique.
3	Building and testing	Associated with three main techniques, Analytic induction, deductive explanation, and pattern matching.
4	Narrative	A collection of analytical approaches to analysis different aspects of narrative.

As highlighted in Table 33, the researcher analysed the qualitative interview data by using thematic analysis in order to identify topics or patterns occurring across the dataset and to help develop and modify the proposed framework for this study. Therefore, the author used NVivo software for the analysis as it "*is a software program that assists in the coding of qualitative data*" (Gray, 2013, p.654).

4.5 Research Design

Figure 55 illustrates a summary of the methods and procedures selected for the research and Figure 56 represents these procedures in more detail. In this study, the research philosophy was pragmatism, while the theory development approach was a combination of both deductive and inductive approaches, which is known as an abductive research approach to theory development. A mixed method research was adopted as the methodological choice, which starts with quantitative research followed by qualitative research. In quantitative research, a survey strategy was used to develop an overview of the situation in the construction industry in Kuwait, in terms of the challenges and adoption of advanced improvement project management approaches such as BIM and Lean Construction.

An online questionnaire was used as a data collection method for the quantitative research. It was distributed to practitioners who work in the construction industry in Kuwait, especially for the public construction projects, using an online survey platform called eSurveyCreator. The target sample size was 383 based on the target population in this industry; however, the researcher received 136 completed responses out of 141. Survey data were presented and analysed using descriptive analysis. For the descriptive analysis, SPSS software was used, in which frequency tables, graphs, pie charts, and bar charts were generated, as well as statistical measures such as mean, mode and standard deviation. This stage of the data collection helped to nominate the cases or types of projects that implemented BIM in public projects in Kuwait to enable the next data collection stage. After that, qualitative research was carried out, which allowing for in-depth investigation of this area. For case studies, primary and secondary data were used as the data collection methods. Semi-structured interviews were conducted from these two cases chosen from the questionnaire results. The sampling was from volunteers, and the ten participants were involved. Next, these interviews were analysed using thematic analysis through NVivo software, and the proposed process protocol/framework was produced at this point. In order to validate the proposed framework, the researcher conducted interviews with three different participants to enable generalisation. Since this process protocol was intended for public construction projects in Kuwait, two different local clients from the largest public construction organisations were invited for structured interviews (face-to-face). However, the researcher also invited an international BIM consultant with experience in BIM across many countries as the third interviewee, in order to draw an unbiased, general conclusion. Participants completed the evaluation form and provided their feedback and comments on the proposed framework. These results were analysed using thematic analysis to refine this framework. Finally, the proposed framework was updated and validated; thus the final version of the BIM – driven Lean Construction Process Protocol was produced.

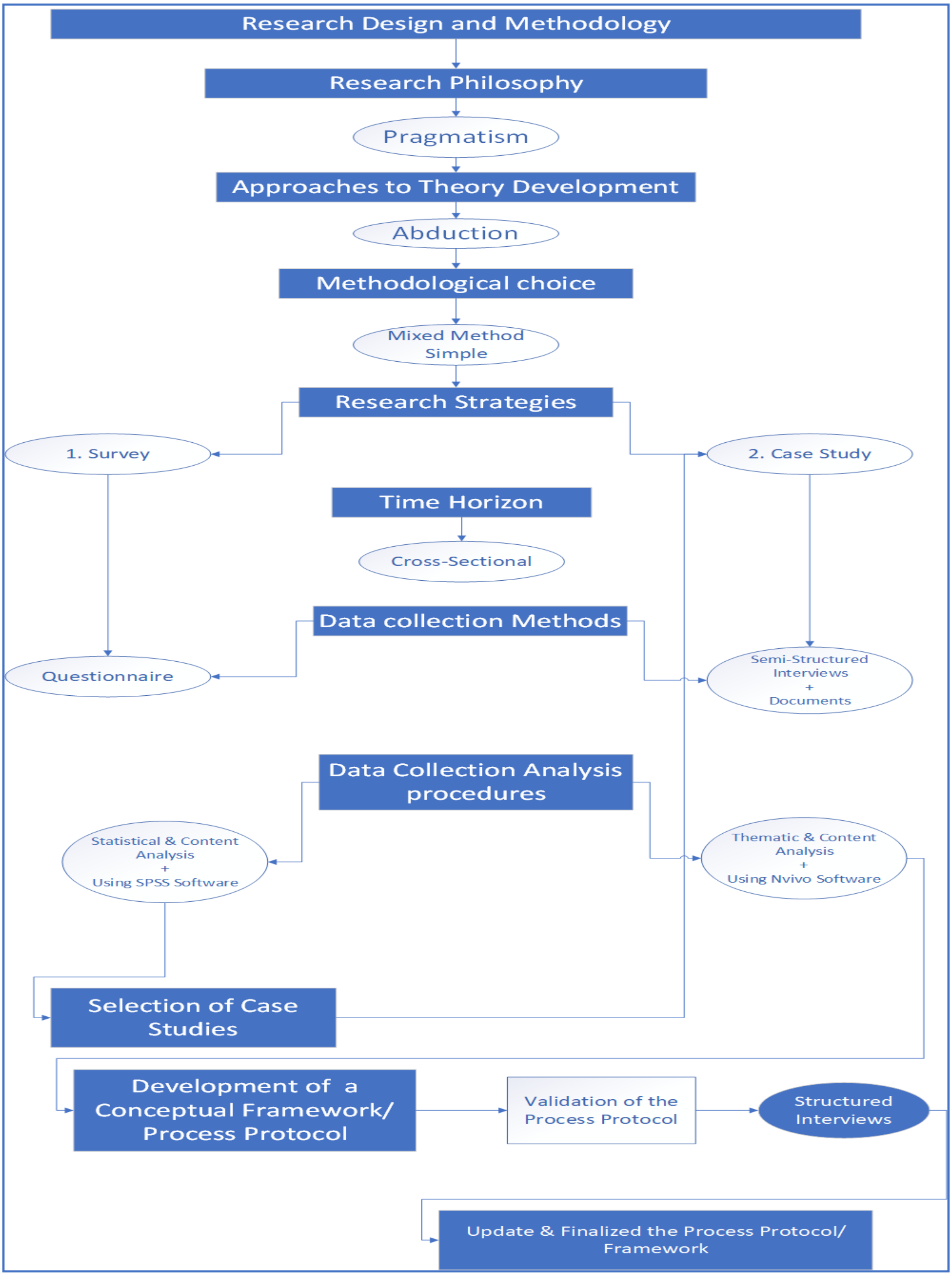


Figure 55: Research design

Figure 56: Research Methodology design

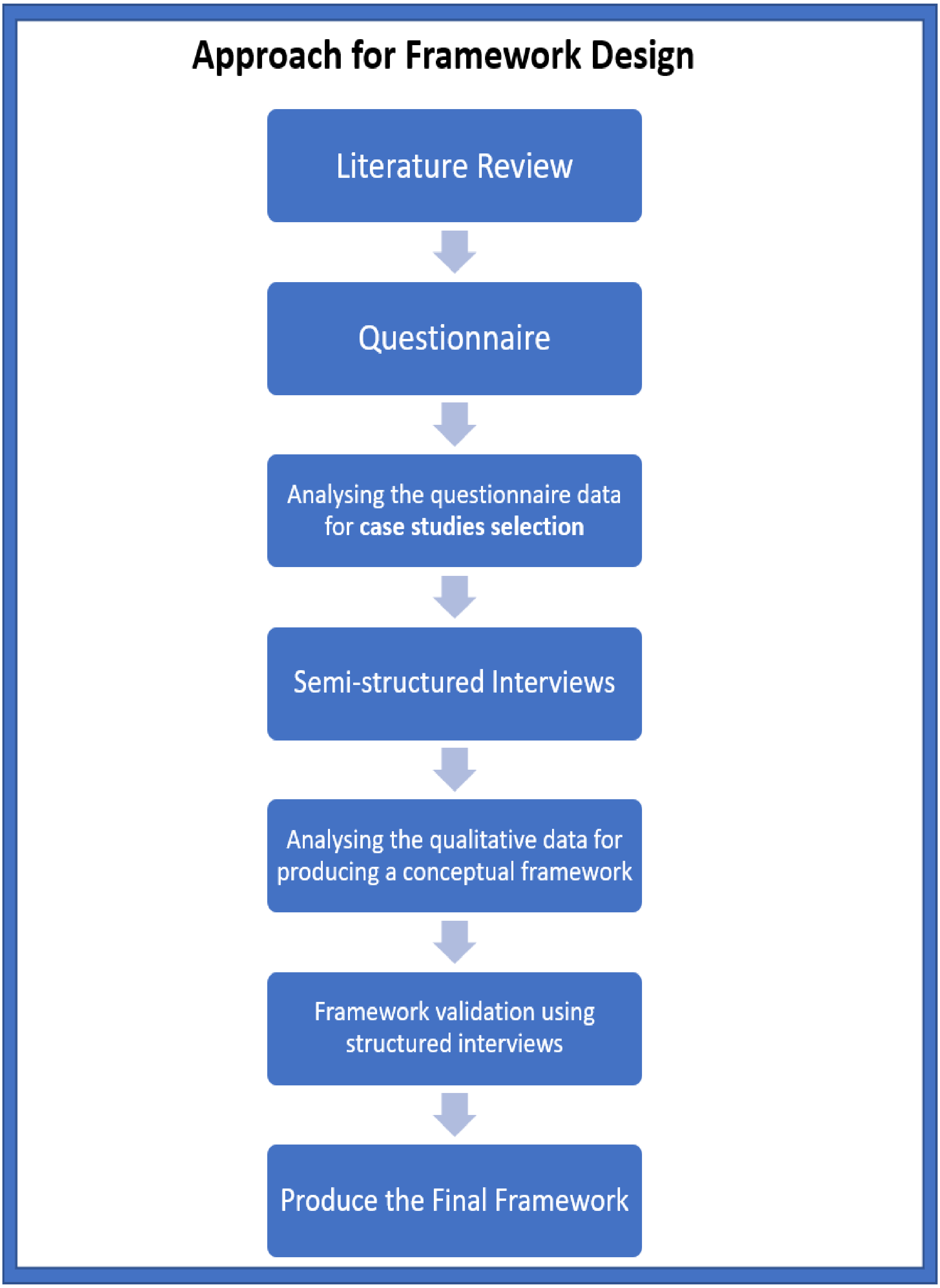


Figure 57: Approach for Framework/ Process Protocol Design

As shown in Figure 57, the framework or the process protocol was designed over several steps and starting with gathering information about existing frameworks that embedded BIM and Lean Construction. Then, the questionnaire was distributed to describe the current industry situation in order to prepare an appropriate solution. After that, semi-structured interviews were conducted to obtain in-depth information about current practices, from which a conceptual framework was developed. Finally, structured interviewed were carried out to validate and finalise the BIM and Lean process protocol/ framework.

4.6 Ethical considerations

Researchers consider participants' respect and rights in their research and stakeholders' legal interests. Thus, ethical approval is an essential procedure of a study as it protects both participant and researcher. Robson and McCartan (2016) stated that there are ethical considerations when conducting real-world research with people because there is a possibility of harm, stress and concern, and numerous other potential harmful effects on participants. Therefore, the researcher should provide participants with adequate information to make independent decisions. Informed consent is an important general principle that is the focus of moral conduct in research. It gives participants the freedom to accept or reject participation or to withdraw at any time, after reviewing full information regarding the nature and aim of the study. This should cover any personal risks, the arrangements for confidentiality and data protection (Gilbert & Stoneman, 2016).

According to the Ethical Support Committee at the University of Salford, ethical approval is mandatory for all examinations that involve people. A few points should be mentioned when considering the ethical approval. Firstly, the researcher should inform all participants by scheduling a commitment frame and screen legitimacy when associating with them. Thereafter, they should likewise be informed about the exploration stage and the information that would be collected from them. As this examination gathered information from non-helpless individuals, this is known as a type 2 in the University of Salford's ethical research types. The author provided a Participant Information Form at the beginning of the questionnaire and interviews to clarify the research objectives, explain to participants the reason for inviting them to participate in this study and provide reassurances about the privacy of the information collected.

4.7 Summary

This chapter provided a summary of the research methodology used in this research. A Mixed Methods research approach was applied to achieve the aim and objectives. Survey and case study strategies were adopted in this research; an online questionnaire was used as a data collection method for a survey strategy, and semi-structured interviews as a method for collecting data for the case study strategy. In the questionnaire, the overall status of the industry was recognised and described, in terms of the challenges facing the construction industry in Kuwait and the tools for improvement to overcome these problems, and how they have been applied. For case studies, in-depth knowledge regarding the implementation of BIM and LC in the industry was collected, thus, a conceptual framework was designed. Finally, structured interviews with local and international participants working in the construction industry who were familiar with BIM technology were conducted to validate and update the proposed process protocol/ framework.

In Chapter 5 and 6, quantitative and qualitative data analysis will be conducted, and conclusions will be drawn from the three steps of the data collection (questionnaire, semi-structured interviews, and structured interviews). The final BIM and Lean process protocol will be introduced and explained in Chapter 7.

Chapter 5: Quantitative Data Analysis

5.1 Quantitative Data Analysis (Questionnaire):

5.1.1 Introduction

In this chapter, quantitative data will be analysed, and conclusions will be drawn from the survey to explore and describe the current state of the construction industry in Kuwait, in terms of its performance, challenges, and improvement techniques. The focus will be on the analysis of the questionnaire that was distributed to construction industry practitioners in Kuwait for the first stage of the data collection. The questionnaire will be analysed using descriptive analysis which will enable the researcher to explore and describe the current situation of the construction industry in Kuwait in terms of the challenges facing this industry and the use of advanced project management approaches, such as BIM and Lean Construction.

5.1.2 Descriptive Analysis

In this section, the researcher summarised the findings of the conducted questionnaire. The questionnaire was distributed to different practitioners in the Kuwaiti Construction industry for both public and private sectors, including clients, contractors, consultants and academia. The number of respondents who completed the survey totalled 136 . The questionnaire was divided into seven parts, each part including questions equivalent to the study. The seven sections of the survey are listed in Table 34.

Table 34: Structure of the questionnaire designed for this study

Section	Focus	Questions
Section 1	Respondent's profile	1 – 4
Section 2	The Challenges and problems facing the Construction industry in Kuwait	5 - 8
Section 3	The awareness of Lean Construction and its implementation, as well as Lean waste in the construction industry in Kuwait	9 – 13
Section 4	The awareness and implementation of BIM, including its maturity levels, type of projects that adopt it, and BIM experience and training.	14 - 23
Section 5	Measuring the synergies between Lean Construction and BIM functions and how they can complement each other and contribute to improved performance.	24
Section 6	Drivers and barriers of BIM implementation in the Construction industry in Kuwait collected from the literature review. In addition, participants were asked whether adopting a BIM-driven Lean Construction Process Protocol will improve the industry or not, and which party should be responsible for that implementation	25 – 28
Section 7	This section was optional, participants were asked to write any suggestions for improving the performance of the construction industry in Kuwait especially for the government construction projects	29

Section 1: Profile of Respondents

The first four questions were asked to gather information about the profile of respondents, which helped the author to prepare coded questionnaire responses. Figures 58, 59 and 60 illustrate the results of the first part of the questionnaire, namely the demography of participants.

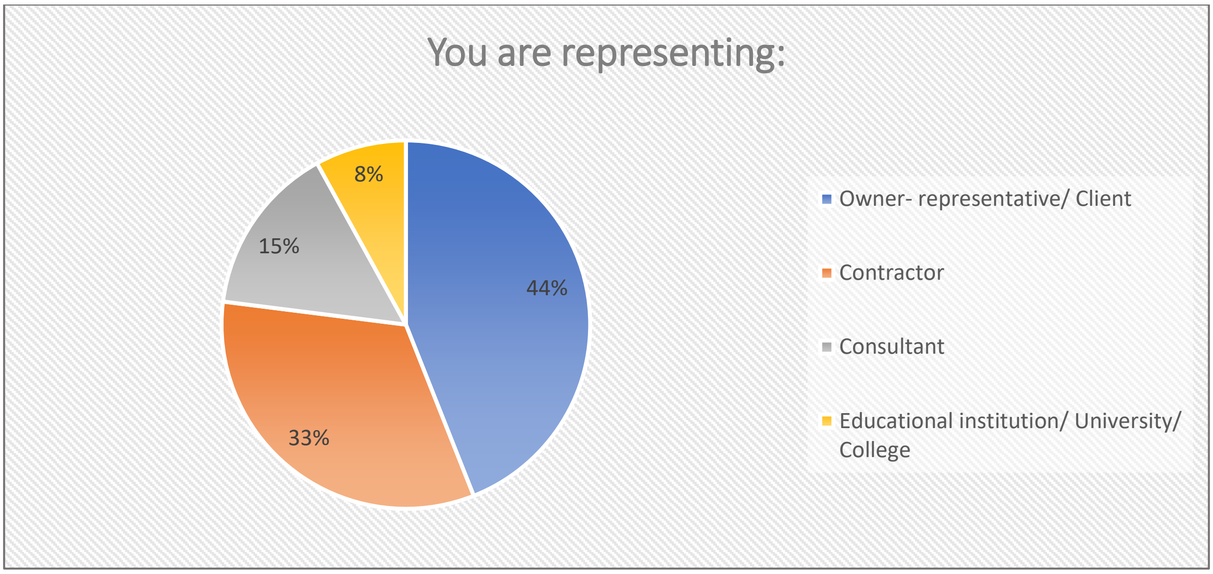


Figure 58: Participant groups

As shown in Figure 58, the majority of participants were client representatives, representing 44% (n=59) of the total, followed by 33% (n=45) from contractors, and 15% (n=20) from consultant companies, while 8% (n=11) were from academia. Diversity in groups of participants helps to gather different points of view.

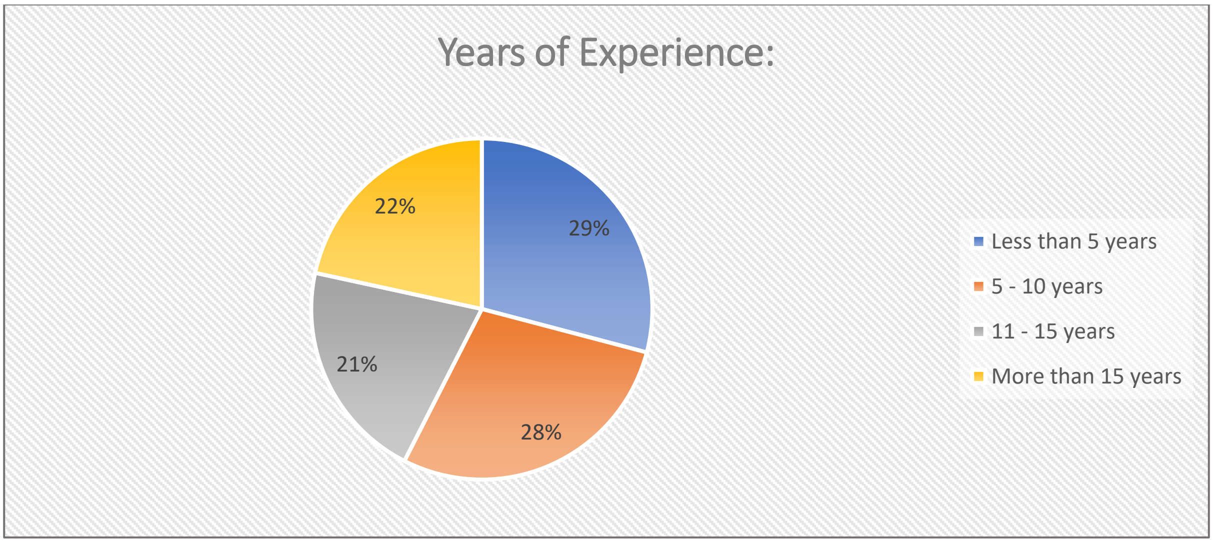


Figure 59: Participants' years of experience in the construction industry

Figure 59 illustrates participants' experience in years in the construction industry; these were categorised in four groups. The results came from different perspectives and levels of experience, in which 29% (n= 39) of respondents had less than 5 years of experience, 28% (n=38) had 5 – 10 years of experience, 22% (n=29) had more than 15 years of experience, and 21% (n=28) had 11 – 15 years of experience. These results highlight that the range between each group was quite limited, leading to more comprehensive results.

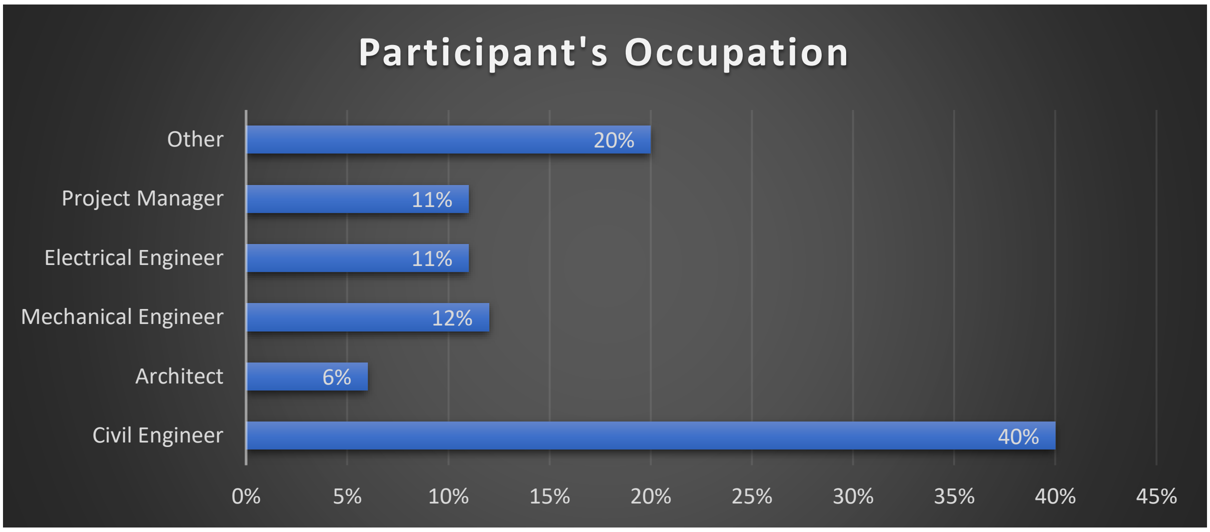


Figure 60: Participant's Occupation

From the questionnaire, it was established that 40% (n= 53) of the respondents were civil engineers, while 6% (n= 8) were architects (see Figure 60). However, there were other job positions that allowed for results from different angles, as shown in Table 35.

Table 35: Other occupations in the questionnaire as written by the respondents.

Job Position	Number of people
Project Coordinator	1
Assistant Undersecretary	1
Company Manager	1
Maintenance Engineer	1
Estimation & Procurement Engineer	1
Petroleum Engineer	1
Professors	3
Computer Engineer	1
Industrial Engineer	2
Chemical Engineer	1
BIM Manager	3
Tender Engineer	1
Quantity Surveyor	1
Project Manager	1
Sales Engineer	1
Assistant Communications Supervisor	1
Consultant	1
Planning Engineer	1
Safety Engineer	1
Chief Contracts Administrator	1
Senior Structural Engineer (Design Project Coordinator)	1
Architectural Engineer	1

Regarding the construction sector, 79% (n=107) of the respondents were working on government construction projects (public sector), while 21% (n=28) were working in the private sector, as represented in Figure 61. These results provide a better understanding of public projects.

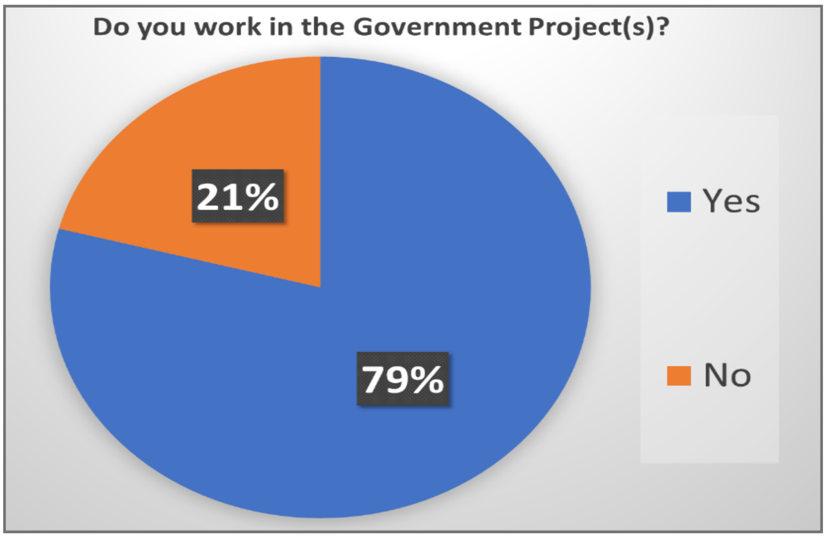


Figure 61: Results for question 4 in the questionnaire

Section 2: Challenges and problems facing the construction industry in Kuwait

The purpose of this section is to understand the challenges facing this sector in order to address them. It includes four questions, as follows:

- Q5: In your career to date what percentage of projects have run "on time" and "within budget"?
- Q6: In your opinion, do you think that by preventing delays in construction projects, cost overrun could be avoided?
- Q7: What are the challenges/problems facing the (public projects) government construction projects in Kuwait? (Other if it is not above) (Matrix questions) (Likert Scale)
- Q8: Does your organisation follow any project management approach (protocol, framework, guidance, etc.) that addresses the problems and challenges facing construction projects?

From the survey, it was discovered that 36% (n= 43) of participants believed that less than 25% of projects were completed within budget and 46% (n= 56) pointed out that less than 25% of the projects were completed on time. In contrast, only 8% (n= 9) indicated that the percentage of projects completed on time was over than 75%, and 11% (n= 13) believed that more than 75% of projects were delivered within the allocated budget (see Table 36). Since less than 25% of projects in Kuwait were completed on time and within budget, the construction industry in Kuwait is suffering from time and cost overruns, leading to lower productivity and insufficiencies.

Table 36: The percentage of projects completed on time and within budget in the construction industry in Kuwait

Percentage of projects completed	0 - 25%		25-50%		50-75%		75-100%	
Participants	%	N	%	N	%	N	%	N
Projects delivered on time	46%	56	24%	29	22%	28	8%	9
Projects completed within budget	36%	43	31%	39	22%	27	11%	13

As shown in Figure 62, 65% (n=80) of participants believed that by preventing delays, cost overruns could be avoided in construction projects, while 17% (n= 20) gave a negative response. Since time is money, it is important to solve the problem of delays in this industry in order to prevent cost overruns.

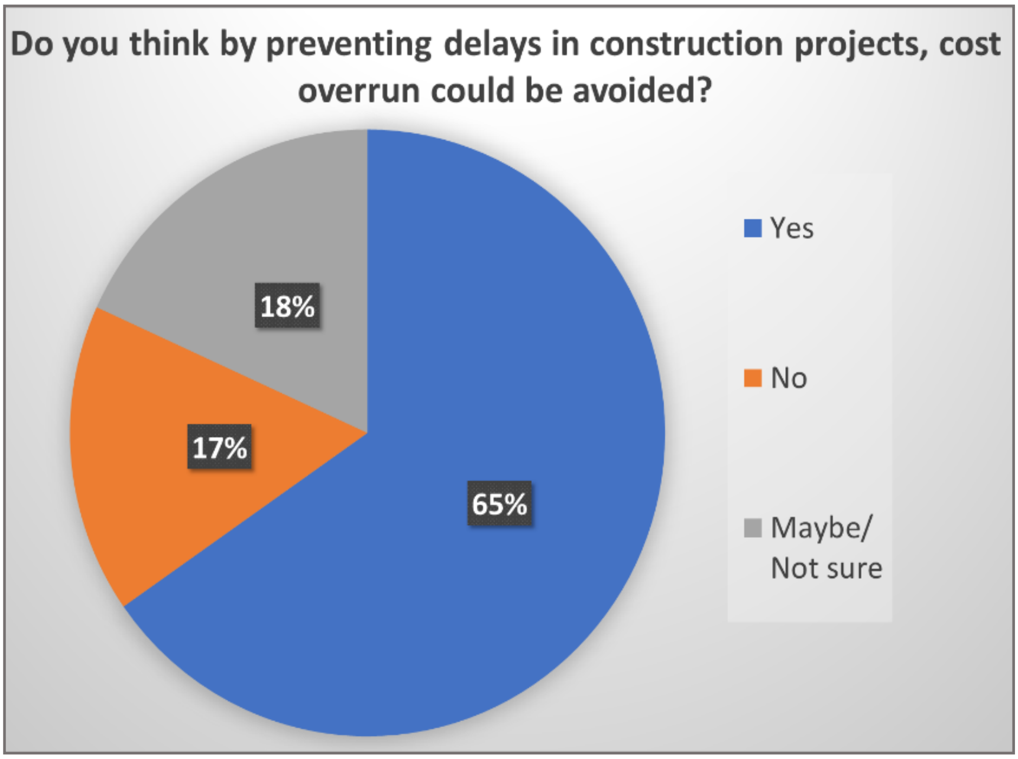


Figure 62: Results for question 6.

Challenges facing the construction projects (public sector) in Kuwait:

In this section, Question 7 was published to assess the occurrence of challenges in construction projects, especially within the public sector. Participants were provided with 11 problems to rate using the five-point Likert scale. The 11 risk factors related to this industry are as follows (with the name of the variable used for analysis in SPSS appearing in parentheses):

- Time overrun/delay (Delay)
- Cost overrun (Cost_overrun)
- Waste in construction materials (Waste)
- Lack of communication and coordination between project parties (Communication)
- Low productivity (Low_productivity)
- Construction accidents (Construction_accident)
- Inadequate project management practice and poor site management (Poor_Mngmt)
- Lack of experience and qualifications (Lack_experience)
- Lack of adopting new technologies (Lack_Technology)
- Poor planning and control (Poor_Planning)
- Change in orders/decisions initiated by the client (Change_orders)

These risks were represented using descriptive statistics, including frequencies of responses, and the weighted means of answers. The purpose for using this analysis is to evaluate patterns in the data provided by the participants regarding these 11 challenges in order to narrow down the number of risks that need to be considered. Therefore, it is used to identify which of the 11 problems most frequently occur in construction projects. The answers for each challenge are provided below (see Table 37), in which 1-5 represent a scaled response with 1 indicating “strongly disagree”, 2 “disagree”, 3 “neutral/not sure”, 4 “agree”, and 5 “strongly agree”. For a better comparison of the significance of these variables, the arithmetic average (Mean) was calculated for each answer.

Table 37: Challenges/problems facing the construction projects (public sector) in Kuwait.

Challenges/ Risks factors	N	Min.	Max.	Mean	Mode	Std. Deviation	Ranking
1. Time overrun/ Delays	122	1	5	4.25	4	0.788	1
2. Cost overrun	120	1	5	3.9	4	0.864	4
3. Waste in Construction materials	122	1	5	3.53	4	1.077	8
4. Lack of communication & coordination between project parties	122	1	5	4.1	5	1.016	2
5. Low Productivity	122	2	5	3.62	4	0.999	7
6. Construction accidents	122	1	5	2.9	3	0.837	10
7. Inadequate Project Management practice & poor site management	122	1	5	3.66	4	1.103	6
8. Lack of experience & qualifications	122	1	5	3.36	4	1.076	9
9. Lack of adopting new technologies	122	1	5	3.82	4	1.052	5
10. Poor Planning & control	122	1	5	4.05	4	1.019	3
11. Change in orders/ Decisions initiated by clients	122	1	5	4.05	4	0.889	3

As shown in Table 37, the highest mean rating is 4.25 for "Time overrun/delay", while the lowest is 2.9 for "Construction accidents". The finding confirms what was found in the literature concerning the major challenges facing the construction industry in Kuwait, especially the public sector. The main challenges facing this industry were highlighted in Table 37, namely, delays in projects followed by a lack of communication and coordination between stakeholders, poor planning and control, and changes in orders. Additionally, participants had an option to add other challenges if they were not listed; they added the following challenges:

- Do not study bids as required and evaluate the technical presentation accurately as the time of study is not enough to enter all the details and impact of the lowest bid price.
- The decision-making process is very slow.

- Government corruption and routine.
- Link between government agencies and make electronic correspondence instead of paper, which disrupts projects.
- Lack of a serious deal and interest from government agencies responsible for the delivery of services to the project, such as the Ministry of Electricity and municipal and fire.
- Corruption in the public sector.
- The ministerial routine and the long documentary cycle beyond the reasonable limits and a fear of taking responsibility by officials.

The researcher considered potential project management approaches; therefore, participants were asked if there were any project management approaches for solving the problems and challenges facing construction projects in Kuwait. From the questionnaire, it was established that 49% (n = 59) indicated that their organisation followed a project management approach to resolve construction risk, while 18% (n = 22) gave a negative answer and 33% (n = 40) were not sure or not aware of it, as shown in Figure 63. Regardless of the existence of project management techniques in public construction projects in Kuwait, they are insufficient and require adjustments or evaluation.

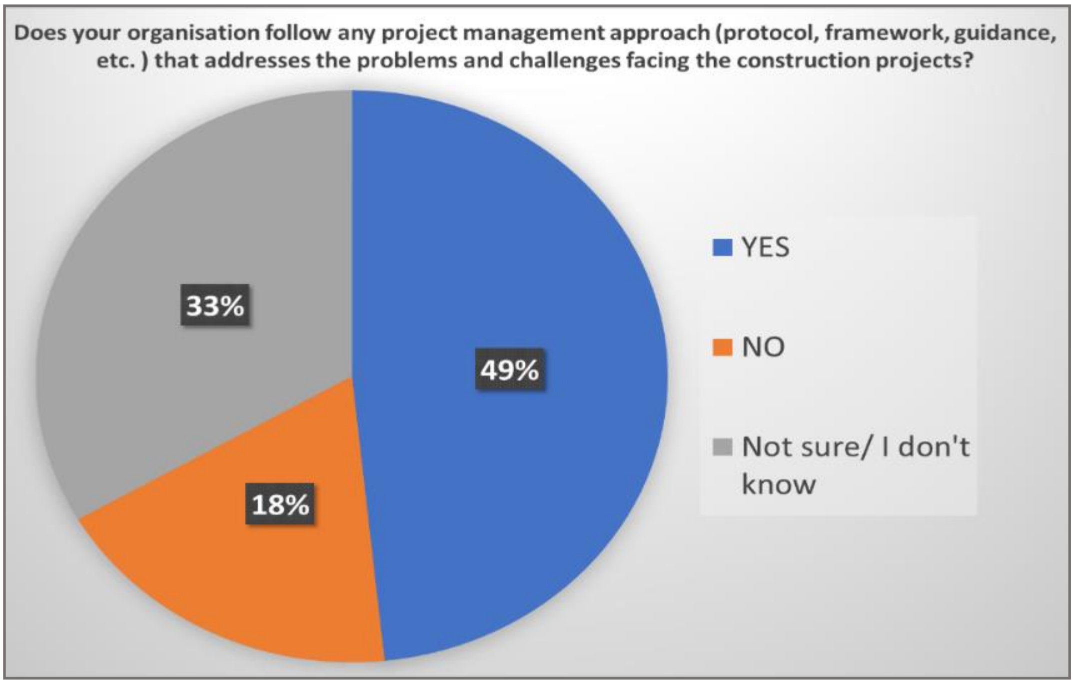


Figure 63: Question 8 participants' answers

Section 3: Lean Construction (LC) in Kuwait

This section aims to evaluate the level of awareness of Lean Construction and its implementation in this industry; it also investigates the eight Lean wastes in the construction projects. It includes five questions, as follows:

- Q9: Are you familiar with the term "waste" or "non-added value"?
- Q10: Do you know any construction firm in Kuwait that applies approaches or tools to eliminate "non-added value" or "waste" in their projects
- Q11: Have you heard about the Lean philosophy or the Toyota Production Systems (TPS) philosophy?
- Q12: Do you know any construction company in Kuwait that applies Lean Construction? If YES, please select the type of project(s) that applied Lean Construction
- Q13: How often the following waste occurred in construction projects? (Matrix

Questions) (Likert Scale)

Table 38 shows the results of the answers to the first four aforementioned questions related to waste and Lean Construction.

Table 38: Awareness and implementation of Lean principles and approaches in the construction projects in Kuwait

Participants' answers	Yes		No	
Number of Participants	%	N	%	N
Are you familiar with the term "waste" or "non-added value"?	78%	92	22%	25
Do you know any construction firms in Kuwait that applies approaches to eliminate waste in their projects?	27%	32	73%	85
Have you heard about Lean Philosophy or the Toyota Production System (TPS)?	19%	23	81%	94
Do you know any construction company in Kuwait that applies Lean Construction?	11%	14	89%	103

From the investigation, it has been found that 78% (n=92) of respondents were familiar with the term "waste" or "non-added value", while 22% (n =25) gave a negative response. However, 73% (n=85) of respondents were not aware of any construction company in Kuwait that applied approaches or tools to minimise waste in their projects, while 27% (n= 32) know of some construction companies that apply waste management techniques in their projects (see Table 38).

Regarding the awareness of Lean principles, it was discovered that only 19% (n = 23) of participants had general knowledge of Lean principles, while 81% (n = 94) gave a negative response. Additionally, 11% (n =14) of participants were aware of construction companies that applied Lean Construction, while 89% (n = 103) gave a negative response (see Table 38). This is an indication of a low level of awareness, experience, and implementation of Lean principles in construction projects in Kuwait.

Nevertheless, participants were asked to select the type of construction projects that implement Lean Construction in the industry. The findings show that 34.8% (n=8) of respondents selected airport projects as a type of project that applied LC in Kuwait, and 17.4% (n=4) of participants selected hospital projects, commercial and other projects (see Figure 64). The purpose of this question was to assist the researcher in choosing case studies for interviews.

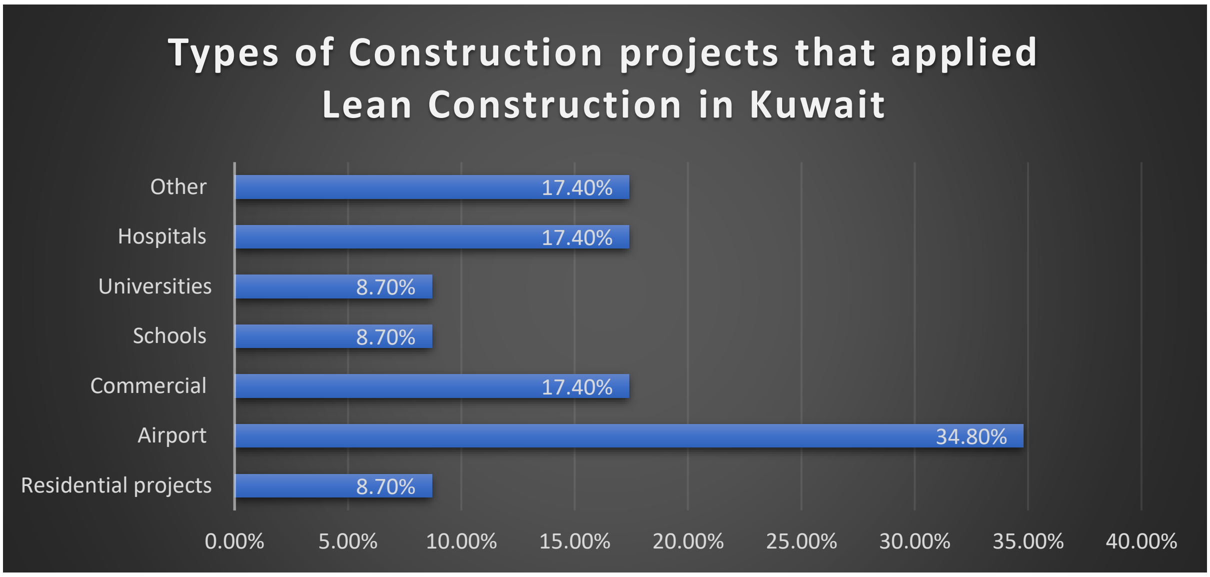


Figure 64: Types of construction projects that implement Lean Construction

With regards to Lean Waste, participants were asked how often Lean Waste occurred in construction projects in Kuwait. The eight Lean wastes were provided in this question to be evaluated by repondents using a Likert scale, in which 1-5 represent a scaled response with 1 representing “Never”, 2 “Rarely”, 3 “Sometimes”, 4 “Frequently”, and 5 “Always”. These waste are as follows:

- Defects
- Over production
- Waiting
- Non-utilized talents

- Transportation
- Inventory
- Motion
- Extra processing

These Lean wastes are presented in Table 39. The mean for all responses was calculated and the results indicated that waiting, non-utilised talents, and defects with arithmetic averages (means) of 4.06, 3.68, and 3.64, respectively, were the main Lean waste generated in construction projects in Kuwait, while the overproduction had the lowest mean at 2.77.

Table 39: Lean waste in the construction Projects in Kuwait

Lean Waste in Construction	N	Min.	Max.	Mean	Mode	Std. Deviation	Ranking
1. Defects (e.g. Rework, Design errors, Incorrect information, inconsistency between contract documents)	114	1	5	3.62	4	0.906	3
2. Over Production	114	1	5	2.77	3	0.873	7
3. Waiting	110	2	5	4.05	5	0.892	1
4. Non-utilized talents	111	1	5	3.68	4	0.896	2
5. Transportation (Materials)	112	1	5	3.15	3	0.932	5
6. Inventory (Excess products & materials being processed)	113	1	5	2.85	3	0.938	6
7. Motion (people) (unnecessary movements by people "e.g. walking")	112	1	5	3.15	3	0.970	5
8. Extra Processing (e.g. pouring concrete where pre-cast concrete would be more effective)	113	1	5	3.19	3	0.851	4

Section 4: The awareness and implementation of BIM, including its maturity levels, types of adopting projects and BIM experience and training.

This section investigates and assesses the level of awareness of BIM, its implementation, maturity levels, types of adopting projects, and BIM experience and training. It includes ten questions, as follows:

- Q14: Have you heard about Building Information Modelling (BIM)?
- Q15: Do you know of any construction company in Kuwait that applies BIM?

If yes, please select the type of project(s) that implements BIM: (Residential projects, Airport, Commercial, Schools, Universities, Hospitals, Other)

- Q16: What is your knowledge of BIM? (None, Beginner, Intermediate, Advanced)
- Q17: Are you a BIM user?
- Q18: Select your years of experience in BIM: (Less than 5 years, 5 – 10 years, 11 – 15 years, more than 15 years)
- Q19: Select your BIM usage: (Design, Detailing, Elements fabrication, Project Management, Facility Management)
- Q20: Your BIM training: (None, Self-training, University/College, In-house training program, other).
- Q21: Please select the level of collaboration between project stakeholders in your organisation/company? (No collaboration, Low collaboration, Partial collaboration, Full collaboration/ integration)
- Q22: Please select how the project information is being produced in your organisation/company?
- Q23: Please select what is the type of information sharing tool that is used in your organisation to share project information amongst the project team.

Questions 14 and 15 are intended to identify the percentage of respondents who are familiar with BIM, have the knowledge of BIM implementation in the industry, and types of construction projects that apply BIM. Table 40 represents the awareness and application of BIM in construction projects in Kuwait according to participants.

Table 40: Awareness and application of BIM in Kuwait

Participants' answers	Yes		No	
Number of Participants	%	N	%	N
Have you heard about Building Information Modelling (BIM)?	65%	69	35%	37
Do you know any construction firms in Kuwait that applies BIM?	46%	49	54%	57

The level of awareness of BIM is high, as well as its employment in construction projects in Kuwait, as 65% (n=69) of participants were aware of BIM and 46% (n = 49) knew some companies that applied BIM in Kuwait, while 35% (n = 37) and 54% (n=57) gave a negative response, respectively, as shown in Table 40. Additionally, respondents with knowledge of BIM application in Kuwait were asked to determine the type of projects that used BIM, as illustrated in Figure 65.

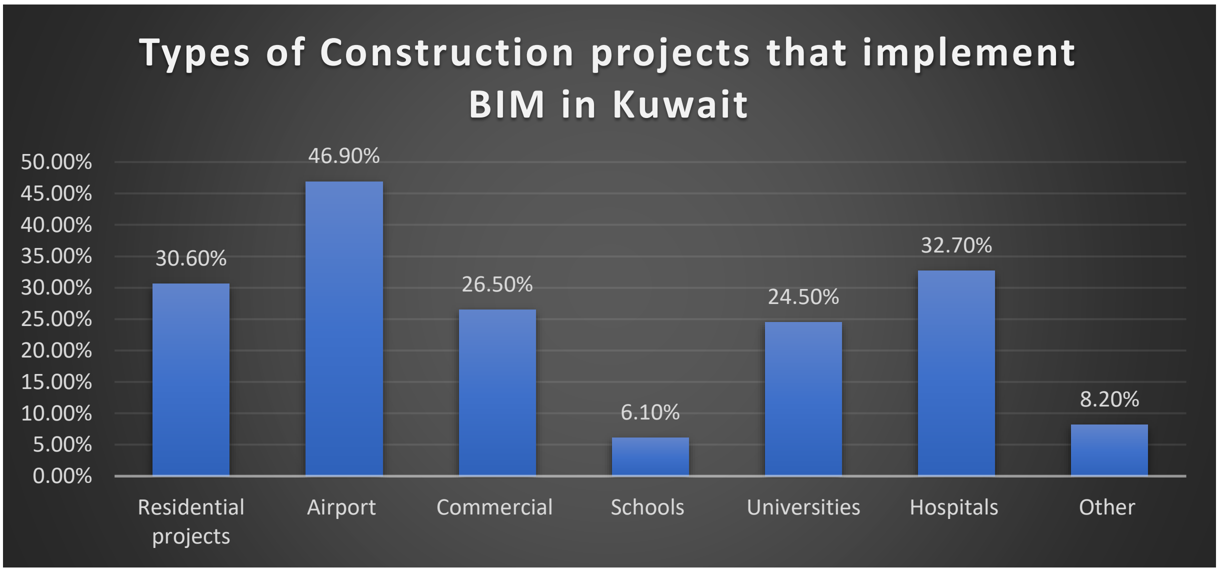


Figure 65: Types of construction projects that applied BIM

The percentage of construction projects operating BIM were ranked the highest for airport and hospital projects, where 46.9% (n=23) of participants selected airport projects and 32.7% (n=16) hospital projects. Therefore, the researcher selected case studies based on the findings, as shown in Figures 64 and 65. This enabled the researcher to gain more in-depth knowledge regarding BIM and Lean Construction in Kuwait.

In contrast, questions 16, 17, 18, 19, and 20 aimed to assess the practitioners' knowledge, experience, usage and training in BIM. The findings of questions 16 and 17 revealed that the majority of practitioners 79% (n=82) in the construction indutsry in Kuwait were not BIM users and 42% (n=43) had basic knowledge of BIM without any experience in projects, as shown in Figures 66 and 67. On the other hand, 9% (n =9) of respondents were experts in BIM and had delivered BIM projects (see Figure 66), and 21% (n = 23) were BIM users (see Figure 67). However, most participants 77% (n=28) who were BIM users had less than five years experience in BIM, while only 3% (n=1) had more than 15 years experience in BIM, as illustrated in Figure 68.

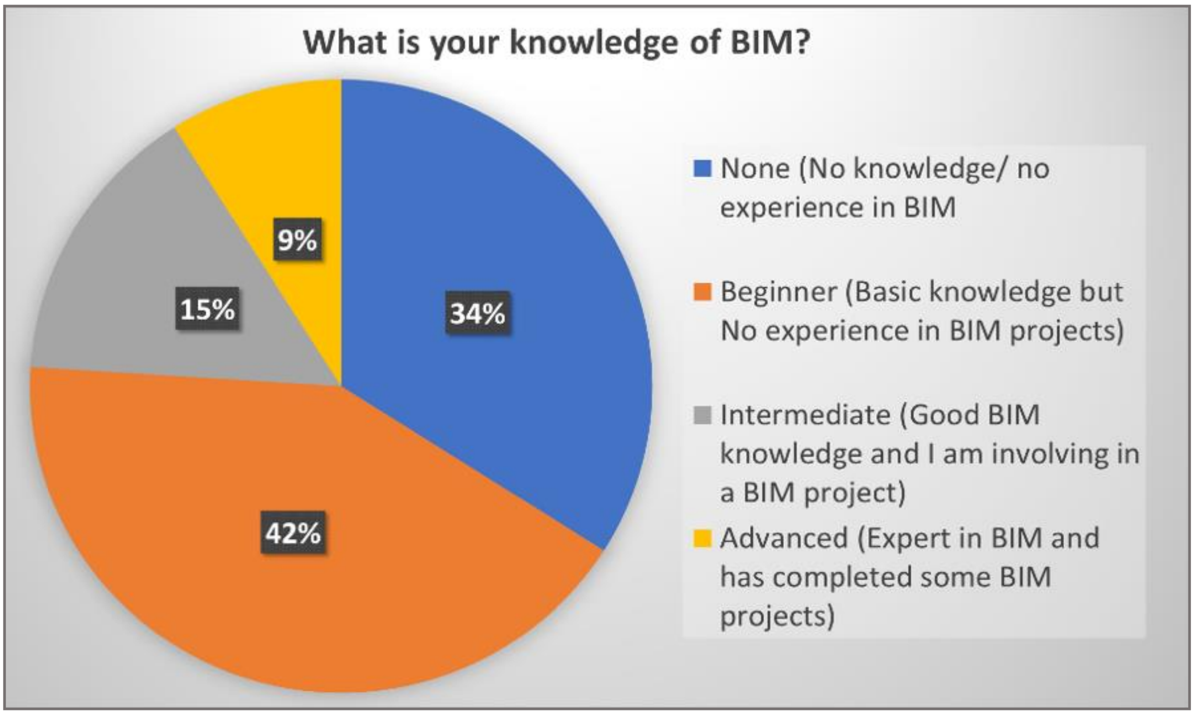


Figure 66: BIM knowledge level of practitioners.

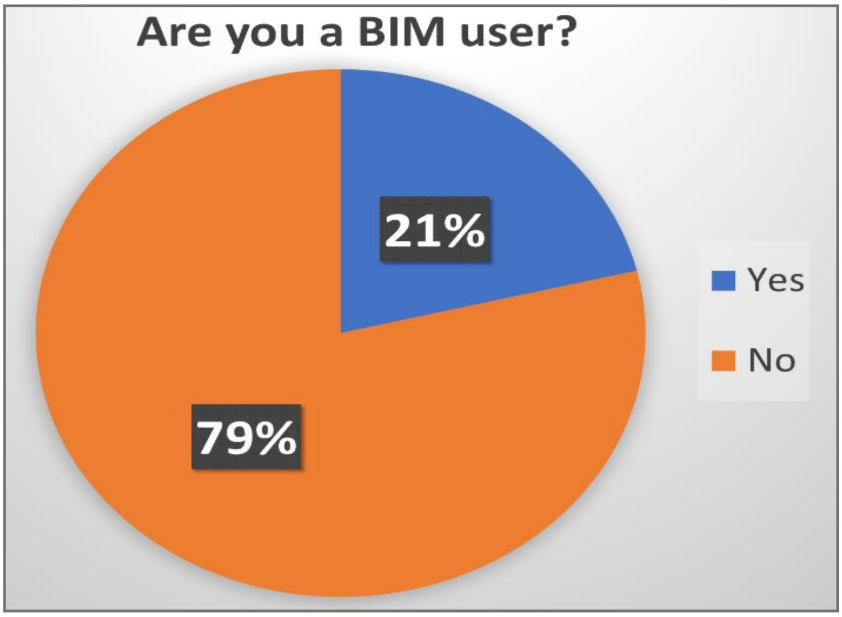


Figure 67: Percentage of BIM users in the construction industry in Kuwait

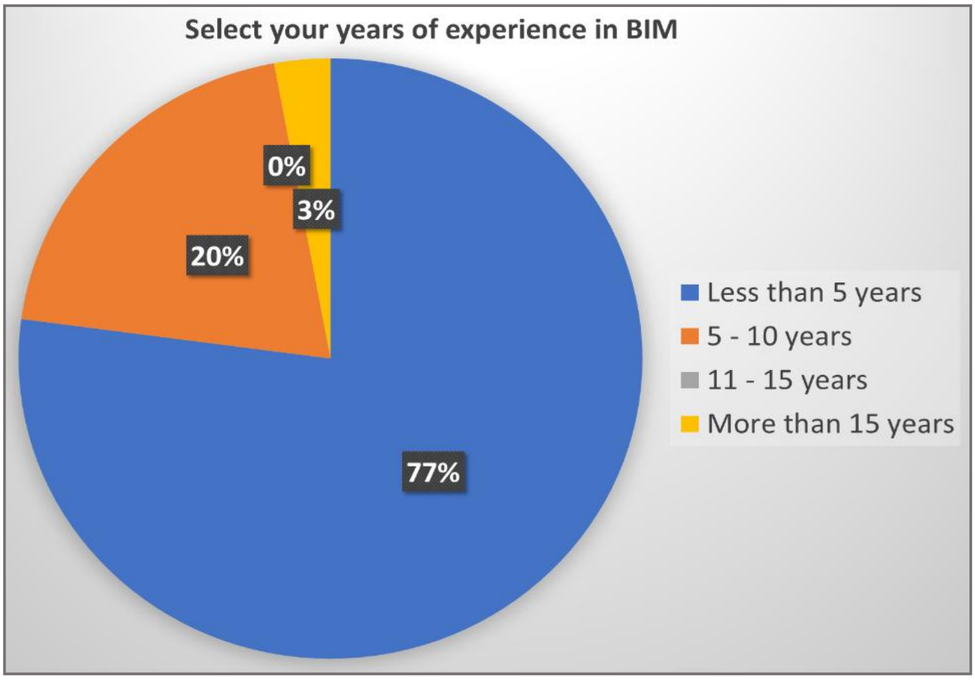


Figure 68: Percentage of BIM users' years of experience in BIM

Regarding BIM usage, respondents were asked to determine how they were using BIM and at what phase. The results revealed that 41.2% (n=14) of BIM users were using BIM for the design phase, 29.4% (n = 10) used BIM for project management (construction phase), 11% (n = 4) for detailing (design phase), and 8.8% (n = 3) for element fabrication (construction phase), while none of the users were applying BIM at the FM stage, as shown in Figure 69.

Additionally, participants who selected "other" 8.8% (n=3) had the option of adding their answers, if they were not listed in the question. Thus, two of the BIM users mentioned that they used BIM in all construction stages, while one indicated "none".

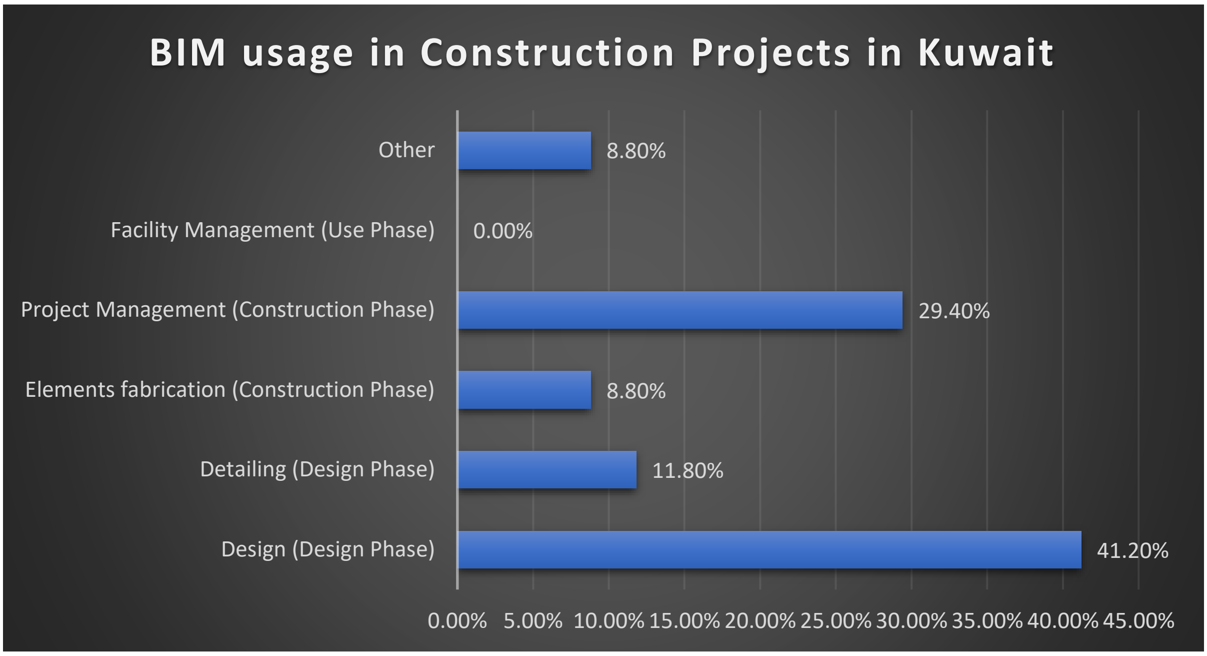


Figure 69: Usage of BIM in the construction projects in Kuwait

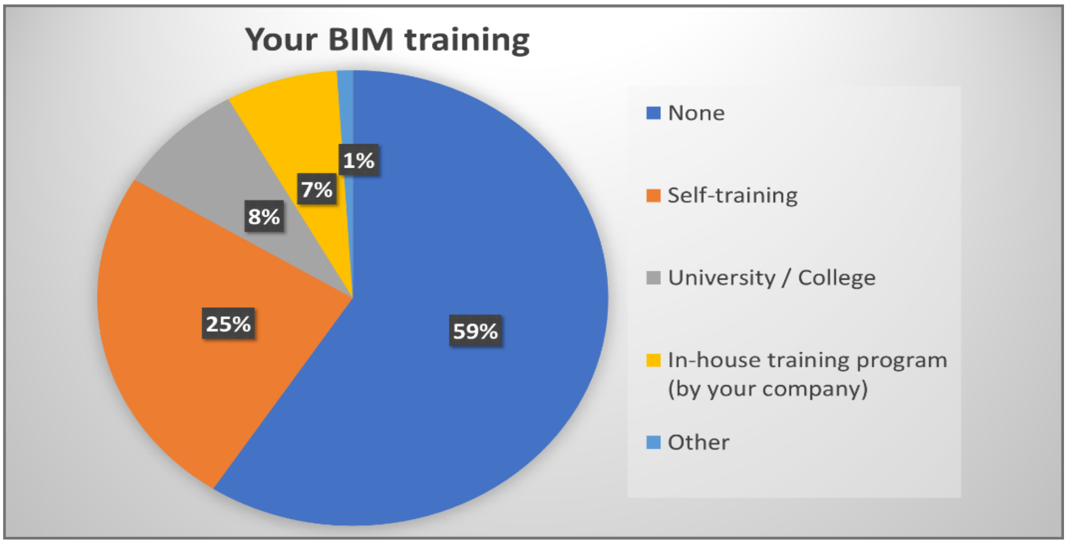


Figure 70: Types of BIM training held by the participant

The result of question 20 revealed that 59% (n=59) of practitioners had not received BIM training and that a few 25% (n=24) had trained themselves, while 7% (n=7) had in-house training by their company (see Figure 70). This indicates that there is a lack of BIM training in this field.

Questions 21, 22, and 23 were designed to evaluate the BIM maturity level in this industry. The result revealed that 47% (n=47) of repondents indicated partial collaboration and 26% (n=27) selected low collaboration between project parties in the construction industry in Kuwait. In contrast, only 19% (n=19) were undertaking full collaboration between project stakeholders, while 8% (n=8) had no collaboration, as illustrated in Figure 71. Accordingly, there is was partial collaboration and coordination between project stakeholders in the industry.

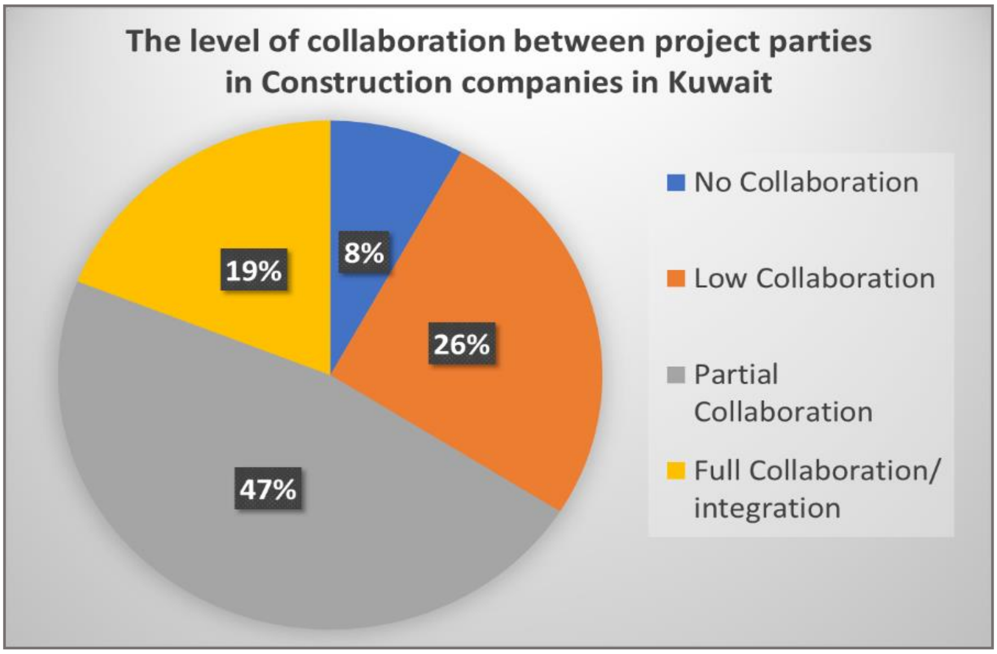


Figure 71: The level of collaboration between project parties in the Construction Industry in Kuwait

In order to understand how construction companies were producing project information in this industry, respondents were asked to specify how project information was generated. The result of this question pointed out that 48% (n=47) of participants generated project information using a combination of 2D and 3D within a common data environment but without integrating finance and cost management packages with CAD. Moreover, 33% (n=32) were using only 2D

AutoCAD to produce project information in this industry. On the other hand, only 8% (n=8) of BIM users were using 6D full lifecycle integration (see Figure 72).

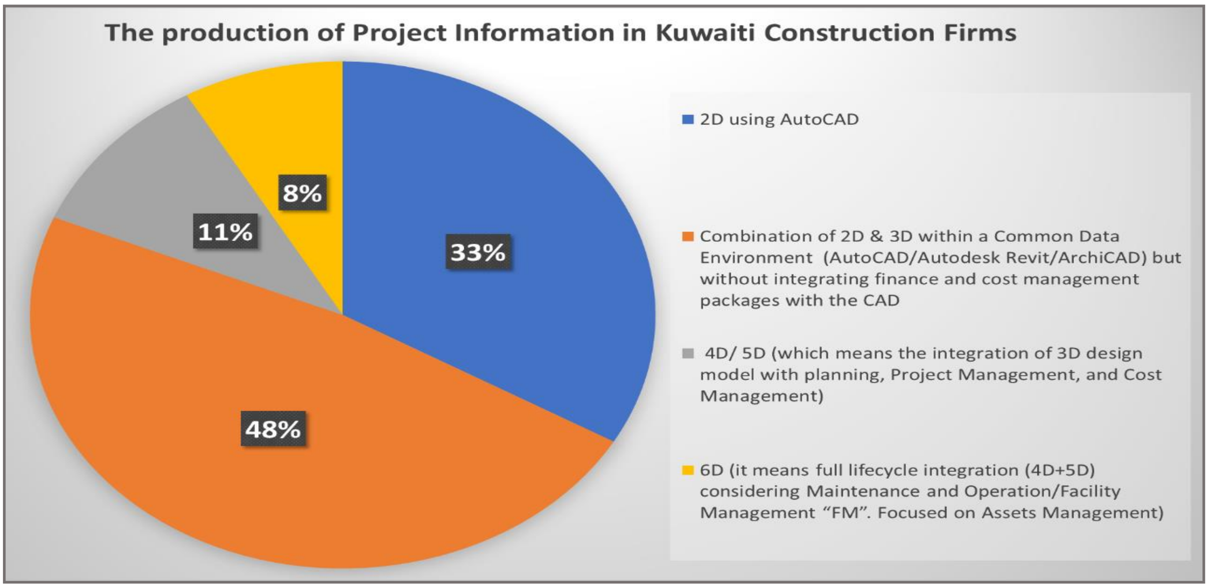


Figure 72: Production of project information in construction companies in Kuwait

Regarding the type of information sharing tool, 57% (n= 55) of practitioners used papers and printouts, or digital means; these were separate sources of information that covered basic asset information. While 5% (n=5) used integrated web services (Cloud-based environment) as a tool to share project information among project teams (see Figure 73). This demonstrates that the maturity level of BIM in the construction industry in Kuwait is at Level 1, according to the UK BIM maturity levels.

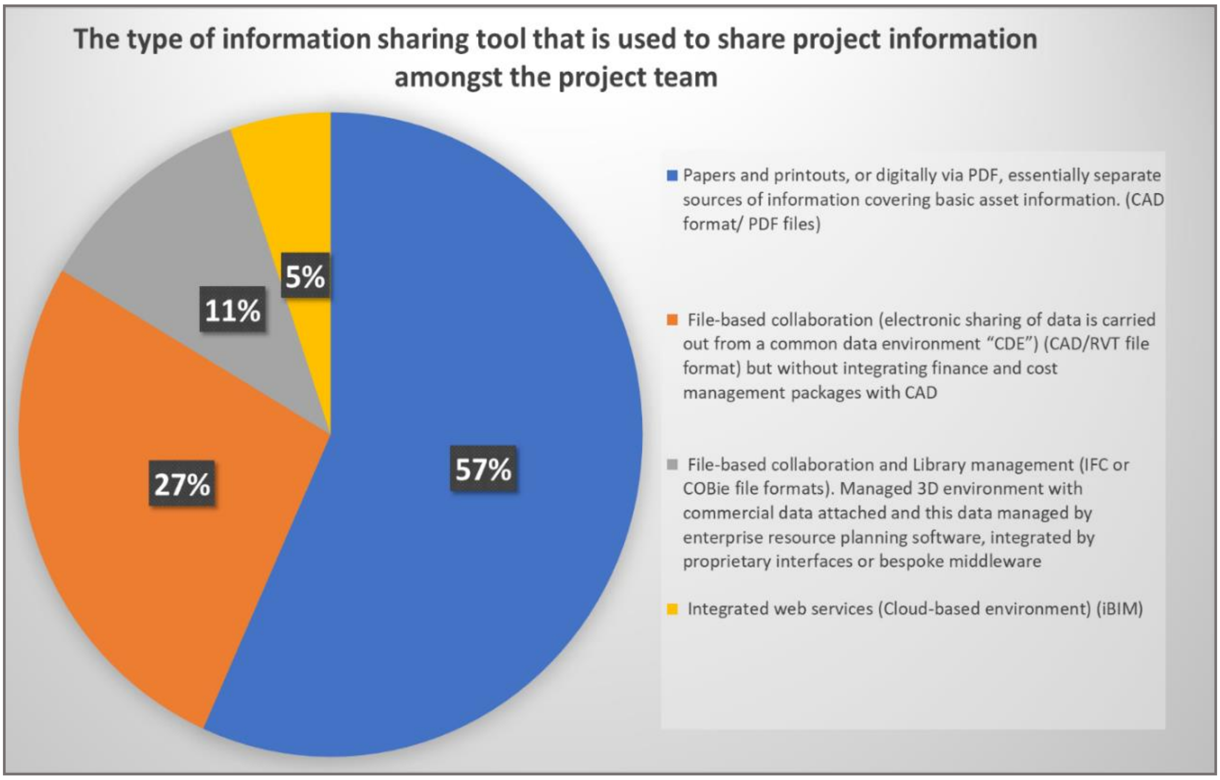


Figure 73: Type of information sharing tool used amongst the project stakeholders in the construction industry in Kuwait

<u>Section 5: Synergies between LC and BIM</u>

From another perspective, participants were asked to determine their agreement level on 11 BIM functions and their interaction with Lean principles, and how they can complement each other and contribute to improved performance. The answer to each statement is provided below (see Table 41), in which 1-5 represents a Likert scale with 1 indicating "Strongly disagree", 2 "Disagree", 3 "Neutral", 4 "Agree", and 5 "Strongly agree". The mean, mode, and standard deviation of all responses were calculated.

Table 41: Synergies between BIM functions and Lean Construction principles

BIM functions & its interaction with Lean Principles	N	Min.	Max.	Mean	Mode	Std. Deviation	Ranking
1. Clash detection function during design phase will eliminate waste in time, money, materials, and efforts	99	1	5	4.18	4	0.825	3
2. The existence of an alternative designs to determine the most appropriate design will eliminate waste in time, money, materials, and efforts.	99	2	5	4.13	4	0.737	4
3. Performance simulations for the most efficient energy solution will eliminate waste in time, money, materials, and efforts.	99	1	5	3.97	4	0.839	11
4. Visualization of solution that ensure clear understanding of the model will improve client value (achieving client's requirements).	98	2	5	4.11	4	0.687	6
5. Using analysis for best result will improve client value (achieving client's requirements)	98	2	5	4.07	4	0.707	7
6. Understanding between client & supplier by use of 3D models & walk throughs will improve client value (achieving client's requirements)	98	1	5	4.19	4	0.741	2
7. Automated generation of changes & material schedules & quantities will improve client value (meet client requirements)	98	2	5	4.00	4	0.732	10
8. Provide accurate information to pre-fabrication (for Pre-cast concrete, etc.) will improve client value (meet client requirements)	98	2	5	4.05	4	0.778	8
9. Visualising of workflow to check for process conflicts (team & tasks) will improve client value (meet client requirements)	95	2	5	4.02	4	0.743	9
10. Making detail schedules of tasks & materials delivery times will facilitate the workflow of the project	97	1	5	4.32	5	0.811	1
11. Working concurrently on same design solution by different teams using BIM approach will achieve collaboration & coordination between all project parties.	98	2	5	4.12	4	0.763	5

According to the responses, the highest arithmetic average (mean) is 4.32 for "Making detail schedules of tasks and materials delivery times will facilitate the workflow of the project", followed by an average mean of 4.19 for "Understanding between client and supplier by use of 3D models and walk throughs will improve client value (achieving client's requirements)" and 4.18 for "Clash detection function during design phase will eliminate waste in time, money, materials and efforts". In comparison, the lowest mean is 3.97 for "Performance simulations for the most efficient energy solution will eliminate waste in time, money, materials, and efforts" (see Table 41).

Section 6: Drivers and barriers of BIM implementation in the construction industry in Kuwait and the development of BIM-driven Lean Construction framework

This section was designed to evaluate the advantages and disadvantages of BIM implementation in the Kuwaiti construction projects found in the literature review. The findings for these questions reinforced what was discovered when reviewing relevant literature, as shown in Tables 40 and 41. Respondents were asked to indicate their opinion on a Likert scale (1 “Strongly disagree”, 2 “Disagree”, 3 “Neutral”, 4 “Agree”, and 5 “Strongly agree”).

Overall, 22 benefits to implementing BIM in Kuwait were evaluated by participants. These variables were represented using descriptive statistics, including frequencies of responses, the mean, the mode, and standard deviation for all responses (see Table 42).

Table 42: Benefits of BIM implementation in Kuwait

BIM Drivers/ Benefits	N	Min.	Max.	Mean	Mode	Std. Deviation	Ranking
1. Cost savings through reduced re-work & RFI's (Request for Information)	89	1	5	4.01	4	0.819	14
2. Improve design quality	88	2	5	4.30	4	0.664	2
3. Accurate construction sequencing	89	3	5	4.33	4	0.599	1
4. Improve built output quality	90	2	5	4.13	4	0.640	6
5. Improve capacity to provide whole life value to client	89	2	5	4.10	4	0.708	8
6. Streamline design activities	90	2	5	3.98	4	0.703	15
7. Time saving	89	1	5	4.17	4	0.727	4
8. Improve communication to operative	90	1	5	4.07	4	0.845	10
9. Facilitate increased pre-fabrication	90	2	5	4.03	4	0.756	13
10. Design health & safety into the construction process	90	1	5	4.06	4	0.826	11
11. Facilitate Facilities Management (FM) activities	89	1	5	4.08	4	0.742	9
12. Reduce waste	88	2	5	4.16	4	0.676	5
13. Smooth & clear flow	89	1	5	4.11	4	0.745	7
14. Reduce errors & avoid risks	88	1	5	4.20	4	0.730	3
15. Collaborative environment	89	1	5	4.16	4	0.752	5
16. Increased productivity	89	1	5	4.10	4	0.769	8
17. Reduced project costs	89	2	5	3.94	4	0.803	16
18. Better communication across stakeholders	89	2	5	4.17	4	0.661	4
19. Less defective work on site	89	2	5	4.10	4	0.769	8
20. Improved site layouts	89	2	5	4.04	4	0.811	12
21. Improved construction & procurement program	89	3	5	4.11	4	0.682	7
22. Improved on Site health & safety	88	1	5	3.88	4	0.907	17

As shown in Table 42, most of the variables received a reasonably high rating and the range of the mean was very limited, with the lowest being 3.88 for "Improved on site health and safety", and the highest being 4.33 for "accurate construction sequencing". The three main benefits of BIM in construction projects in Kuwait were highlighted in yellow. These drivers were 'accurate construction sequencing', 'improved design quality', and 'reduce errors and avoid risks'.

In contrast, the challenges to implementing BIM in the industry were assessed by participants based on their knowledge and experience in the construction industry in Kuwait. In total, 15 barriers were rated by respondents using a Likert scale (1 "Strongly disagree", 2 "Disagree", 3 "Neutral", 4 "Agree", and 5 "Strongly agree"). These variables were also presented using descriptive statistics, including the frequencies of responses, the mean, mode, and standard deviation for all responses (see Table 43).

Table 43: Barriers to BIM implementation in Kuwait

BIM Barriers / Challenges	N	Min.	Max.	Mean	Mode	Std. Deviation	Ranking
1. Lack of national BIM standard for the industry	83	1	5	3.78	4	0.938	6
2. Lack of skilled personnel (e.g. BIM experts)	83	1	5	4.00	4	0.870	2
3. Organisational issues (Process problems, learning curve, lack of senior support ownership)	83	1	5	4.01	4	0.848	1
4. Legal issues (responsibility for inaccurate licensing problems, copyright protection for ownership data. Privacy etc.)	83	1	5	3.70	4	0.907	8
5. Time needed for hiring/ training people to use BIM	83	2	5	3.88	4	0.739	5
6. Cost of hiring or training people to use BIM	83	1	5	3.69	4	0.840	9
7. Lack of businesses desire to change to BIM processes/ or against change	82	1	5	3.93	4	0.886	4
8. Complexity of BIM system	83	1	5	3.17	3	0.973	13
9. Information lost between different software	82	2	5	3.62	4	0.841	12
10. Issues for collaborating with multiple stakeholders	83	1	5	3.71	4	0.819	7
11. Absence of trust	83	1	5	3.63	4	0.984	11
12. Lack of client demand	83	1	5	3.69	4	0.974	9
13. Cost of investing in software & equipment	83	1	5	3.64	4	0.932	10
14. Lack of knowledge about BIM	83	1	5	3.99	4	0.848	3
15. Misuse of BIM	83	1	5	3.63	4	0.907	11

The findings revealed that the variable with the highest mean at 4.01 was "organisational issues", while the lowest average was 3.17 for "complexity of the BIM system". The three main barriers to BIM implementation in the industry were highlighted in Table 43, namely, 'organisational issues', 'lack of skilled personnel', and 'lack of knowledge about BIM'. Hence, considering these obstacles will help in developing a strategy for successful implementation; by identifying weaknesses, it is then possible to address them to enable greater viability.

In addition, participants were asked whether adopting a BIM-driven Lean Construction process protocol/framework will improve the industry or not, and which party should be responsible for that implementation. The results indicated that 75% (n=63) of respondents believed that by developing a protocol or framework that utilized a BIM approach to manage and control the whole lifecycle of a project and minimise waste would improve the performance of the construction industry and solve construction problems in Kuwait, while 4% (n=3) gave a negative response (see Figure 74).

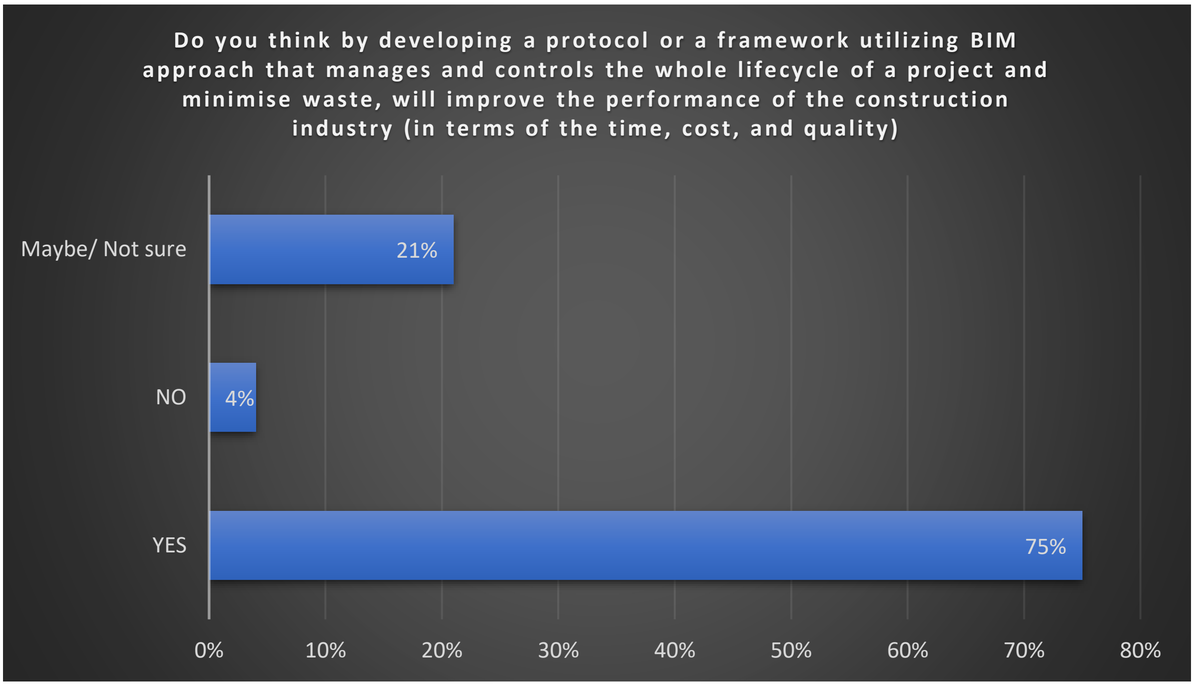


Figure 74: Participant agreement on having a framework to solve the addressed issues.

Moreover, respondents were asked to identify which of the project stakeholders should push BIM implementation in the construction industry in Kuwait. The answers revealed that 66% (n=55) of participants believed that the client or government should drive this adoption, while 2% (n=2) indicated “all parties” in the “other” option (see Figure 75). Therefore, the government should encourage the implementation of BIM in the public sector.

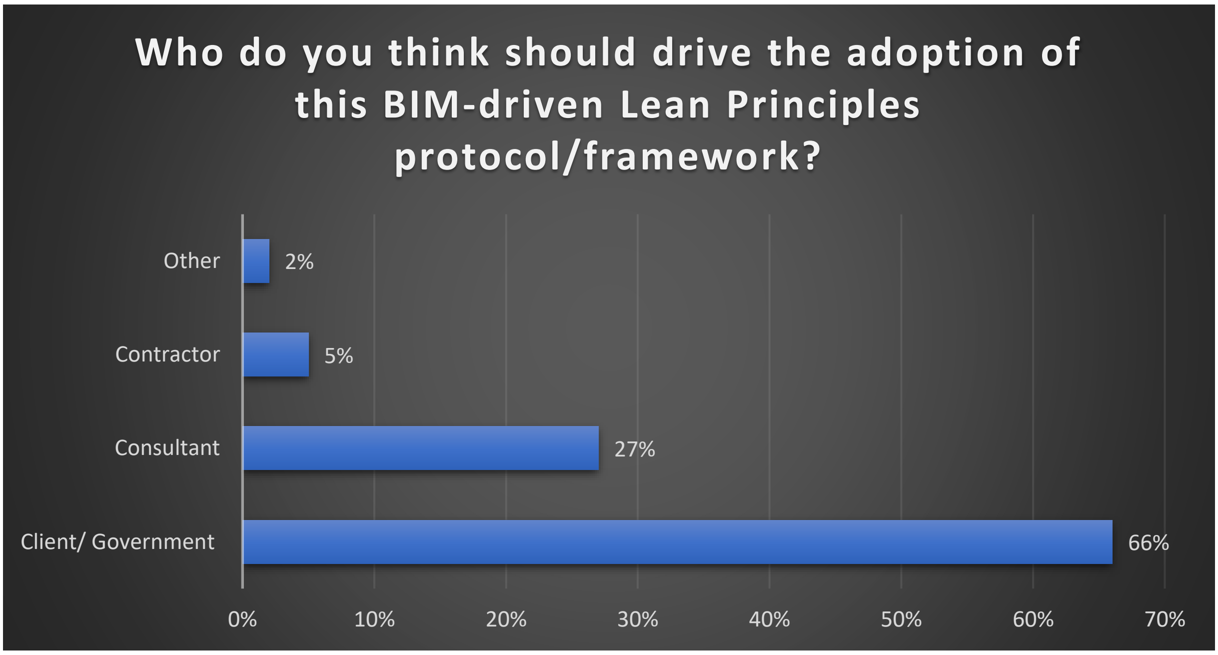


Figure 75: Who should drive the implementation of BIM-driven Lean framework in Kuwait?

<u>Section 7: Participants’ suggestions (optional and open question) qualitative question.</u>

Finally, participants were given the opportunity to add any suggestions to improve the performance of the construction industry in Kuwait, especially for government construction projects. Table 44 shows participants' suggestions for this improvement.

Table 44: Participants' suggestions from the questionnaire

	Participants' suggestions for improving the performance of the construction industry in Kuwait especially for the government construction projects?
BIM Users	*"Mandate BIM technology"* - *BIM Manager, Consultant*
	"Routine and long approval cycle" - *Project Manager, Contractor*
	"Adoption of New Technologies" - *Civil Engineer, Consultant*
	"Innovate and try to pioneer in new technologies" - *BIM Manager, Contractor*
	"Develop the governmental software ability" - *Civil Engineer, Consultant*
Non-BIM Users	*"To raise awareness of all the developments in the construction process in the whole sector (marketing and media work for professionals)"* - *Civil Engineer, Client*
	"Simply The government and all stakeholders must use it. It's a matter of decision making. I have enforced it in design, unfortunately other sectors did not (contracts, construction, etc.)" - *Assistant Undersecretary, Client*
	"Corruption should stop Later on we would improve our construction industry" - *Petroleum Engineer, Client*
	"Amend Central Tenders Committee regulations of lowest price winning project" - *Project Manager, Client*
	"Upgrading the skills and knowledge of personnel in key positions, such that they set standards for their teams to follow. Continuously monitoring performance and acting on any shortcomings" - *Mechanical Engineer, Contractor*
	"More restrictions and construction regulations are needed" - *University/College Professor, Client*
	"The exclusion of the consultant in case there is a representative of the owner of the site, because it works to disable the project for the longest possible period, because it is not accounted for time and cares only about monthly salary" - *Mechanical Engineer, Contractor*
	"By legislation" - *Project Manager, Contractor*
	"Conditions and terms of BIM principles should be mentioned in the contracts by the government (client) to obligate the contractor for full implementation" - *Civil Engineer, Contractor*
	"Simplifying the procedures between the different ministries to save time and money" - *Civil Engineer, Client*

As shown in Table 44, suggestions were divided into two groups based on the utilization of BIM; each stakeholder group was highlighted in a different colour. It can be concluded from these suggestions that there is a need for development in the building and construction industry in Kuwait, and the modernisation of building regulations and legislation in the current system. In addition, the industry would benefit from standarising the project implementation processes.

5.1.3 Questionnaire Reliability

Research reliability relates to obtaining identical results if more data were gathered using the same procedure (Saunders, Lewis, & Thornhill, 2016). Moss (1994) defined reliability as the consistency of respondents' answers on a given scale. It can be calculated by Cronbach's alpha on a scale of 0% - 100%, with higher values representing more consistent answers and greater reliability. The minimum acceptable value is 0.70, which indicates that the answers are reliable. In this study, SPSS software was used to perform a Cronbach's alpha analysis to estimate the reliability of responses in all sections of the survey: Challenges facing the construction projects (public sector) in Kuwait, Lean waste in the construction projects in Kuwait, synergies between BIM functions and Lean Construction principles, the benefits of BIM implementation in Kuwait, and the barriers to BIM implementation in Kuwait. Table 43 represents the reliability value of each section of the questionnaire. Since the Cronbach's alpha value of all sections is over 0.7, the questionnaire is reliable and consistent.

Table 45:Reliability Statistics (Cronbach's Alpha)

Section	Cronbach's Alpha	No. of items
Challenges facing the construction projects (Public Sector) in Kuwait	0.804	11
Lean waste in the construction projects in Kuwait	0.791	8
Synergies between BIM functions and Lean Construction principles	0.902	11
Benefits of BIM implementation in Kuwait	0.955	22
Barriers of BIM implementation in Kuwait	0.855	15

5.1.4 Summary

As mentioned earlier, the questionnaire was designed to explore challenges facing the construction industry in Kuwait and to gain an overview of the implementation of BIM and Lean Construction in this industry, which mainly focused on the public sector.

In the survey, it was found that most of participants worked for the client in the public sector; with diversity in their level of experience and professional background, suggesting a broad understanding of construction projects in the public sector. In addition, diversity in the groups of respondents helps when gaining results from different perspectives.

The main challenges and problems facing the construction industry in Kuwait were highlighted. The results reinforced what was found in the literature indicating that the industry suffered from delays and cost overruns resulting in underperformance. The four main risks in the industry were found to be delays, lack of communication and coordination between stakeholders, poor planning and control, and changes in orders by the client. Although public organisations may follow a project management approach, it is ineffective and needs improvements. For this purpose, the researcher investigated appropriate solutions to solve these issues using the project management approaches mentioned in Chapters 2 and 3 (literature review).

The survey was structured to obtain an overview of the implementation of Lean Construction or any waste management techniques, while also highlighting the eight Lean wastes in the industry. The findings indicate that there is a lack of knowledge and experience in waste management approaches such as Lean Construction. As a result, waiting, non-utilised talents, and defects were the main Lean wastes in construction projects in Kuwait.

With regard to Building Information Modelling (BIM), the questionnaire showed that the level of awareness and implementation in the industry was high, even though, there was a lack of expertise in this field. Also, it was revealed that the majority of BIM users in Kuwait applied BIM only in the designing phase, which indicated an abuse of BIM technology in this area. In this industry, there is a shortage of BIM training, as BIM users trained themselves with this technology.

It was discovered that the level of collaboration was mainly partial among project stakeholders in the construction industry in Kuwait, in which the project information was shared using papers and printouts, or digitally through PDF; separate sources of information covered underlying asset information. Consequently, the maturity level of BIM in the construction industry in Kuwait was mostly BIM Level 1 according to the maturity levels of BIM in the UK.

In addition, the survey results revealed that BIM applications had a significant impact on achieving Lean principles. By focusing on the proper implementation of BIM, Lean principles could be obtained.

The implementation of Building Information Modelling has its benefits and barriers that were gathered from literature, and examined through the questionnaire. It was found that the main three benefits of BIM implementation in Kuwait were: "accurate construction sequencing", "improved design quality", and "reduced errors and avoid risks".

On the contrary, the most significant challenges to BIM implementation in the construciton industry in Kuwait were organisational issues, a lack of skilled personnel, and a lack of BIM knowledge. These findings support the discoveries from the literature review. Therefore, BIM benefits should be the drivers for this implementation and take into consideration the barriers and weaknesses in order to avoid any complications when proposing a development solution.

The development of a BIM-driven Lean construction process protocol/framework would improve the industry's performance in terms of time, cost, and quality; hence, it will help to overcome the addressed challenges. The government (client) must be the driver behind the adoption of this framework to ensure the proper implementation of these approaches for the benefit of the industry.

In brief, the construction industry in Kuwait needs to keep pace with other developed countries by adopting new technologies such as BIM, focusing on the process of the whole project lifecycle to improve communication and performance, and developing legislation and law via the government. The researcher will conduct interviews from two selected cases (airport and hospital projects) for further investigation in order to develop and validate an improvement BIM-driven Lean Construction framework for this industry.

Chapter 6: Qualitative Data Analysis

6.1 Introduction

In this chapter, qualitative data will be analysed, and conclusions will be drawn from the case studies and validation interviews. First, semi-structured interviews will be analysed from two case studies to gain in-depth knowledge of current practices in the industry and how BIM and Lean are implemented. Thus, it will facilitate the development of the proposed BIM and Lean Process Protocol. Finally, structured interviews will be conducted as a validation process. They will be analysed to validate the proposed framework and inform the modification and update of the final version of the BIM and Lean Process Protocol. This validation process will be discussed in more detail in this chapter.

6.2 Qualitative Data Analysis (Interviews)

6.2.1 Introduction

Case studies were selected according to the questionnaire results, in which participants were asked to highlight the type of projects in which have applied BIM and Lean Construction within the construction industry in Kuwait. Two different projects were selected for the same client, which is a public organisation in Kuwait that leads most of the public construction projects in the state.

Although the interviews were semi-structured, the answers were verbal and open, allowing for further clarification and distinction in the data and a deeper insight into the attitudes and beliefs that underlie the behaviour. The purpose of the interviews is to develop an improved version of the process protocol that incorporates BIM and Lean principles, thus helping the client to implement BIM while minimising waste in construction projects in Kuwait. As a result, the performance of this industry will be enhanced.

General information about these two cases was gathered from various sources, such as documents, newspapers, and official government websites. The semi-structured interview questions were categorised into five sections:

1. An awareness of the nature and processes of the construction project (including phases, deliverables, and participants).
2. Current practices of Building Information Modelling (BIM) and Lean Construction within the organisation and their challenges.
3. Investigation of the current BIM standard and the requirements of BIM ISO 19650.
4. The existing level of coordination and collaboration between project parties.
5. Use of BIM-based applications and software.

Data were gathered then examined for recurring themes that would make a more rigorous and detailed contribution, and achieve the research aim and objectives.

The researcher interviewed 10 participants from different stakeholders to allow for more diversity and avoid any bias in the outcome. Participants volunteered to be interviewed, and the sample was random. Three participants from the client organisation, three consulting firms, and four contracting companies participated. Four interviews were conducted for the first case study (airport project), and six interviews for the second case study (hospital project), as shown in Table 46. Additionally, the variety of experiences and backgrounds of the interviewees provide rich information about the current situation.

Table 46: Interviewee's information

Case study	Participants	Gender	Position	Experience	Work for	Years of experience
Case 1 (Airport Project)	A1-A	Male	Head of construction engineering team	Construction Projects	Client	• 17 years of experience
	B1-A	Male	Mechanical Structural Engineer	As a Fabricator As an Architect In BIM	Consultant	• Years of experience in Construction as a fabricator: 3 years • Years of experience in Construction as an architect: 8 years • Years of experience in BIM: 14 years
	C1-A	Male	Deputy Design Director	Construction BIM	Contractor	• years of experience in Construction Projects is: 25 years and last 15 years around BIM
	C2-A	Male	Senior Architect	Construction BIM	Contractor	• years of experience in Construction Projects is: 4 years • Years of experience in BIM is more than 10 years
Case 2 (Hospital Project)	A1-H	Female	Manager	Construction / Civil Engineer	Client	• 30 years of experience
	A2-H	Female	Architect	Construction / Architect	Client	• 17 years in the construction projects • Experience in BIM: two training courses and this project
	B1-H	Male	Project Manager	Construction	Consultant	• 40 years of experience
	B2-H	Male	Site Engineer	FF & PL Engineer/ Mechanical Engineer	Consultant	• 10 years of experience in Construction Projects • 6 years in BIM Projects
	C1-H	Male	Civil Engineer who has a MSc Construction Management	Construction	Contractor	• 31 years of experience
	C2-H	Male	Architect and MSc construction Project Management	Architect BIM	Contractor	• 4 years and 6 months experience as an Architect • 5 years of experience in BIM

Qualitative data was collected from these case studies using semi-structured interviews with various project parties in order to understand the different perspectives of these projects. Figure 76 illustrates the structure of the case studies.

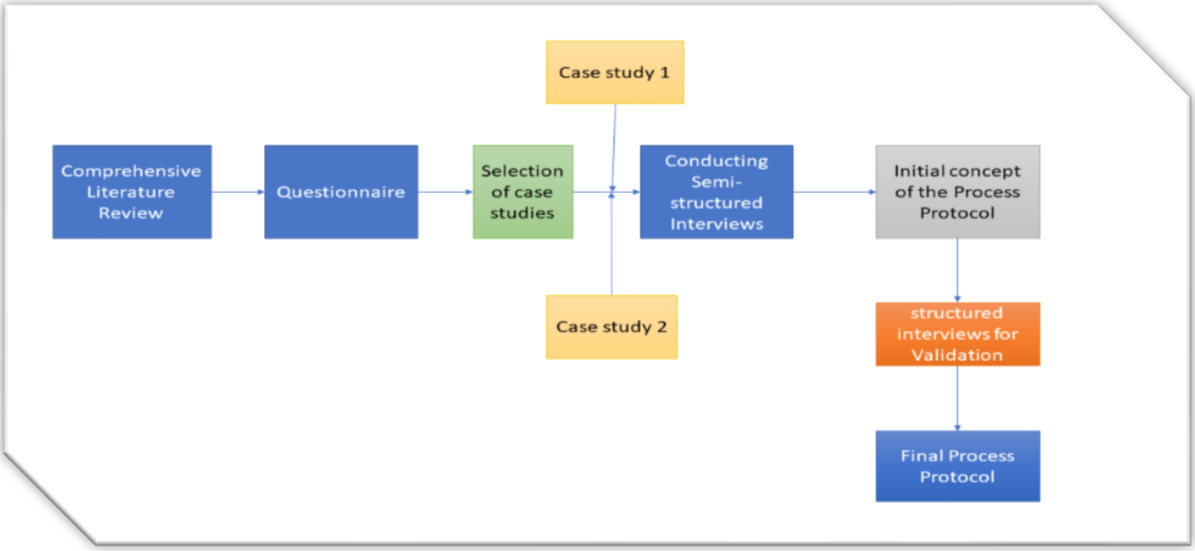


Figure 76: Case studies' structure

6.2.2 Case study 1: Airport project

Project type	Location	Client	Project Status	Types of Contract	Years of completion
Commercial	Kuwait	Public organisation	Under construction	Traditional (D-B-B)	2024

Case Study One is a significant project as it represents a paradigm shift in infrastructure and air transport. It is one of the projects within the Government development plan that aims to achieve the New Kuwait vision. It is an important step towards transforming Kuwait into a financial centre by making Kuwait Airport a hub for travellers around the world. The total cost of this mega project is KD 1.413 billion (US $ 4.647 billion) with a total area of 504,257 square meters and a construction area of 130,000 square meters. The parking capacity is 4,500 cars. It is an ongoing project at the implementation phase involving a number of international partners in providing design and construction. Furthermore, this project received the world's first LEED Gold Certified Building (GulfConsult; MPW, 2017; NewKuwait, 2017).

The project delivery is based on the typical traditional project delivery approach in the local construction industry in Kuwait. A traditional procurement system (D-B-B) was adopted for this project with a traditional lump sum contract. This project was set in 2010, its construction started in 2017, and it was expected to be delivered in 2020. Yet, this project has suffered from long delays and high-cost overruns. Therefore, the completion date of the project was postponed to 2024.

Regarding BIM implementation, this project implemented BIM in the design phase due to the recommendation of the international designer to follow this approach. However, the implementation was improper as the contractor was unable to access the BIM model, and only shop drawings were provided. Thus, there was a lack of cooperation between project parties in this case study.

As a result, the contractor team re-created a BIM model based on information in the shop drawings provided by the designer. Additionally, the coordination of BIM models and clash detection were carried out by the contractor. All project parties have separate individual contracts with the client, which indicates little collaboration between stakeholders, resulting in a waste of time, effort, and money.

6.2.3 Case study 2: Hospital project

Project type	Location	Client	Project Status	Types of Contract
Commercial	Kuwait	Public organisation	2016 - Under construction	Design and Build (D&B)

The second case study is a hospital project that intends to provide state-of-the-art facilities for gynaecology patients' care and treatment, as well as a major new neonatal facility. The project will host 780 beds (464 Acute, 76 ICU, 240 NICU) in a dedicated area with its own support facilities, including 27 operating rooms (10 obstetrics, 14 gynaecology, 3 IVF) and 60 labour and delivery areas. The project consists of a main hospital building, with a total building area of about 241,600 square meters, a supplementary building designed containing outpatient clinics with a built-up area of about 49,206 square meters, a multi-storey parking area with a capacity of 1,300 cars, a central services station, and three linking bridges to connect the new buildings with the existing surrounding facilities.

Service areas that support healthcare functions, such as the laundry, CSSD, and material and waste management, are placed in the basement of the main hospital. On the upper levels, including the ground floor and six floors above ground, the central departments of the hospital are located, as are the emergency, surgery ward, neonatal intensive care unit and the radiology unit. Above this "podium", there are three towers – of six, nine, and 11 floors– designated for inpatient wards. The annex building accommodates the hospital's administration as well as all outpatient departments for obstetrics and gynaecology and neonatal health.

This project adopted the Design and Build (D&B) Project Delivery System, in which a contractor is assigned to design and construct the project. The contractor in this type of project practice will appoint a designer for the design phase and will work together in a high level of collaboration. A Building Information Modelling (BIM) approach was implemented in this project. However, this implementation was improper as the contractor was unable to obtain the BIM model from the designer, which resulted in delays and cost overruns.

6.2.4 Analysis of Case Studies One and Two:

In this section, interviews from the two case studies have been analysed using thematic analysis; where data has been sorted into different categories. This data has been analysed using NVivo software. Analysis of both cases was combined in order to gain a comprehensive understanding of the framework development.

First, the researcher has transcribed the interviews manually then these data were inserted in the NVivo software which categorised it into 12 main themes, namely: process, BIM, Lean Construction and waste management, deliverables and submissions, building permits and approvals, procurement system or contract project type, collaboration and coordination, participants, monitoring progress of the project performance and quality control, evaluation of work or feedback loop, archive of the evaluation of previous projects, and recommendations (see Figures 77, 78 and 79). These themes helped the researcher organise ideas in order to draw conclusions, thus producing the process protocol.

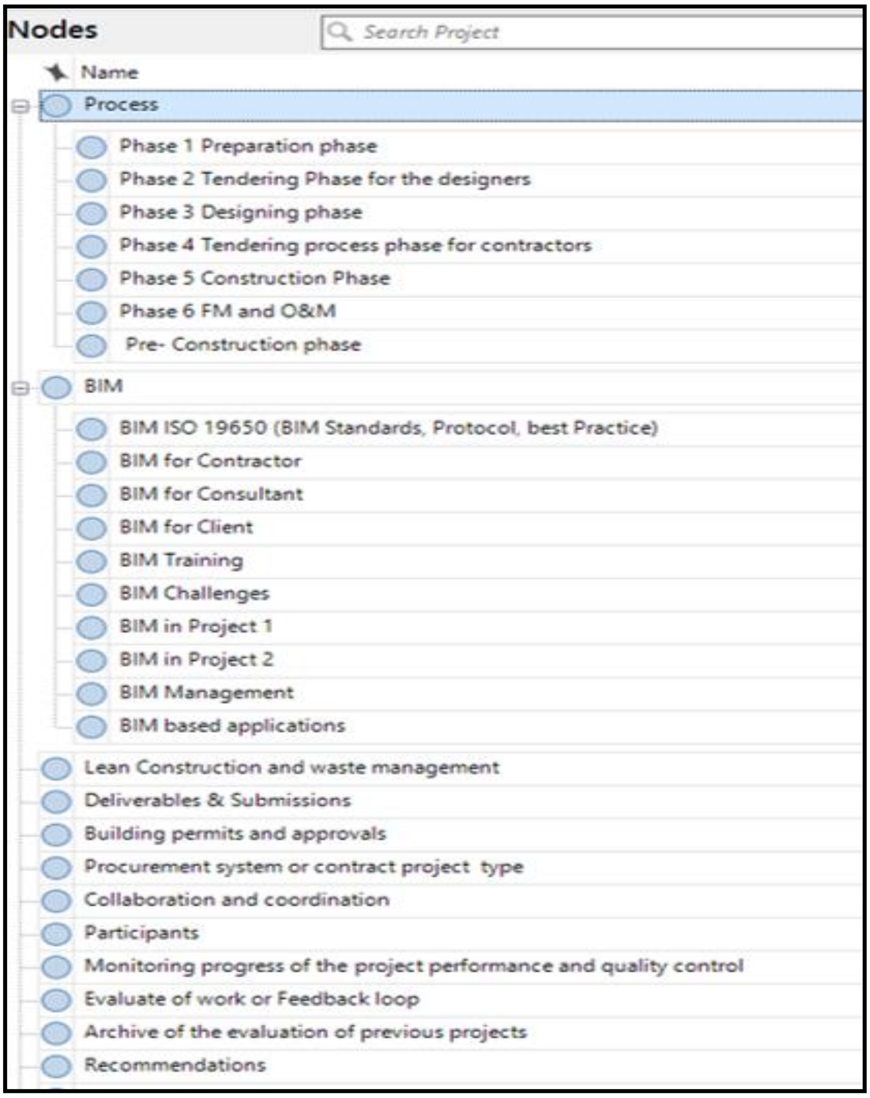


Figure 77: Interview themes

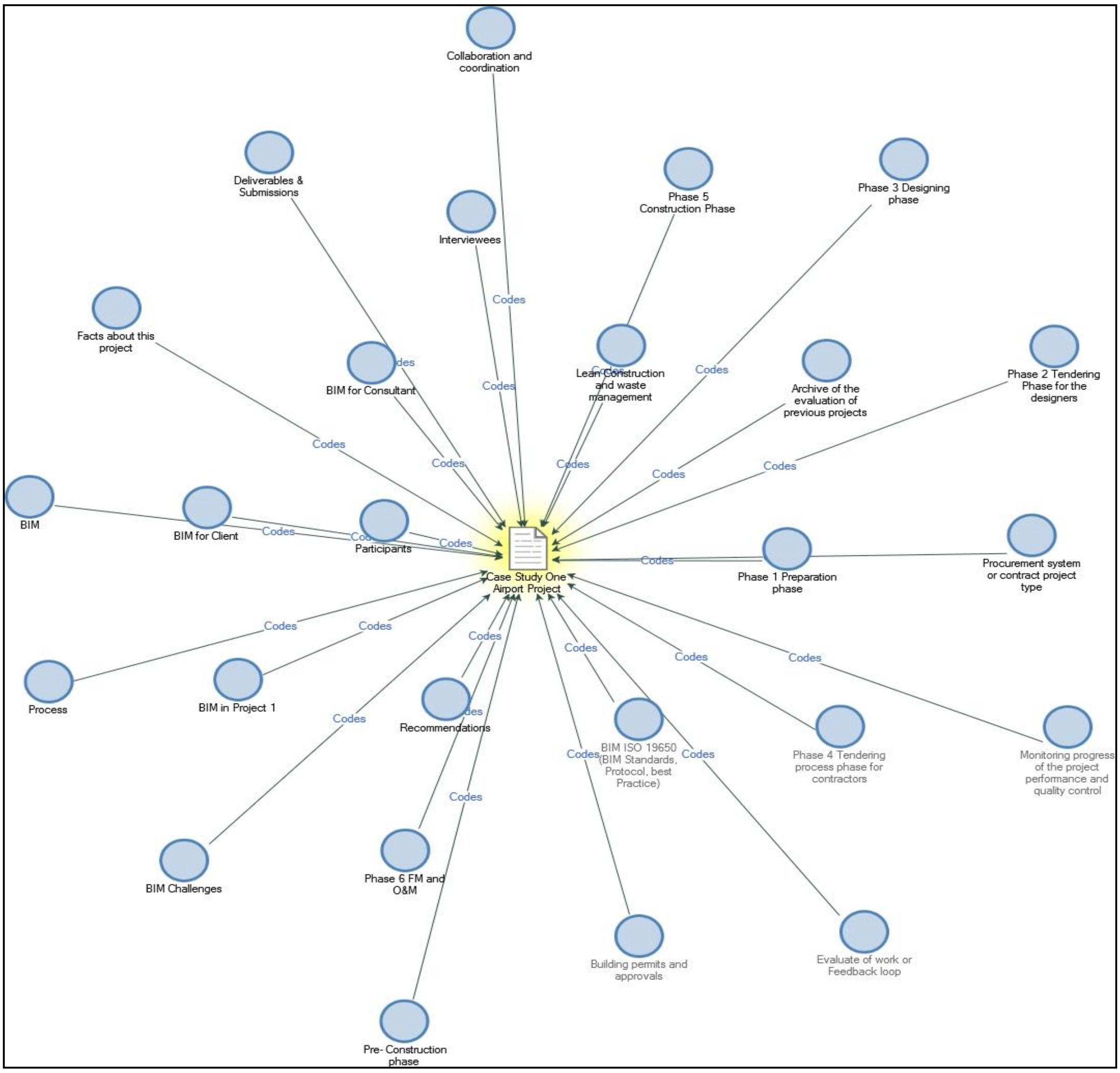


Figure 78: Themes of case study 1: Airport Project

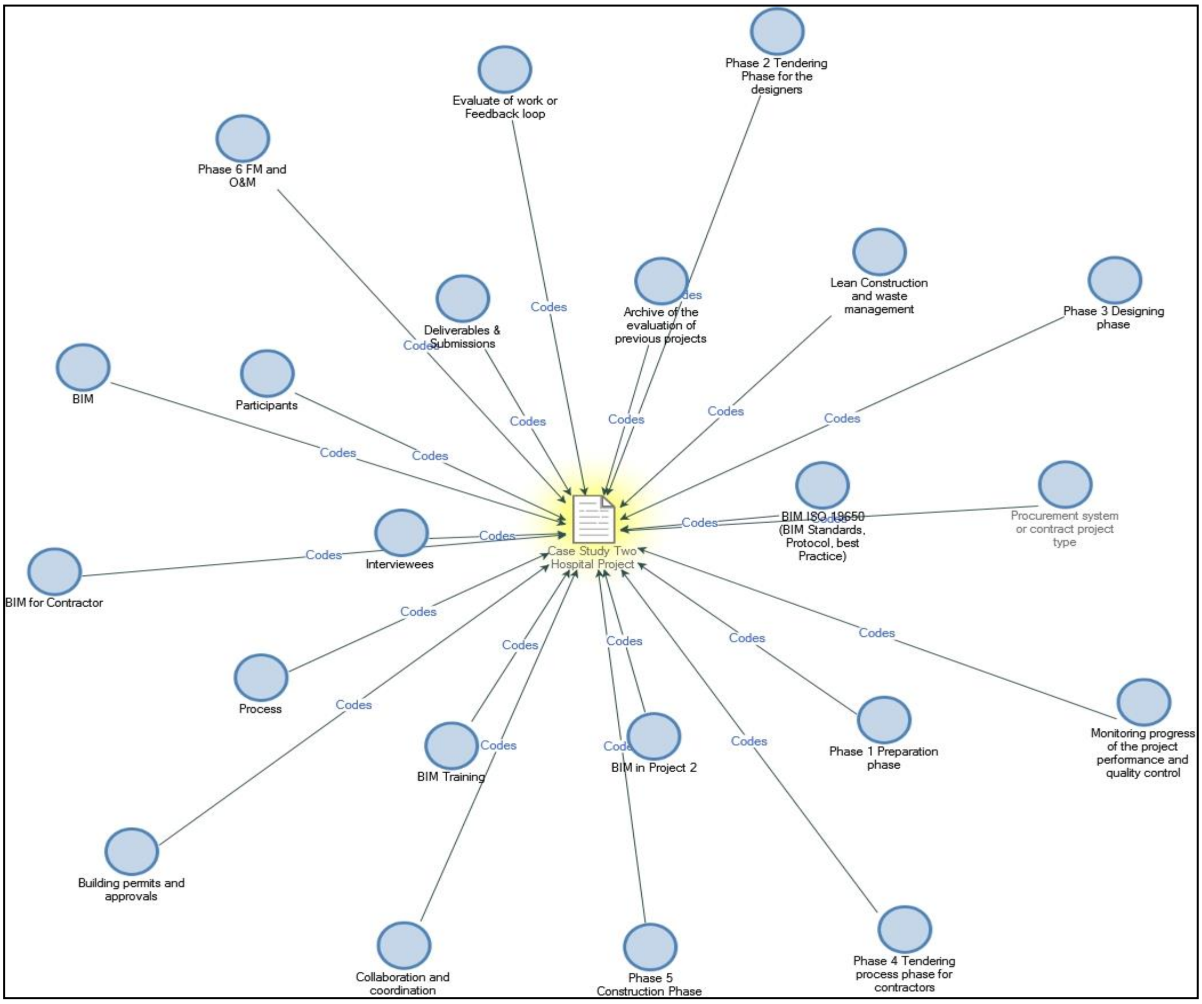


Figure 79: Themes of Case Study 2: Hospital Project

6.2.4.1 Process:

In this theme, interviewees were asked about each phase of the project and what processes should be included. Since each project has a different procurement system, one of the projects has more phases than the other. The traditional procurement system has eight phases: pre-project phase; tendering phase for design consultants; four design phases - *data collection phase, concept design phase, design development, and final design and contract document phase*; tendering phase for contractors, and construction phase. In comparison a Design and Build project has seven phases: pre-project phase; tendering phase for contractors; four design phases, and the construction phase. However, the researcher developed an approach that could encompass both types of contract, and was inspired from the RIBA Plan of Work 2020. An absence of the facility management phase in the BIM implementation was found in two projects. Nevertheless, the client is considering engaging FM in BIM by defining the FM requirements at the beginning of the project. It was recommended that "*FM teams should be involved at the beginning of the construction phase to ensure sufficient information is embedded in the models at an early stage*" *(*Consultant B1-A, personal interview, Nov 4, 2019*).*

6.2.4.2 BIM:

In this category, BIM implementation was discussed with each interviewee. It involved different perspectives, BIM for stakeholders, BIM standards, BIM training and application, BIM challenges, and BIM status in these two projects. There were 10 groups in this category, as follows:

- BIM ISO 19650 (BIM standards, protocol, best practice)

In Kuwait, public construction projects follow a combination of UK and USA BIM standards due to their simplicity, and ease of understanding. Therefore, it is important to publish their BIM standards for the construction industry in Kuwait to avoid any conflict or misunderstanding.

- BIM for contractors

In both case studies, the contractor team is responsible for producing a BIM model based on the shop drawings given by the client. Also, they are responsible for BIM coordination, clash detection, and updating the BIM LOD 300 to LOD 400, which is opposed to the purpose of the BIM process.

- BIM for consultants

In these two projects, the consultant captured BIM requirements given in the TOR and started developing the BIM model. Large consulting firms should have a BIM expert within their teams. In fact, the designer produces the BIM model LOD 300 and extracts the shop drawings from this model for the tendering phase.

- BIM for clients

Clients in the construction projects in Kuwait lack the knowledge and experience required to implement BIM. So, they seek help from BIM advisors in order to gain more knowledge and get some training.

- BIM training

All project stakeholders are undertaking BIM training within their organisation. But it is more extensive within the contractor and the consultant firms to keep up with other countries and to be able to compete in mega construction projects.

- BIM challenges

According to the interviewees, there are several barriers to implementing BIM in the industry, which are summarised in Table 47 based on the case study and participant group.

Table 47: Challenges to implementing BIM in Kuwait (from interviews)

BIM Challenges	Case studies	Participant
• Lack of expertise	Case study 1: Airport Project	Client
• A partial implementation of a BIM solution with not all subcontractors responsible for it. • Unclear protocols for who is responsible for coordinating and reviewing the model content. • Absent client requirements for FM/BMS systems • Undefined roles for BIM model management • Broken links between on-site validation of installed systems • Absent instruction for Health and Safety/ Temporary works BIM models showing on-site utilities for workers. • Disconnects within the factory environment linking the BIM model to the fabrication process.	Case study 1: Airport Project	Consultant
• There are too many parties, and it is difficult to align them • Restrictive contractual arrangements prevent getting advantages of BIM	Case study 1: Airport Project	Contractor
• Lack of hardware and software • Lack of an appropriate training for large groups	Case study 2: Hospital Project	Client
• The wrong idea about BIM in Kuwait	Case study 2: Hospital Project	Consultant
• Lack of resources • Lack of best practices • Not following BEP	Case study 2: Hospital Project	Contractor

It can be concluded from Table 47, that the main barriers to the adoption of BIM in the construction industry in Kuwait are: a lack of experience, resources, training, and best practice; partial implementation of BIM solutions; unclear BIM protocols; undefined roles for BIM management; the absence of FM requirements and H&S instructions from the client; a lack of knowledge of BIM and its purpose, and the lack of appropriate legislation for BIM implementation.

- BIM in Project 1 (Airport Project)

In the first case study, it was found that the BIM model was not required in this project, because it was a traditional project, wherein 2D drawings were issued not the 3D model and then they discussed BIM. At the beginning of the project from the concept design to the detailed design, BIM model was not a requirement. In fact, the consultant made recommendations to implement BIM and the client turned them into requirements. Recently, the implementation of BIM in construction projects has been mandated by the client, despite their lack of experience and knowledge, which suggests they are on a learning curve. As a result, BIM was implemented incorrectly.

After signing the design contract, BIM was used restrictively by the design consultant office for management because they had specific KPI's required and carbon targets for inclusion. Since there were a lot of data and typical AutoCAD models restrict the generation of information, BIM was used to achieve all targets using a schematic/detailed design. Although a BIM model was not provided to the contractor, the contractor was responsible for: producing a BIM model based on the shop drawings given by the client, setting the BIM strategy, and the BEP for delivering the BIM model from LOD 200 up to LOD 400. Additionally, clash detection and BIM coordination were carried out by the contractor in this project.

- BIM in Project 2 (Hospital Project)

In the second case study, it was discovered that BIM was mainly used by contractors in Kuwait, and more recently used by consultants. Similar to the first case study, a BIM model was not provided to the contractor, and the contractor had to recreate it based on the shop drawings given by the client. Depending on the agreement, the contractor could purchase a BIM model from the consultant. Although this project is Design and Build, there is almost zero collaboration between project stakeholders, indicating a misunderstanding of BIM adoption. In this project, the designer only undertook the conceptual design, hence the cost estimate. After that, the tendering phase started, so the contractor was responsible for the design phase and the creation of the BIM model, as well as construction phase.

- BIM management

In interviews, there are questions about assigning a BIM management team within the client organisation (in-house team) to facilitate the adoption of BIM. In both case studies, participants believed that client organisations are incompetent at this step, and that they needed more training and experience. Therefore, it is recommended to outsource a BIM advisor at the beginning of the project. The BIM management team should be responsible for preparing the BIM strategy and standards, BIM requirements for each project, and assessing the client's objectives in order to develop a framework for incorporating long-term objectives (post-construction) into the construction BIM Execution Plan. Moreover, this team could facilitate the integration/management of fabrication and construction principles at the design stage. Thus, a BIM consultant should facilitate BIM implementation throughout the entire project life cycle.

- BIM based applications

For both case studies, consultants and contractors used various software depending on the objectives and requirements of the project, thereby involving any software that helped realise BIM process, including Word and Excel until Revit, Navisworks, and Dynamo. For instance, Revit can be used for modelling or whatever program requested by the client and Navisworks for clash detection, simulation, and 4D.

6.2.4.3 Lean Construction and Waste Management:

In this section, LC and waste management approaches will be examined for both (airport and hospital) projects according to the interviews. It was found that waste management approaches were used by the consultant and the contractor, however, the client was not aware of these techniques.

In the first case study, the client believed that minimising waste in materials was the contractor's responsibility because he was the one to benefit. But regarding environmental waste, some materials would be recycled such as concrete cubes used for testing. Likewise, the consultant thought that it was the contractor's job to deal with waste and they were not involved in how the contractor decided to develop. Regardless, the designer would consider Lean Construction techniques depending on the project scale. Their main concern was sustainability in terms of water, energy, materials and environmental quality. Since this project required LEED Gold, the focus was on the design and function, so they monitored sustainable targets over the detailed and construction phases. Additionally, the design consultants provided design guidance and often proposed various solutions to minimise construction waste. During the construction phase, they advised to the best of their abilities on the approach chosen by the contractor, and occasionally evaluated alternatives if this had a significant impact on either their own sustainable design targets or design quality.

On the other hand, the contractor was responsible for site waste and for ensuring that the construction works followed the requirements and standards in order to be certified as a LEED Gold project. In addition, there were KPI's for the internal quality control team so, the contractor's team identified series items, reports and targets.

In the second case study, it was revealed that the client only focused on design (area in-use and functional), so there was a lack of appropriate waste management techniques. Moreover, the client said that this was the contractor’s responsibility as he would benefit from it. In the consultant company, a Value Engineering (VE) check was applied to ensure that the design was optimum and to avoid waste in the design.

Unfortunately, there was also a lack of proper Lean Construction and waste management approaches within the contractor company. However, one contractor suggested that to reduce waste, purchases should be obtained in a timely manner and ensure that they were stored properly. He added that if the clashes in the model were resolved during the design phase, rework would be avoided, and therefore, wastage would be reduced.

Regarding off-site construction, in the first project, the consultant mentioned five or six mega factories on site. These factories produced partial pieces on-site, such as concrete panels and steel, because of the huge size of the project. However, off-site construction had not yet started, as major architectural finishes required more accurate information. In the second project, precast concrete was used with no prefabricated/offsite units. For example, half of the building or more was precast concrete, which included restricted slabs, but no prefabricated units were used in this project.

In summary, there was an absence of Lean Construction (LC) techniques, where the entire project lifecycle would be assessed and broken down into processes in order to understand weaknesses and to thence address and strengthen those weaknesses. Thus, waste could be reduced and the performance optimised.

6.2.4.4 Deliverables and Submissions:

This theme helps the researcher to identify and present the required outputs for each phase of the project framework. Since both cases had the same client organisation, procedures and deliverables would be similar, and the only main difference was the contract type – a traditional procurement system and Design and Build.

Firstly, the client prepares and produces a well-developed TOR with the advisor's help (if required). After that, the bidding phase for designers begins. Bidders submit technical and financial proposals based on the specified Terms of Reference (TOR), including specifications, Bill of Quantities (BOQ), drawings, particular and general conditions. Then, the winning designer starts with the first design phase, called the data collection phase, in which the conceptual design and data collection report are submitted. Next, the second design phase starts, called the schematic design, where three design alternatives are presented. The following phase is the detailed design, in which the chosen design is developed, and an equivalent report and environmental impact assessment produced by the designer. In the final design phase, complete design drawings and the contract document are prepared by the designer. Additionally, at each design phase, the design consultant submits three reports: the meet phase report, mid-way progress report, and detailed report.

At this point, the tendering phase for contractors starts, during which the bidders submit their technical and financial proposals. The winner produces the coordinated design model and shop drawings. Then, the construction begins, with the contractor submitting weekly and monthly progress reports. Finally, operation and maintenance manuals, as-built drawings, and the reference of equipment are produced by the contractor at the handover phase. Table 48 shows a summary of outputs for each phase along with the responsible party.

Table 48: Summary of outputs for each phase with responsible party (from the interviews)

	Phases	Deliverables	Repeated outputs	Responsible Party
Pre-project	Planning phase	• TOR >> Design Agreement	-	Client / advisors
	Tendering phase 1 (for Designers)	• Technical Proposals • Financial Proposals • Drawings, BOQ, Specifications, particular conditions, General conditions.	-	Bidders (designers)
Design Phases	Concept Design (Data collection)	• Conceptual Design , Data collection report	• Meet phase report • Mid-way progress report • Detailed report	Winner designer (Consultant)
	Schematic Design (3 design alternatives)	• Schematic design (3 design alternatives)		
	Detailed Design	• Detailed design, Equivalent report (From Mechanical & Structural Engineers) • Environmental impact assessment		
	Final Design & Contract Documents	• Complete Design drawings • Contract document		
	Tendering Phase 2 (for Contractors)	• Technical Proposals • Financial Proposals		Bidders (Contractors)
	Construction Phase	• Quality Assurance (QA) and Quality Control (QC) plans • Coordinated design • Shop drawings • Weekly & monthly Progress Reports		Winner Contractor
	Delivery Phase	• O&M manuals • As-built drawings • Reference of equipment		Winner Contractor

6.2.4.5 Building permits and approvals:

In this section, approvals from different official authorities were highlighted. For each phase of the project, approvals needed to be obtained, either by the client, consultant, or the contractor, from 15 different local authorities, and up to 22 approvals, in total. For instance, the financial approval had to be obtained from the Ministry of Finance, project approval from the State Audit Bureau, and design agreement approval from the CAPT.

6.2.4.6 Procurement system or contact:

In public construction projects in Kuwait, Traditional Procurement (D-B-B) is the main system where the contract is lumpsum. However, in some cases, a Design and Build (D&B) approach is used, depending on the urgency of the project. For Design-Bid-Build projects (D-B-B), there are two tendering phases, one for designers and another for contractors. While in a D&B project, there is one tendering phase for contractors, in which the winning contractor hires a designer for the design. So, in the D&B, the contractor is responsible for the design.

6.2.4.7 Collaboration and coordination:

In both cases, it was found that there was a low level of collaboration between project stakeholders, indicating the misuse of BIM. For example, the designer produced a BIM model up to LOD 300, but this was not shared with the contractor. Therefore, the contractor redesigned the model based on the given shop drawings, and then developed and coordinated the model to LOD 350 and up to LOD 400 depending on the agreement. Additionally, the contractor was also responsible for clash detection.

6.2.4.8 Participant:

The researcher acquired different points of view from a range of stakeholders in order to produce an improved process protocol for this industry. So, participants were from the client organisation, design consultants, and contractors.

6.2.4.9 Monitoring progress of the project performance and quality control:

In this study, it was found that each of the project stakeholders had their own approach to project monitoring and quality control. For example, in the design phase, the client team monitored the design against the project' objectives and sustainability targets, while the designer applied a

Value Engineering check, and performed QC by using performance mock-ups, visual mock-ups, and Critical Path Method (CPM). In the construction phase, the client assigned a supervision team to monitor the contractor's work and evaluated the consultant's work. On the other hand, the contractor prepared QC and QA strategies for construction at the beginning of the project, which were included in the BEP, such as visual checks for clash detection.

6.2.4.10 Evaluation of Work or Feedback Loop:

In the client organisation, several evaluations need to be undertaken, such as the performance appraisal of each project for the consultant's work at both the design and supervision phases, a six-month evaluation of the contractor's work, and an evaluation for the TOR. It was indicated that the client should contain a feedback loop at each phase for improvement, since the client reviewed every phase and approved the design in each phase. These evaluations would be kept in the records and will considered when they are pre-qualifying consultants and contractors at a later date, as they would be available and transferred to the Central Agency for Public Tenders. However, there was no evaluation for the project as a whole.

"*A feedback loop is helpful in most circumstances. For instance, a BIM manager should keep track of best practices. Alternatively, anyone within the client's circle of trusted collaborators can be used to document and report on best practices. Ideally, each discipline would perform internal reviews of their workflow and share across team to maximise efficiency*" (B1-A, personal interview, November 3, 2019).

6.2.4.11 Archive of the Evaluation of Previous Projects:

It was pointed out that there is no point in having an archive for previous projects, as they did not have recurring projects and it was difficult to implement this idea. But at some level, it could help the client organisation's engineers to improve their performance and skills on specific projects. Although there was no archive legacy to evaluate previous projects in the client organisation, the organisation in general was in a continuous improvement cycle. For example, if there was a mistake in a decision or in the approach they followed, it would be modified and improved. Even if laws contain loopholes, they present proposals and amend them. Therefore, circulars and decisions were always subject to amendment.

In contrast, the consultant and the contractor believed that it was important to have an archival legacy from previous projects for learning and improvement purposes. For instance, this would enhance the team performance by reviewing previous projects, addressing the challenges, and identifying new BIM tools for use in future projects.

6.2.4.12 Recommendations:

From the interviews, the researcher gathered some recommendations and suggestions (some of which are shown in Table 49) for improving the construction industry in Kuwait with regard to digital construction or BIM technology.

Table 49: Recommendations from interviews

Participants	Recommendations
A1-A (Client)	• Improving the electronic communication between local authorities/ organisations
B1-A (Consultant)	• At the planning stage, the client should establish a conversation with BIM team to help setting the requirements for the BEP. • The contractor should be involved in the design phase • In the construction industry in Kuwait, it is preferable to outsource BIM services due to the lack of experience and knowledge. • A BIM advisor should be involved as soon as possible. • Involving sub-contractors at the design phase will be very beneficial, so that they can collaborate together with the designer. • The designer/ architect should lead the selection of the various project parties to ensure that the concept design is based on a like-minded working relationship. • There should be a BIM consultant within the contractor team.

In summary, construction projects in Kuwait need improvement in terms of digitisation, collaboration, and communication. Project stakeholders must work together to present the final product and electronic communication must be strengthened in order to achieve the maximum efficiency and utilisation of BIM technology.

6.2.5 Summary

This section discusses the integration of both case studies in order to understand the current process and phases in this industry. In traditional projects (D-B-B), there are six main phases, while in Design and Build (D&B) there are five main phases (see Figure 80).

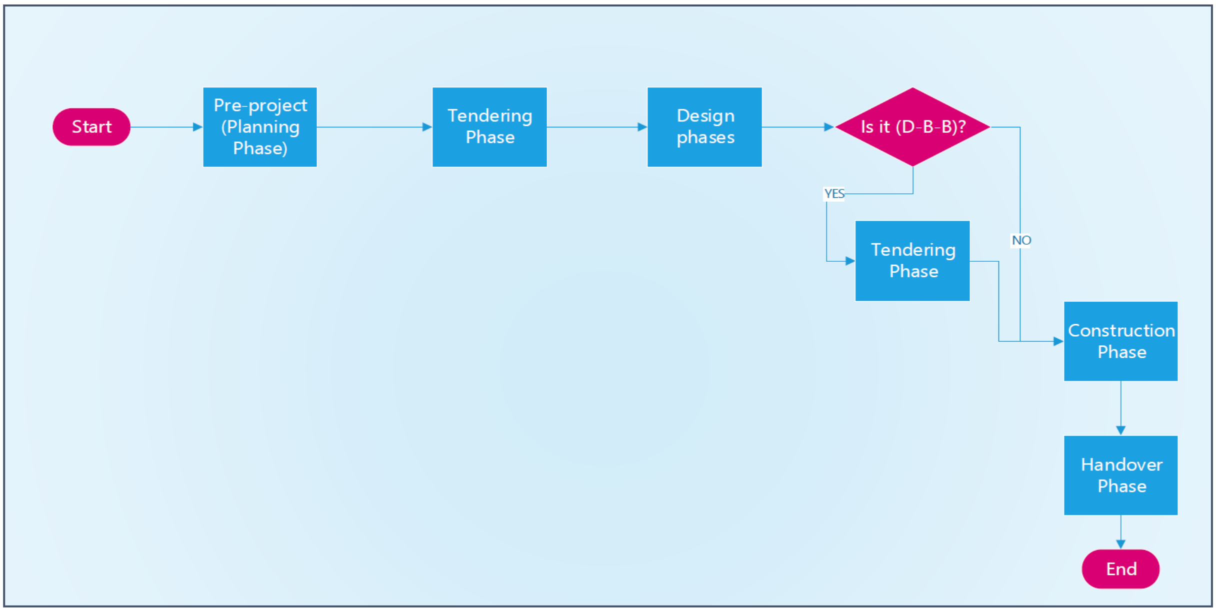


Figure 80: Project phases in Kuwait (interviews)

Typically, in public construction projects, the project starts with an end-user (beneficiary), who approaches the client's organisation to build a project. The end-user comes with the project purpose, and the allocated area obtained from the Municipality. The client team starts preparing a well-developed TOR with help from advisors (if needed). After that, the client will get the local authority's approval of the budget.

Next is the tendering phase, where designers are invited to submit their proposals. Then, the client's team and their advisors evaluate these proposals and send these evaluations to official authorities to select the winner. After that, the winning designer will sign the design agreement and start the design, if this is a traditional project. If the project is Design and Build, the bidding phase will be for contractors instead of designers, and the winning contractor is responsible for the design and construction phases. Thus, the contractor will hire a designer for the design.

In the design phase, there are four stages: data collection, schematic design, detailed design, and final design and contract documentation. In the data collection stage, the conceptual design is available, however, the designer sets a meeting with the end user to collect any required modifications. In the schematic design, the designer suggests three different valid design alternatives and the selected design is developed at the detailed design stage. Finally, the designer produces the final design drawings along with the contract documents if it is a traditional project. However, if it is a D&B project, the design consultant produces the final design drawings without a contract document because no further bidding phase is required in D&B projects. Moreover, at all stages of design, the designer must submit progress reports such as the meet phase report, mid-way progress report, and detailed report. The client team should approve each design phase based on what is required in the TOR in terms of project's objectives, and design targets.

There is another tendering phase in a traditional project after the design phases, where contractors submit their proposals (financial and technical). The winning contractor carries out the construction phase. But in BIM projects, the contractor redesigns the BIM model LOD 200 up to LOD 400 based on the shop drawings given by the client. Model coordination and clash detection are the contractor's responsibility. In addition, several approvals and licences must be obtained by the contractor before construction begins.

In the construction phase, a supervision team are assigned from the client to check the contractor's work and provide technical support to the contractor's team (if needed). Client representatives participate in this phase, for monitoring, approval, and evaluation purposed. The final phase here is the handover phase, where the project is delivered to the client with O&M manuals, as-built drawings, and reference equipment.

Although there is a high level of awareness of BIM in this industry, there is no implementation process model or protocol for employing BIM in this sector. As a result, the adoption of BIM in these two case studies was insufficient and erroneous, resulting in time and cost overruns. Hence, designing a clear process for this implementation and applying Lean principles would facilitate development in this sector.

Therefore, the researcher believes that it is important to create a structured framework - or process protocol - that includes four components, namely: phases, deliverables, participants and activities/processes, in order to facilitate the process flow and achieve a Leaner process. These components are based on the results of the interviews, shown in Tables 46 and 47, and adopts the structure of the Generic Design and Construction Process Protocol (mentioned in section 3.5.1.2). Additionally, some elements from the RIBA Plan of Work and the BIM ISO 19650 Standards will be used in the development of the proposed Processes Protocol, such as tasks and outputs mentioned in these two frameworks.

As a result, the researcher has produced a process protocol/framework that embeds BIM technology and Lean Construction principles for public construction projects in Kuwait. This framework will serve as a blueprint to facilitate BIM implementation and promote digital transformation by raising awareness and knowledge within the client organisation. It consists of five main components: phases, processes, participants, deliverables, and procurement route.

Since the development of the process protocol is intended for public organisations, it will be validated using structured interviews with various local client organisations.

6.3 Validation of the Framework (Structured Interviews)

6.3.1 Introduction

This section discusses the validation process for the proposed process protocol/framework. The final version of the process protocol/framework will be developed based on feedback provided by participants in the validation interviews.

6.3.2 Validation process

The purpose of the validation process is to validate the proposed framework. The proposed process protocol/framework was developed from the two case studies mentioned in section 6.2, and information from the RIBA Plan of Work and BIM ISO 19650. In order to update and release the final version of the process protocol, structured interviews were conducted. As mentioned in section 4.4.5.1, there are two main government organisations responsible for undertaking construction projects in Kuwait, namely the Ministry of Public Works (MPW) and Public Authority for Housing Welfare (PAHW). Therefore, one participant with more than 15 years of experience and an interest in BIM implementation was selected from each public organisation (client). As the industry in Kuwait lacks BIM experts, an international BIM consultant with experience in the Middle East region was selected to ensure an appropriate implementation of BIM.

These interviews provided sufficient feedback from different perspectives to evaluate the applicability for the proposed process protocol in the industry, thus help to update the final version of the process protocol. The researcher conducted each face-to-face interview with local participants, while a virtual meeting was held with an international BIM consultant. These interviews began with a brief description and explanation of the proposed framework, then participants answered the required questions. Additionally, they could add any comments to the framework for improvements.

6.3.3 Structured Interviews

The researcher used structured interviews with a feedback form (see Appendix 6) - a questionnaire - to validate this framework. However, participants were free to add any comments and give their feedback on the proposed process protocol. Three participants were selected for interview and none were interviewed in the previous data collection phase. Two were from major local client organisations in Kuwait and the third one was an international BIM consultant with experience in the Middle East and countries around the world. From the interviews, comments on the framework were reordered to adjust and update the framework. Accordingly, the process protocol was developed and updated to produce the final version. The interview procedure was as follows:

- Validation feedback and participant consent forms sent to participants before the interview, along with the proposed framework.
- In each interview, the researcher started with a presentation to describe and explain the proposed process protocol.
- After that, interviewees filled out the questionnaire and shared their comments with the researcher.

Table 50 represents general information on each participant.

Table 50: Interviewees' information

Participant	Occupation	Years of experience	Sector	Country	Interview Type
H-1	Deputy Director General for Planning & Design	+15	Public (Client)	Kuwait	Face-to-face
M-1	Construction projects director	+15	Public (Client)	Kuwait	Face-to-face
I-1	strategic BIM consultant	+15	Private (Consultant)	Australia	Video call (Teams)

Comments were collected from the validation interviews in order to update and produce the final valid version of the process protocol. Table 51 illustrates these comments along with the interviewee, and the required changes to the final version.

Table 51: Interviewee comments from the validation interviews

Comments on the proposed framework	Participants	Changes on Final Framework
1. Recently, there is only Traditional procurement system (D-B-B)	Clients (H-1 & M-1)	Remove the D&B procurement route
2. Absence of FM department	Clients (H-1 & M-1)	Make FM phase optional
3. There should be an In-house BIM department	Clients (H-1 & M-1)	Creating a BIM implementation steps for in-house BIM
4. Make it simple and flexible	All participants	Considering these in the final framework
5. To make BIM implementation on phases with the first phase being very simple and easy to perform with the current position.	Client (H-1)	Creating a BIM implementation steps for in-house BIM
6. The first 2 design phases are different: Data collection and 3 design alternatives	Client (M-1)	Considering these in the final framework
7. Add some kind of dependency, clarify the sequence of processes (which process should be done before this process) not necessary for all processes.	BIM consultant (I-1)	Considering these in the final framework
8. Determine required milestones of each phase and the optional ones.	BIM consultant (I-1)	Considering these in the final framework
9. Reduce some processes	BIM consultant (I-1)	Considering these in the final framework
10. Improve the visual language of the framework (add: colours, icons, symbols)	BIM consultant (I-1)	Considering it in the final version of the framework
11. Separate the internal BIM implementation framework than external one (information management and project management)	BIM consultant (I-1)	Considering it in the final version of the framework
12. Use multiple Pilot BIM projects to prepare BIM team	BIM consultant (I-1)	Creating a BIM implementation steps for in-house BIM
13. Add minimum requirements to be met for each phase rather than having a rigid line.	BIM consultant (I-1)	Considering it in the final version of the framework
14. Training for all BIM users. Public awareness plan for official authorities; by including different presentations for the various stakeholders and create a high level internal and external marketing and implementation strategy.	Clients (H-1 & M-1)	Considering these in the final framework
15. To have a legal review (depending on the entity) on process components, if it will be implemented in the government sector.	Client (H-1)	Considering it in the final version of the framework

According to interviews from two different local clients, the traditional procurement system (D-B-B) is the only type used in their projects, because they stopped using Design and Build (D&B) contracts. In the Kuwaiti public sector, client organisations are not responsible for Facility Management (FM), so they do not have FM team within their organisation. Regarding BIM team, both clients agreed that they established in-house BIM departments within their organisations. Therefore, they thought the framework should be updated to facilitate this establishment by setting up a BIM implementation diagram to prepare the BIM team. All comments in Table 51 were considered when updating and improving the proposed framework/process protocol, and accordingly, the final version was produced.

6.3.4 Proposed Changes to the Process Protocol/Framework

In this section, comments from the validation interviews were considered when making changes in the final version. Ten comments were mentioned and accordingly, the final version of the process protocol was modified.

6.3.4.1 Prepare In-House BIM

In the proposed process protocol, the outsourcing of BIM services was suggested (see Figure 91). However, participants were encouraged to set up a BIM team within their organisation due to some restrictions in the regulations, and to avoid any wasted time, money and effort. Therefore, the researcher developed a diagram on preparing a BIM team before implementing the process protocol. This diagram consists of five steps to setup a BIM team within the client organisation that will be discussed in detail in the next chapter.

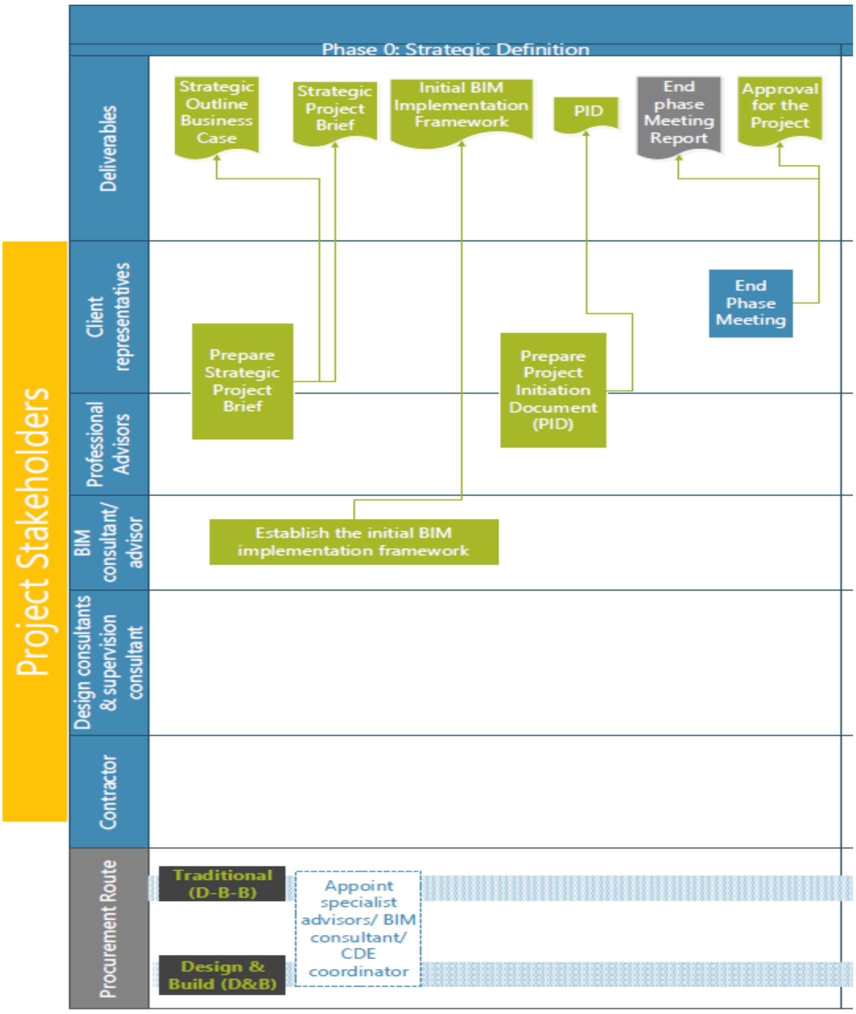


Figure 81: Screenshot of the Proposed Process Protocol (for Phase 0)

6.3.4.2 Improving Visual Language in the Process Protocol

In the proposed process protocol, visual language was inadequate and weak, as few colours and shapes were used. Consequently, it was improved by using more colours and shapes to facilitate reading and understanding. Figure 92 represents a screenshot of the proposed framework.

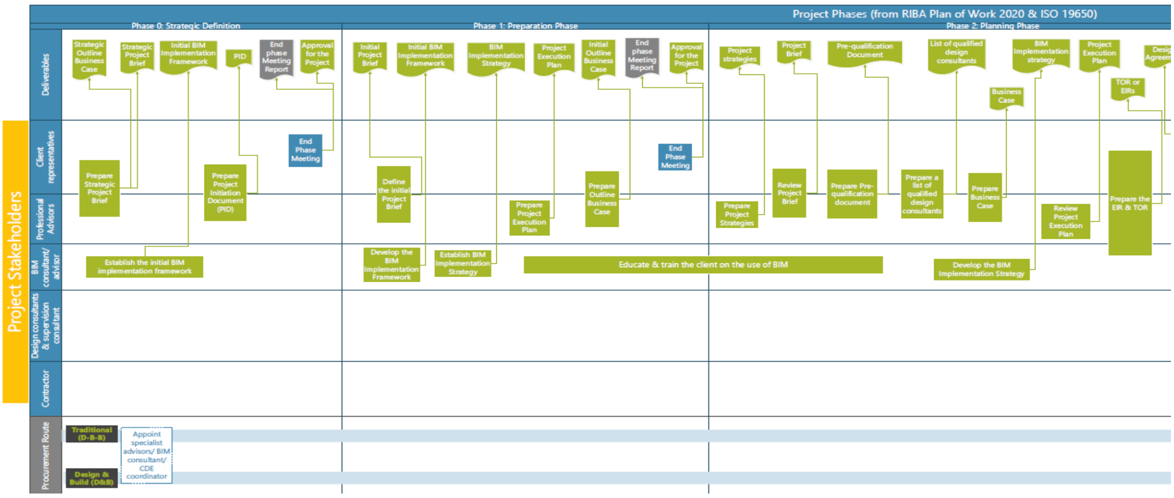


Figure 82: Screenshot of the Proposed Framework

6.3.4.3 Procurement Route

In the proposed framework, a procurement route was added, which was inspired by RIBA Plan of Work 2020. Since client organisations only use the traditional procurement system (D-B-B), the part highlighted in the proposed process protocol was removed (see Figure 93). The portion marked in a dashed red rectangle represents the procurement route.

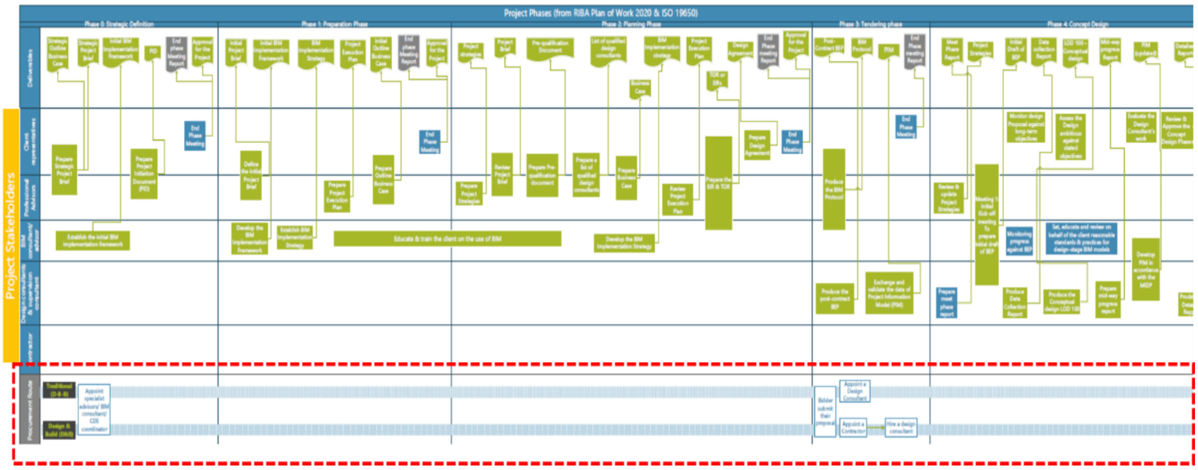


Figure 83:Screenshot of the Proposed Process Protocol

6.3.4.4 Tendering Phases

Since the proposed framework was design to be used for both procurement systems (traditional and Design & Build), one tendering phase was added (see Figure 93). However, the final version of the process protocol contained two tendering phases. Thus, the researcher added another tender phase to correspond with the traditional projects.

6.3.4.5 Facility Management Phase

The results of the validation interviews indicated a lack of Facility Management team within the client organisations. Therefore, this phase was optional until an FM team is set up in their organisation.

6.3.4.6 Minimum Requirements for Each Phase

In the proposed framework, there was a rigid line indicating that all processes must be met before moving on to the next stage. Nevertheless, the findings of the validation process suggested defining the minimum requirements for each phase in order to add flexibility. As a result, minimum requirements were specified at each phase of this framework.

6.3.4.7 Remove Some Processes and Simplify the Framework

The exclusion of some processes was suggested in the proposed process protocol to avoid any complication during its implementation. As simplicity was key, the framework was modified and simplified.

6.3.4.8 Dependency and Sequencing

The proposed process protocol was designed based on the Generic Design and Construction Process Protocol (GDCPP), in which there were no communication flow lines or clear sequences between processes. So, it was recommended that dependency and sequence were added between some of the processes, which would help the client to prioritise their operations and improve the flow of operations.

6.3.4.9 Separation of BIM Strategies (Internal and External)

The international BIM consultant suggested separating the internal and external BIM strategy/framework in order to enable adequate BIM implementation. An internal BIM strategy should focus on managing information within the client organisation, while an external BIM strategy should relate to project information and must be undertaken by project stakeholders. Accordingly, the final version of the framework incorporated and defined internal and external BIM strategies.

6.3.4.10 Design Phases

Within the proposed framework, the design phases were as follows: Conceptual design, schematic design, design development, and final design. According to the results of the validation interviews, names of these design phases were changed to: Data collection phase, design alternatives phase, detailed design phase, and final design and contract document phase.

6.3.5 Summary

The importance of this section lies in its update to the proposed framework, which enables feasibility in construction projects in Kuwait, especially in public construction projects. Thus, the researcher sought expert opinions on the framework who had experience in public projects and knowledge in BIM. As a result, two participants from the two major public organisations for construction projects and an international BIM consultant with experience in construction projects in the Middle East were interviewed.

Comments and suggestions from these three interviewees were recorded and analysed, and ten topics were found, namely: BIM setup internally, visual language improvement in the framework, procurement path, bid stages, FM phase, minimum requirements for each phase, simplification of the framework, dependency and sequencing, separate BIM strategies, and design phases. These themes were considered and accordingly the final BIM and Lean process protocol was produced.

6.4 Validity and Reliability

The validity and reliability of the construct are key issues that need to be taken into consideration when developing a model for a particular market orientation (Hair, 2006). Rossiter (2002) and Suddaby (2010) agreed that it is crucial to consider these two as they ensure the items created correlate at a tolerable level and thus develop a greater measurement scale. This reduces the probability of receiving an incorrect answer, which indicates that emphasis is required on the reliability and validity of the research design (Saunders et al., 2015).

6.4.1 Validity

Validity "*is the process of verifying research data, analysis, and interpretation to establish their validity/credibility/authenticity*" (Saunders et al., 2015, p.206). Saunders et al. (2015) indicated that triangulation is a validation technique that requires the use of more than one data collection method to emphasize the validity/credibility/authenticity of research data, analysis, and interpretation. For instance, the triangulation of data of this study's data was conducted through distributing a questionnaire and conducting interviews as well as using secondary sources such as documents, pictures, videos, etc.

Since the researcher adopted a mixed methods research design that started with a questionnaire, was followed by semi-structured interviews and ended with structured interviews, a triangulation validation technique was conducted, namely "*a combination of methodologies in the study of the same phenomenon*" (Jick, 1979, p. 602).

Shenton (2004) pointed out that triangulation covers both credibility and confirmability (trustworthiness), whereas utilizing background information to create a context will address transferability (applicability) and delivering a full description of the applied methodology will address dependability (consistency). Accordingly, this research can be considered valid research.

6.4.2 Reliability

A reliable method is a method that can be replicated repeatedly and yields the same results (Chapman, McNeill, & Mcneill, 2005). Robson and McCartan (2016) claimed that to ensure a high level of theory reliability, the following threats should be minimised:

- Participant error: Refers to errors in respondent's responses that appear during the data collection. In this study, respondents had enough time to answer the questions because the questionnaire was distributed online. For the interviews, interviewees selected a convenient time to participate in this research, hence, this gave them sufficient time to answer the questions.
- Participant bias: This indicates that participants' answers could be affected by the judgment of their managers. Consequently, the researcher assured that their responses would remain strictly confidential so that they could feel free to express their views.
- Observer error: Relates to the fact that the questionnaire must be designed in a structured manner to reduce the risks to its reliability.
- Observer bias: Subject to how the answers are interpreted. Nevertheless, this risk

should not occur because only the author has access to, and can analyse, the answers.

In order to ensure quantitative reliability, a number of procedures were applied, including the use of a suitable sample size. According to Saunders et al. (2015), the minimum size required for statistical analysis is 30. Internal consistency was used to evaluate the reliability, which included associating the responses to questions with each other (Mitchell, 1985). There are many ways to calculate internal consistency, of which one of the most commonly used is Cronbach's alpha. Cronbach's alpha test was applied to check the internal consistency and reliability of the questionnaire. It consists of an alpha coefficient with a value between 0 and 1, and the value of Cronbach's alpha should be higher than 0.7 in each question to ensure acceptability and consistency in the research (Saunders et al., 2015). This was calculated in Section 5.2.3, so the research is reliable.

Chapter 7: Final Process Protocol/Framework (BIM and Lean Construction framework):

7.1 Introduction:

The purpose of the process protocol is to facilitate the implementation of BIM for construction projects in Kuwait. This framework was initially developed based on interviews undertaken by the researcher along with the use of some information from the literature review, such as the RIBA Plan of Work 2020, ISO 19650, and the Generic Design and Construction Process Protocol. Subsequently, interviews were conducted to validate and update the proposed process protocol to ensure it is suitable for the construction industry in Kuwait. This framework has been designed based on the principles of Lean Construction, where processes, responsibilities, and deliverables are clear to each of the project parties with the early participation of the appropriate team. It provides a transparent process for client organisations to promote process improvement by allowing the detection of weaknesses and strengths for the entire project process. In addition, this will help the client to exploit the new technology and where it should be implemented in the process.

Moreover, visual language has been used to enable easy comprehension, as shown in Table 52, and colour codes from a colour-blind safe palette have been utilised in the process protocol (Figure 84).

Table 52: Symbols table

Symbol	Name	Function
	Multiple documents	It indicates multiple documents
	Document	It indicates data that can be read by people, such as printed outputs
	Input/output	A parallelogram represents input or output
	Process or task	An orange rectangle represents a process or task
	Decision point	A diamond indicates a decision-making point
	Process or task	A blue vertical rectangle represents a process or task that involves multiple participants / stakeholders within one process
	Preparation	Initial setup and other preparation steps before start of process flow
	Process or task	A turquoise rectangle represents a process or task that repeats more than once.
	Stored data or information	It indicates any type of stored data
	Database or cloud-bases data	It indicates a list of information with a standard structure that allows for searching and storing. Also, it indicates cloud-based models.
	Flow line	A flow line used to indicate the flow of logic by connecting symbols. It can provide some type of dependency between processes or represent the outcome of each process.
	Flow line (dashed)	Decision direction flow (used for decision point)

Figure 84: Colour code from Colour-blind Safe palette (Cravit, 2019).

With the absence of a clear process model or protocol in the construction industry in Kuwait, this framework is a leap towards development and digitisation. It is intended to improve public projects in Kuwait, helping the client to embed BIM into their project in a proper manner. It will be the basis for designing the client's business process framework.

According to the interviewees, they mostly have traditional projects (D-B-B). However, the process protocol promoted the early participation of areas of activity when necessary. IPD is recommended within this framework in order to enable the early participation of project stakeholders, hence, providing a solution to assist in the appropriate implementation of BIM and Lean principles.

The BIM and Lean process protocol will be proposed to client organisations to facilitate their monitoring processes over the whole life cycle of the project. It consists of 10 phases, starting from phase 0 to phase 9 (see Appendices 8). The different responsibilities and outputs for each project stage will be defined for all project stakeholders. Each phase relates to a specific key decision. Accordingly, client teams hold a key decision meeting at the end of each phase to ensure the necessary actions and decisions have been taken, and thus the project can start the next stage.

7.2 Preparing BIM Internally:

It is recommended that BIM diagram (5 BIM implementation steps) is applied before starting any project or using the final process protocol. This diagram was developed based on the findings of the interviews and will assist and prepare the client organisation for internal BIM implementation (Figure 85).

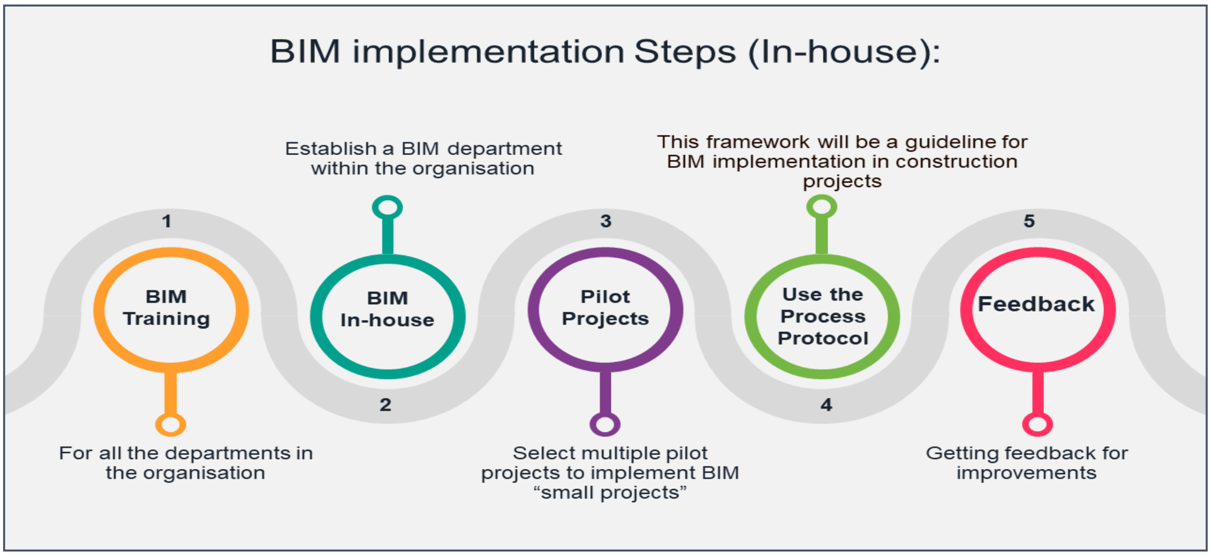


Figure 85: In-house BIM diagram

The five steps of the BIM implementation diagram are as follows:

1. BIM training

   It is recommended that the client organisation initiates BIM training for each department in the organisation, and educate various stakeholders about BIM benefits and its applications.

2. BIM in-house

   Since the framework was designed for public construction organisations, it is preferable to establish a BIM department within the client organisation. This department will be responsible for several tasks such as evaluating BIM capabilities and maturity, establishing BIM standards and EIR, and monitoring the progress against BEP.

3. Pilot projects

   From validation interviews, it was suggested that the client organisation should start with multiple pilot projects using BIM technology. These projects can be small projects to avoid any complications.

4. Use the process protocol

   After BIM training, establishing BIM in-house, and selecting pilot projects, it is recommended to use the process protocol to enables the implementation of BIM in the industry along with the application of Lean Construction concepts.

5. Feedback

   After testing the framework, feedback can be obtained for improvement purposes, since the BIM process is a learning curve. From feedback, the BIM implementation framework can be updated, and BIM standards can be generated and improved.

7.3 Phase 0: Pre-Project

In this phase, the end-user or beneficiary reaches the client organisation who is responsible for building the project. The end-user will come with a need or a project purpose along with the allocated area of the Municipality. The end-user/ beneficiary should provide a decision letter from official authorities that includes:

- A barrier – free site designated by the municipality
- Clear, signed and approved ready requirements
- The budget

The client will capture the end-user's requirements and proceed with the preparation of the Project Initiation Document (PID). This is also called the "New Construction Project Form" and should be prepared by the beneficiary and with the client help (if needed) (Figure 97). At this stage, only client teams are involved. The client may consider appointing some professional advisers, depending on the project type and size, such as:

- Health and safety advisor
- Sustainability advisor
- Legal advisor
- Financial advisor
- Representatives from funders
- Security advisor
- Construction advisor
- Operational advisor
- Asset information advisor
- BREEAM/LEED advisor
- BIM advisor

To help the client develop their requirements and the business case.

However, the early participation of project team members who are available and appropriate for project development is recommended, and they should be encouraged to participate in the earliest possible stages (e.g. designer, contractor, subcontractors, suppliers).

At this stage, it is recommended that a BIM team is involved to produce an internal BIM implementation framework (initial). A BIM department should be responsible for preparing an internal BIM implementation framework for information management. This framework consists of two layers - inner and outer - as proposed by May, Mattews, and Lane (2017). The inner layer includes people, processes, technology, and organisation, while the outer layer includes policy (Figure 86).

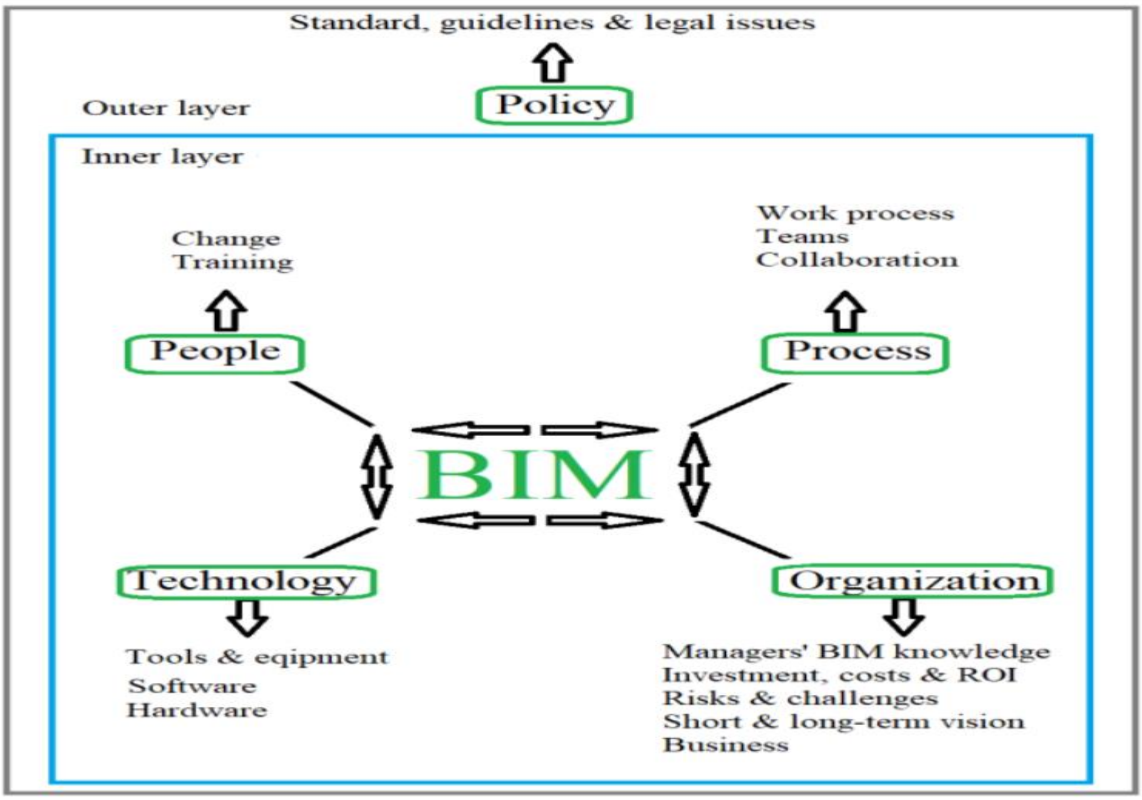


Figure 86: Key factors and BIM fields (Kouch, Illikainen, & Perälä, 2018)

Before starting this phase:

The following prerequisites are required:

- Purpose of the project/requirements/needs >>> by end-user or beneficiary
- Obtain allocated area and make sure it is a barrier-free site from the Municipality >>> by end-user or beneficiary

Participants:

- Client representatives including project management and BIM teams
- Professional advisors/specialist consultants (if needed)

Key high-level objective:

- Demonstrating the need

Deliverables:

- Strategic project brief (optional)
- Project Initiation Document (PID) or new construction project form
- Internal BIM implementation framework (for step 1: understanding BIM)
- End phase meeting report (optional)

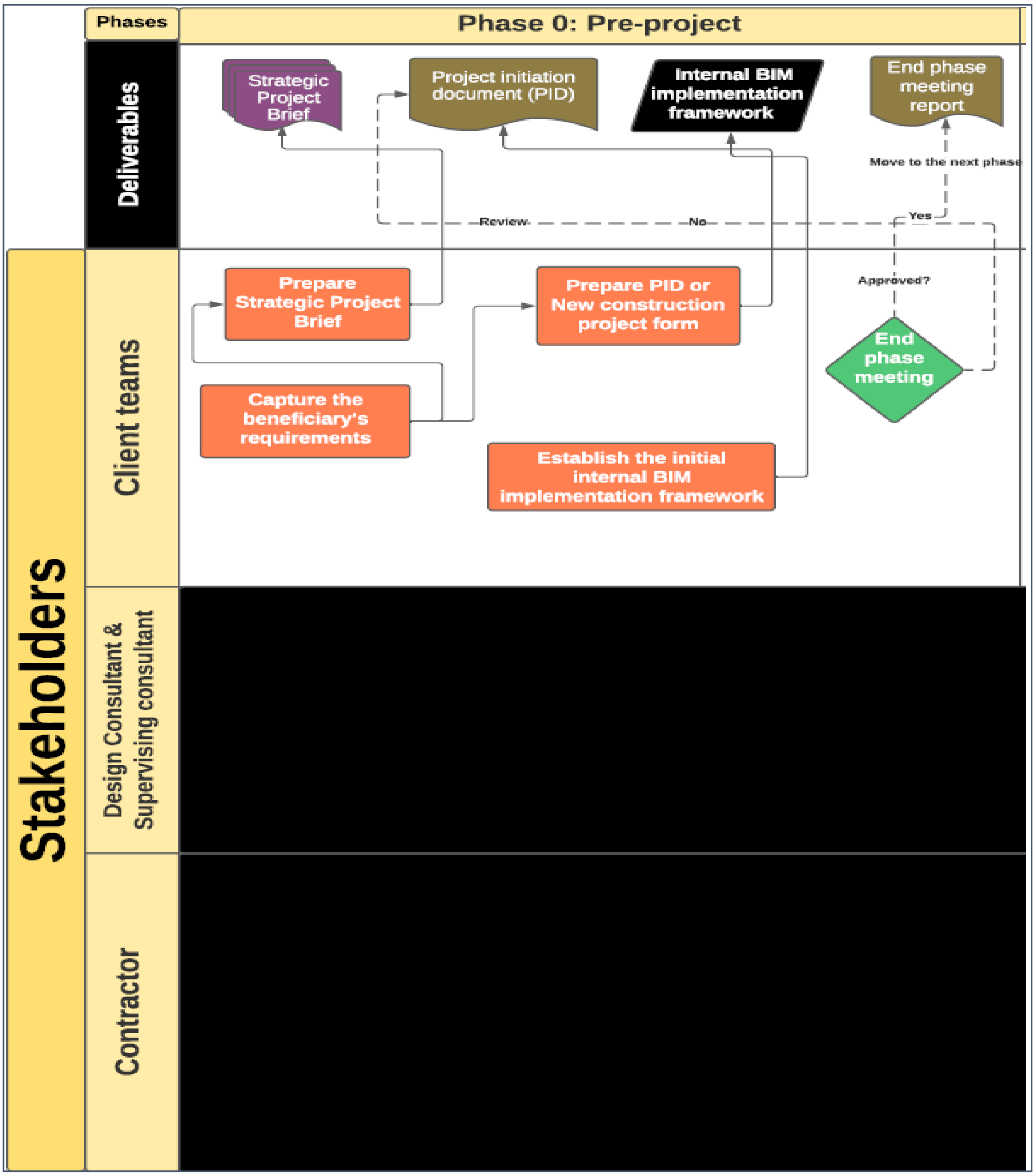


Figure 87: Phase 0: Pre-project

Minimum requirements to be met at this phase in order to move to the next phase:

- Project initiation document (PID) or new construction project form
- Approval for the project from local authorities

Processes/tasks:

- Capture beneficiary's requirements
- Prepare strategic project brief (optional)
- Determine the purpose of the project
- Prepare the end-user's requirements
- Prepare project requirements
- Establish environmental requirements
- Define BIM requirements and scope of the services
- Determine the planning meeting schedule
- Determine the project budget
- Determine the project risks
- Determine Health and Safety requirements
- Determine fire safety requirements
- Determine the type of procurement system
- Undertake a site inspection and appraisals
- Determine spatial requirements
- Review feedback from previous projects
- Select project management team
- Prepare strategic outline business case
- NOTE: Project brief is a live document that must be referred to throughout the project, providing a benchmark for measuring project delivery and success.
- Prepare Project Initiation Document (PID) or new construction project form (required)
- Establish the initial internal BIM implementation framework (required)

- Step 1: Understanding BIM
- Spreading BIM knowledge
- Setting long-term vision and strategy (from DBB to IPD)
- Setting short-term targets and views
- Determine financial support and investment
- Determine challenges and opportunities
- Establish new business model
- End phase meeting.
- It is a decision – making point
- If yes approve and then move to the next phase, if no, review the requirements
- In this meeting, the client will grant approval in order to proceed to the next phase or request a review.
- Prepare end phase report
- Get approval for the project budget from Local Authorities.
- The client will get the financial approval from the Ministry of Finance.

The outcome of this stage:

- Achieve clear requirements of the end-user.
- Determine the main project objectives and project delegation and limitations.
- Outline the internal BIM implementation framework
- Approval required to proceed to the next phase
- Appointment of the project manager

7.4 Phase 1: Planning Phase

In this phase, client teams will develop a project brief and update the internal BIM implementation framework, as well as prepare strategies for internal and external BIM implementation. Finally, TOR/EIR will be produced by the client and will be ready for tendering (Figure 88).

Before starting this phase:

We require the following prerequisites:

- Approval from local authorities (for the budget)
- Clear client requirements
    - Project Initiation Document (PID) or new construction project form.

Participants:

- Client representatives including project management and BIM teams
- Professional advisors/specialist consultants (if needed)

Key high-level objective:

- Is the identified project achievable?

Deliverables:

- Project Brief
- Project execution plan or (project management plan) (optional)
- Outline business case (optional)
- Internal BIM implementation strategy
- It is for information management (for the organisation)

- External BIM implementation strategy
- It is for project information.
- Updated internal BIM implementation framework (required after preparing BIM implementation strategies)
- Terms of Reference (TOR/Exchange Information Requirements (EIRs) (required)
- BIM protocol (required)
- Design agreement
- Pre-qualification document (optional)
- Qualified design consultants list (optional)
- End phase meeting report (optional)
- Approval for the project from local authorities (required)

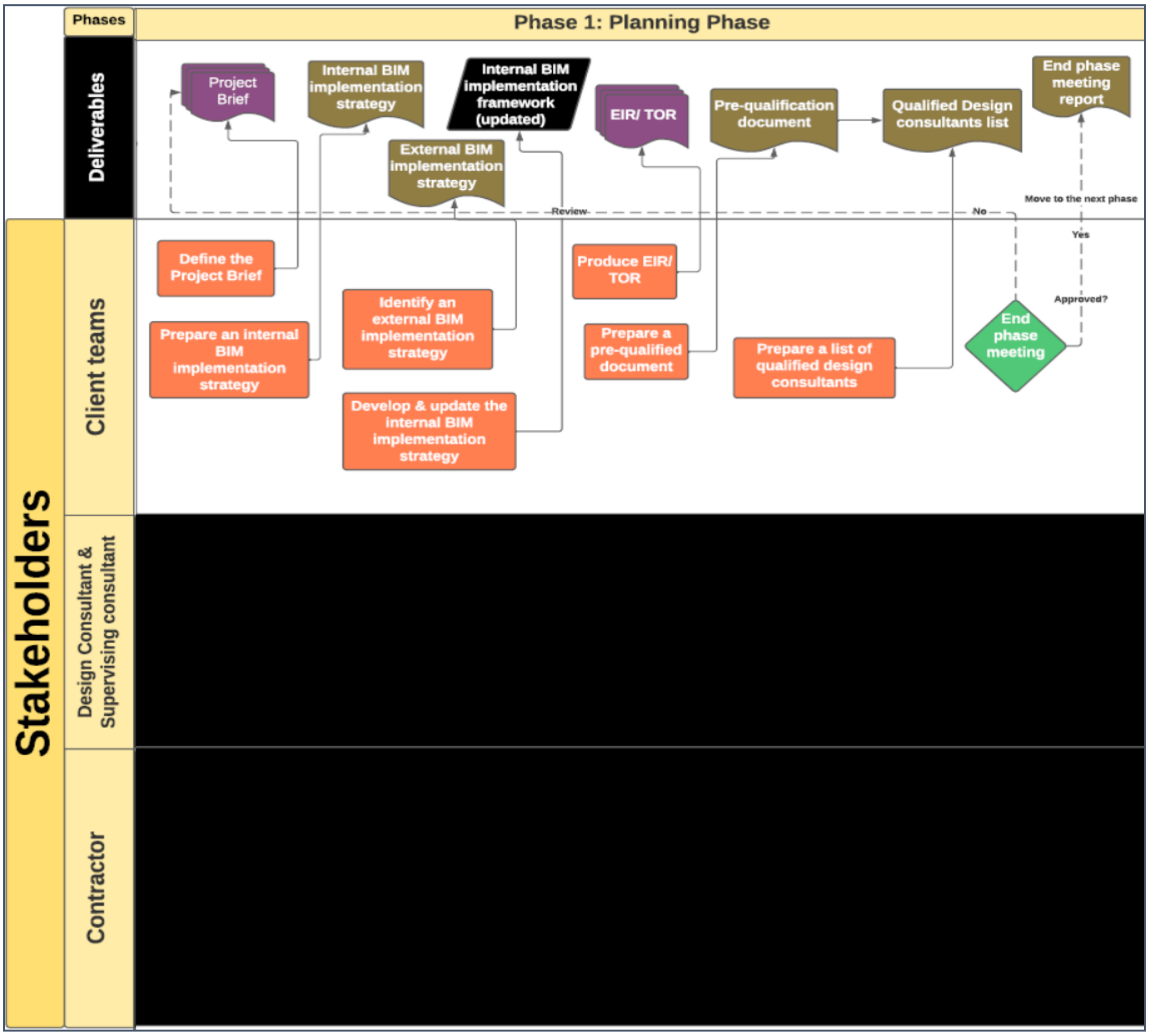


Figure 88: Phase 1: Planning Phase

Minimum requirements to be met at this phase in order to move to the next phase:

- Project brief
- Internal BIM implementation strategy
- External BIM implementation strategy
- Internal BIM implementation framework
- TOR/EIR
- Approval for the project from local authorities

Processes/tasks:

- Define the project brief
- Consider the client requirements in more detail
- Determine the long-term goals
- Define the project objectives
- Determine the project outcomes
- Consider the environmental impact
- Determine the sustainability outcomes
- Prepare sustainability study
- Determine the quality goals
- Determine the procurement strategy
- Prepare the project programme
- Consider scenario planning
- Undertake feasibility studies
- Consider construction-stage monitoring
- Determine soft-landing strategy (handover)
- Prepare facility management requirements
- Consider energy-use and material use
- Prepare source site information including site survey
- Prepare project strategies
- Prepare Quality Control (QC) and Quality Assurance (QA) plans
- Prepare facility management plan
- Prepare sustainability strategy & environmental report
- Prepare outline business case (to submit it to the authorities)

- Prepare project execution plan
- Prepare an internal BIM implementation strategy
- Determine BIM capabilities
- Determine maturity level (identify the competences of team members and organisation)
- Determine capabilities/skills of the team members (IT and design and build integration)
- Assess the existing IT infrastructure
- Evaluate capabilities and capacities
- Determine the scope of BIM services
- Manage expectations and risks
- Define management criteria
- Produce the Client Information Model (CIM)
- Prepare Organisational Information Requirements (OIRs)
- Prepare Asset Information Requirements (AIRs)
- Identify an external BIM implementation strategy for project information (required before updating the internal BIM framework)
- Determine general BIM guidelines
- Determine BIM deliverables
- Determine BIM level of detail
- Determine BIM objective and responsibility matrix
- Determine procedures of BIM modelling and collaboration
- Determine Quality Assurance (QA) and validation
- Determine BIM standards

- Determine the level of collaboration
- Evaluate BIM and review Return on Investment (ROI) (optional)
- Prepare Project Information Requirements (PIR)
- Define information requirements
- Prepare the Exchange Information Requirements (EIR)
- Consider project technology & system integration
- Create contract requirements
- Examine supply chain capability & capacity
- Develop & update the internal BIM implementation framework (Step 2: Planning BIM)
- Appoint the BIM team
- Analyse the current process (who, what, means)
- Design the new BIM based process including:
- Trained HR (Who) >> people
- Process and WBSs (What) >> process
- BIM based software & hardware (Means) >> technology
- Get feedback
- Define the BIM policy:
- Determine legal issues
- Establish standards & guidelines
- Produce the Exchange Information Requirement (EIR) and Terms of Reference (TOR)
- Prepare the design agreement
- Prepare the BIM protocol

- The BIM protocol creates the requirement for suppliers (consultant or contractor) to provide specified BIM at defined levels of detail and incorporating provisions which support the production of deliverables for 'data drops' at defined project stages.
- Prepare a pre-qualification document
- Prepare a list of qualified design consultants
- End phase meeting
- Prepare end phase report
- Get approval for the project from local authorities.

The outcomes of this stage:

- Project brief
- BIM guidelines and requirements
- Recruitment of the BIM team
- Preparation on BIM implementation strategies and internal BIM implementation framework
- BIM protocol with the design agreement
- EIR
- Approval to proceed to the next phase

7.5 Phase 2: Tendering Phase - Appointing a Design Consultant

At this stage, qualified design consultants (bidders) will be invited to submit their proposals in response to the EIR/TOR provided by the client. They should submit technical and financial proposals along with the pre-contract BEP. Then, these proposals will be assessed by the client and his advisors. Finally, a winning designer will sign the design agreement and proceed to the design phases (Figure 89).

However, the early involvement of team members is recommended to enable the effective deployment of BIM. It requires project stakeholders to work together from the early stages of the project to ensure the delivery of a fully integrated and evaluated design[1].

Participants:

- Client representatives
- Professional advisors/specialist consultants
- Design consultants

Key high-level objective:

- Is the bidder suitable for the project?

Deliverables: Submitted documents by the bidders:

- Financial proposal
- Technical proposal
- Pre-contract BEP

[1] **Note:** A designer should have a BIM consultant in his team either in-house or outsourced.

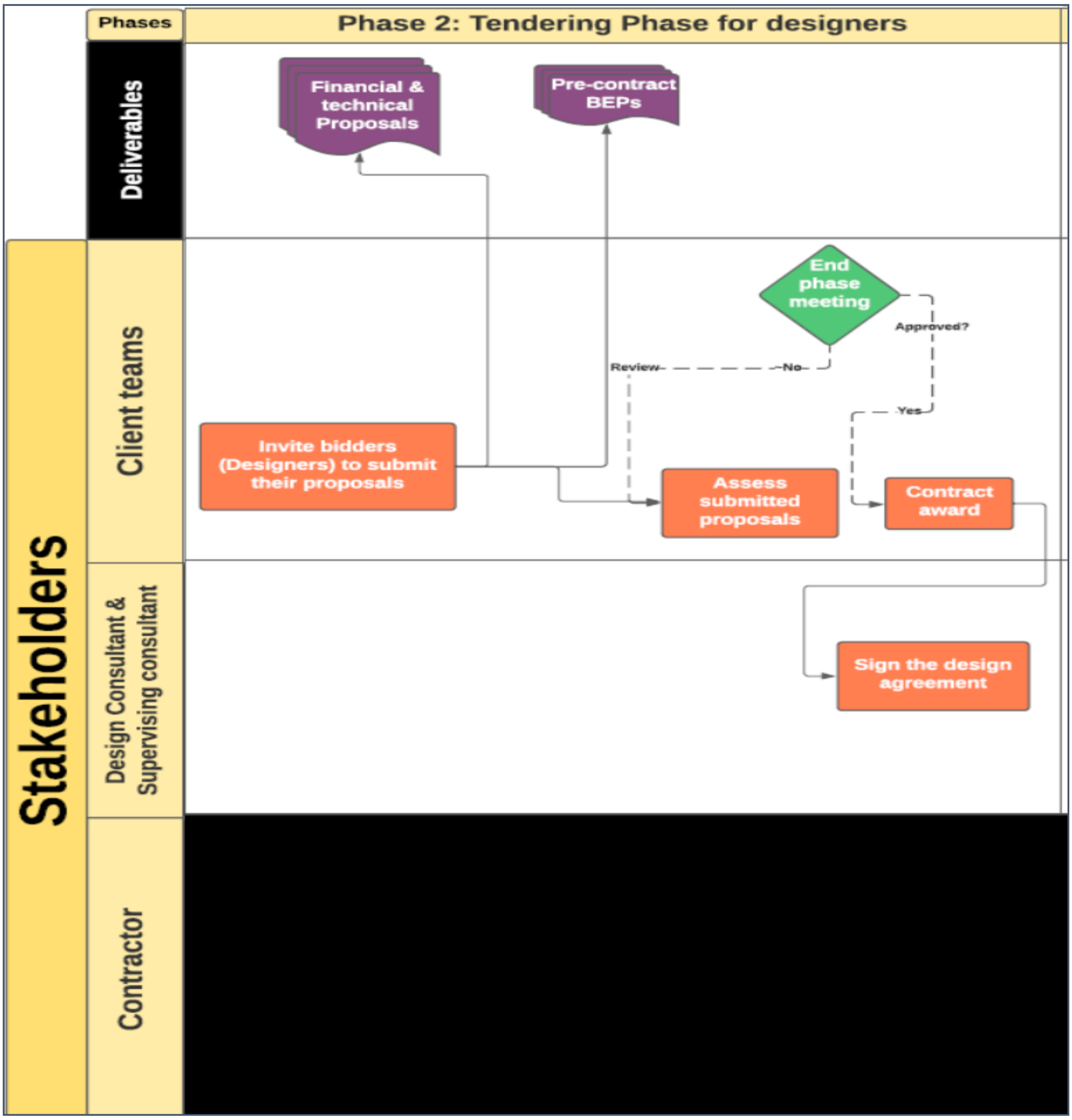


Figure 89: Phase 2: Tendering Phase for Designers

Processes/tasks:

- Invite bidders (designers) to submit their proposals
- Qualified design consultants (bidders) will be invited to submit their proposals in response to the EIR/TOR provided by the client.
- They should submit technical and financial proposals along with the pre-contract BEP.

- Assess the submitted proposals
- The client team will evaluate the submitted proposals.
- End phase meeting
- Contract award
- Select the winning bidder (designer)
- Sign the design agreement
- The designer (winning bidder) will sign the design agreement and proceed to the design phases.

The outcome of this stage:

- Appointing the designer (design consultant)

Design phases:

7.6 Phase 3: Data collection phase

In the data collection phase, the designer will meet with the beneficiary to confirm the information given by the client; any modifications can be undertaken it in this phase (without a financial or time claim). Additionally, at this stage, an external BIM implementation framework should be prepared by the BIM team within the client organisation and the design consultant team, and it should be a focus of project management. This should be updated during design and construction phases (see Figure 90).

Before starting this phase:

The following prerequisites are required:

- EIR

- Approval from local authorities
    - Appointment of the designer according to the type of contract (D-B-B) (winning bidder)

Participants:

- Client representatives
- Professional advisors/specialist consultants/PM (if needed)
- Design consultant

Key high-level objective:

- What do we need to build?

Deliverables:

- Meet phase report
- Post-contract BEP (required)
- Data collection report
- Mid-way progress report
- Detailed report
- End phase meeting report (optional)

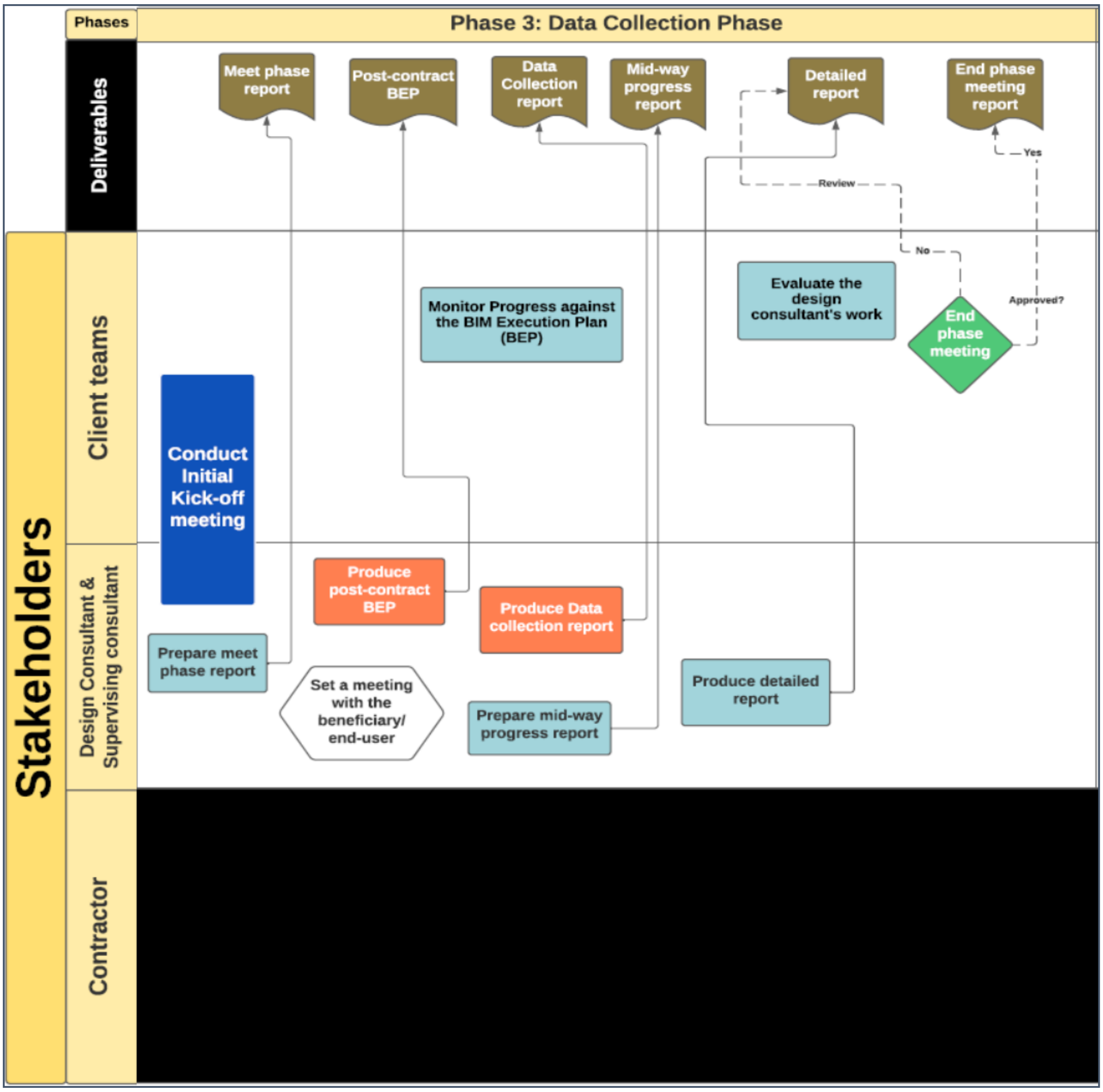


Figure 90: Phase 3: Data Collection Phase

Minimum requirements to be met at this phase in order to move to the next phase:

- Post-contract BEP

Processes/tasks:

- Conduct initial kick-off meeting: Identify BIM goals and uses (meeting 1)
- This meeting involves the client teams and the designer team.
- Define the scope of BIM implementation on the project

- Define information management & CDE strategy (optional “advanced level”)
- Determine the Common Data Environment (CDE)
- Prepare the CDE strategy
- Select the information manager (either the design team leader or from the project management team)
- Define BIM/ AIM/ GIS strategy (optional “advanced level”)
- Note: Geographic Information System (GIS), which is a form of geospatial data
- Create a strategy to determine built asset security (optional “advanced level”)
- Define soft landings approach (optional “advanced level”)
- Create project lifecycle process map (optional “advanced level”)
- Implement BIM level 1 approach (optional “advanced level”)
- Prepare a draft agenda for meeting 1.
- Prepare the meet phase report
- Set a meeting with the end-user/beneficiary
- Confirm the information given by the client; if there are any modifications, they can undertaken them in this phase (without a financial or time claim).
- Produce the post-contract BEP
- Prepare the Master Information Delivery Plan (MIDP)
- Prepare the Task Information Delivery Plan (TIDP)
- Prepare the Responsibility Matrix (RACI)
- Produce the data collection report
- Prepare the mid-way progress report
- Monitor progress against the BIM Execution Plan (BEP)
- This process will be undertaken throughout the project until delivery.

- Once the initial BIM execution plan is created, it will need to be continuously communicated, monitored and updated throughout the project.
- Adherence to the BEP must be monitored throughout the term of the contract to ensure that the PIM is developed in accordance with the MIDP and all relevant standards (Scottish Government, 2018) (optional)
- Produce a detailed report
- Evaluate the design consultant's work
- End phase meeting

The outcome of this stage:

- Submission of the BEP by the appointed party (designer)
- Initiate the development of the Project Information Model (PIM) in accordance with the EIR requirements.

7.7 Phase 4: Design Alternatives (Three Concept Designs)

In this phase, the design consultant will present three valid design alternatives. The client will choose the most suitable design, then the designer will proceed with the schematic design for the selected option. Additionally, BIM teams from the client and designer will collaborate to produce a BIM project execution process map. A LOD 200 model will be developed at this point (Figure 91).

Before starting this phase:

We require the following prerequisites:

- BEP that needs to be updated throughout the project.

- Data collection report

Participants:

  - Client representatives
  - Design consultant

Key high-level objective:

  - What do we need to build?

Deliverables:

  - Meet phase report
  - Three valid design alternatives (concept designs)
  - BIM project execution process map
  - Mid-way progress report
  - Schematic design
  - Detailed report
  - LOD 200 – approximate geometry
  - PIM
  - End phase meeting report

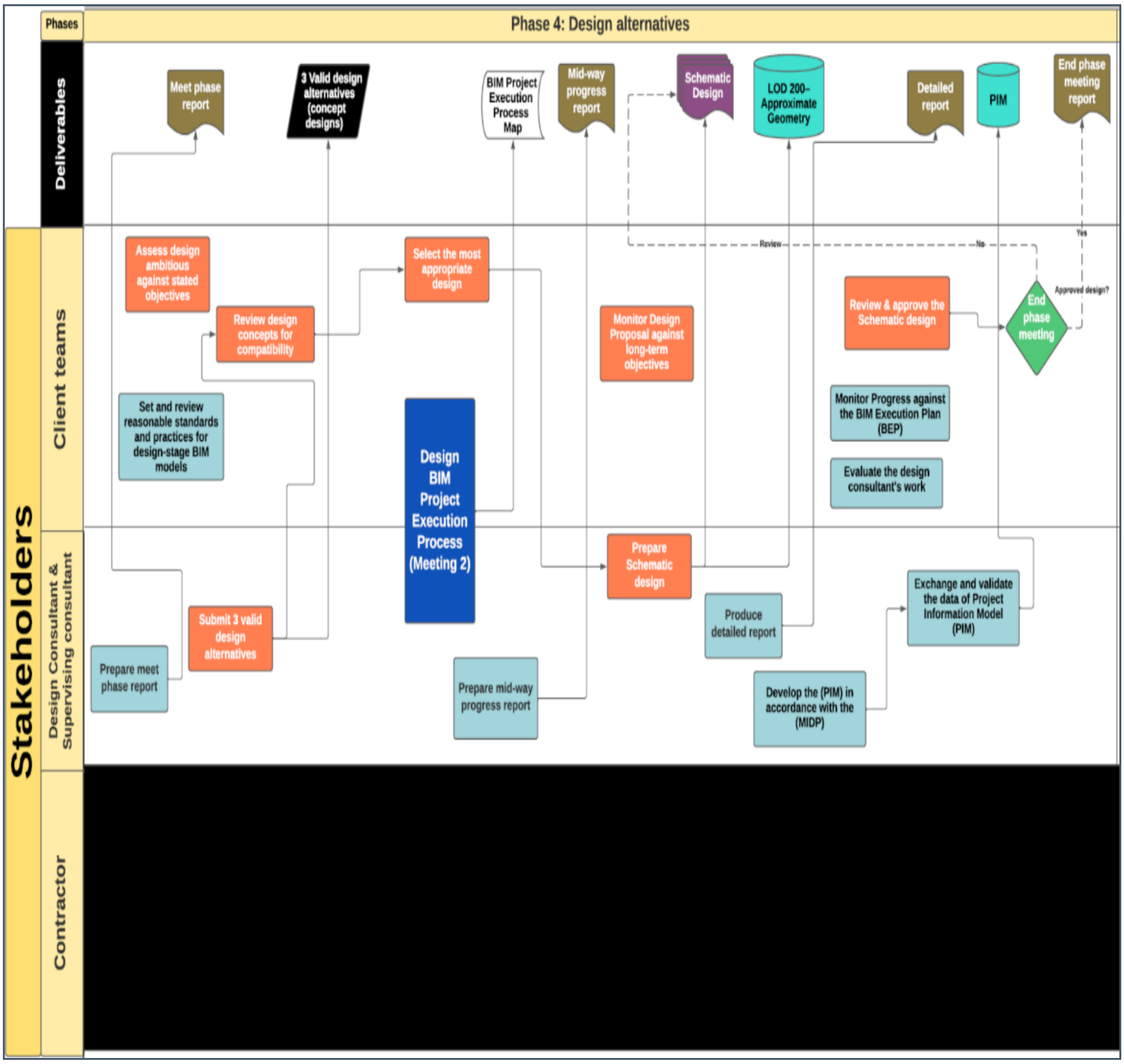


Figure 91:Phase 4: Design alternatives phase

Minimum requirements to be met at this phase in order to move to the next phase:

- Three valid design alternatives (concept designs)

Processes/Tasks:

- Prepare meet phase report
- Submit three valid design alternatives (required)
- Assess design ambitious against the stated objectives
- Set and review reasonable standards and practices for the design-stage BIM

models

    - Review the design concepts for compatibility
    - Select the most appropriate design
    - Design the BIM project execution process (meeting 2)
    - Determine the BIM process flow
    - Create a process that includes tasks supported by BIM along with an information exchange (project execution process map)
    - Update BEP
    - Prepare a draft agenda for meeting 2
    - Prepare a mid-way progress report
    - Prepare a schematic design
    - Prepare the basis of design (drawings, plans, 2D CAD)
    - Produce a LOD 200 model – approximate geometry (schematic design)
    - Monitor the design proposal against the long-term objectives
- Monitor progress against the BIM Execution Plan (BEP)
    - This process will be undertaken throughout the project until delivery.
    - Once the initial BIM execution plan is created, it will need to be continuously communicated, monitored and updated throughout the project.
    - Prepare a detailed report (should be done by the designer)
    - Develop the Project Information Model (PIM) in accordance with the Master Information Delivery Plan (MIDP).
    - Exchange and validate Project Information Model (PIM) data
    - During the project development process, the PIM continues to develop in accordance with the Master Information Delivery Plan (MIDP).

- Evaluate the design consultant’s work
- Review & approve the schematic design
- End phase meeting

The outcome of this stage:

- Initiation of the BIM project execution plan
- Production of the LOD 200 schematic design
- Development of the PIM

7.8 Phase 5: Detailed Design

In this phase, the design team will develop the detailed design and produce the LOD 200/300 model. The client team will monitor the designer’s work by evaluating and approving deliverables (Figure 92).

Before starting this phase:

The following are prerequisites:

- BEP, that needs to be updated throughout the project.
- BIM LOD 200 schematic design
- Detailed report
- PIM

Participants:

- Client representatives
- Professional advisors/specialist consultants /PM (if needed)
- Design consultant

Key high-level objective:

- ○ How will the identified project look?

Deliverables:

- ○ Meet phase report
- ○ Mid-way progress report
- ○ LOD 200/300 model – typical geometry (detailed design)
- ○ Environmental impact assessment
- ○ Design stage report
- ○ Equivalent report
- ○ Detailed report
- ○ PIM (updated)
- ○ End phase meeting report

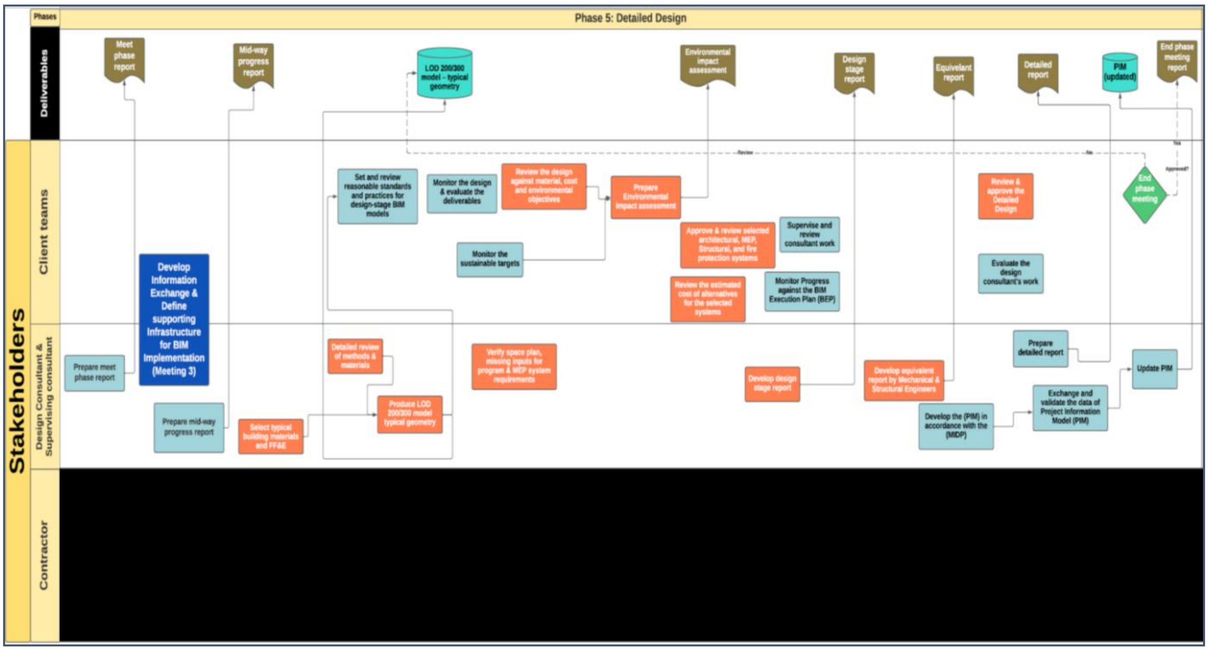


Figure 92: Phase 5: Detailed Design phase

Minimum requirements to be met at this phase in order to move to the next phase:

- LOD 200/300 model typical geometry

Processes/Tasks:

  - Prepare the meet phase report
  - Develop the information exchange & define the supporting infrastructure for the BIM implementation (meeting 3)
  - Define the information exchange between parties
  - Describe the project and company infrastructure needed to support the implementation
  - Prepare draft agenda for meeting 3
  - Prepare a mid-way progress report
  - Select typical building materials and FF&E
  - Conduct a detailed review of methods & materials
  - Produce a LOD 200/300 model, typical geometry
  - Develop typical details and coordinate these in the model
  - Develop a scalable 3D model with all major systems and spaces coordinated
  - Verify and finalize the space plans, structural MEPFP, material selection and coordinate these in the model.
  - Reduce initial clashes in the 3D models
  - Verify the space plan, missing inputs for the program & MEP system requirements
  - Set and review reasonable standards and practices for the design-stage BIM models

- Monitor the design & evaluate the deliverables
  - Monitor the sustainable targets
  - Review the design against materials, cost and environmental objectives.
  - Prepare an environmental impact assessment
  - Approve & review the selected architectural, MEP, Structural, and fire protection systems.
  - Review the estimated cost of alternatives for the selected systems
- Supervise and review the consultant's work
  - Develop the design stage report
- Develop an equivalent report by mechanical & structural engineers
- Prepare a detailed report
- Monitor the progress against the BEP
- Review & approve the detailed design/design development phase
- Develop the Project Information Model (PIM) in accordance with the Master Information Delivery Plan (MIDP).
- Exchange and validate the Project Information Model (PIM) data:
  - During the project development process, the PIM continues to develop in accordance with the Master Information Delivery Plan (MIDP).
- Update the PIM
- Evaluate the design consultant's work
- End phase meeting

The outcomes of this stage:

- Development of a BIM strategy (through a series of meetings)

- Production of a LOD 200/300 model, typical geometry
- Updated PIM

7.9 Phase 6: Final Design and Contract Document

This is the final design phase, when the designer completes the works and drawings along with the contract document. The LOD 300 model will be produced at this point. After the client's approval, the next phase will start (Figure 93).

Before starting this phase:

The following are prerequisites:

- BIM LOD 200/300 model
- Project execution process map

Participants:

  - Client representatives
  - Professional advisors/specialist consultants/PM (if needed)
  - Design consultant

Key high-level objective:

  - How would the identified project function?

Deliverables:

  - Meet phase report
  - Mid-way progress report
  - LOD 300 model – precise geometry

- Detailed report
- Final design (work & drawings) and contract document
- PIM (updated)
- End phase meeting report

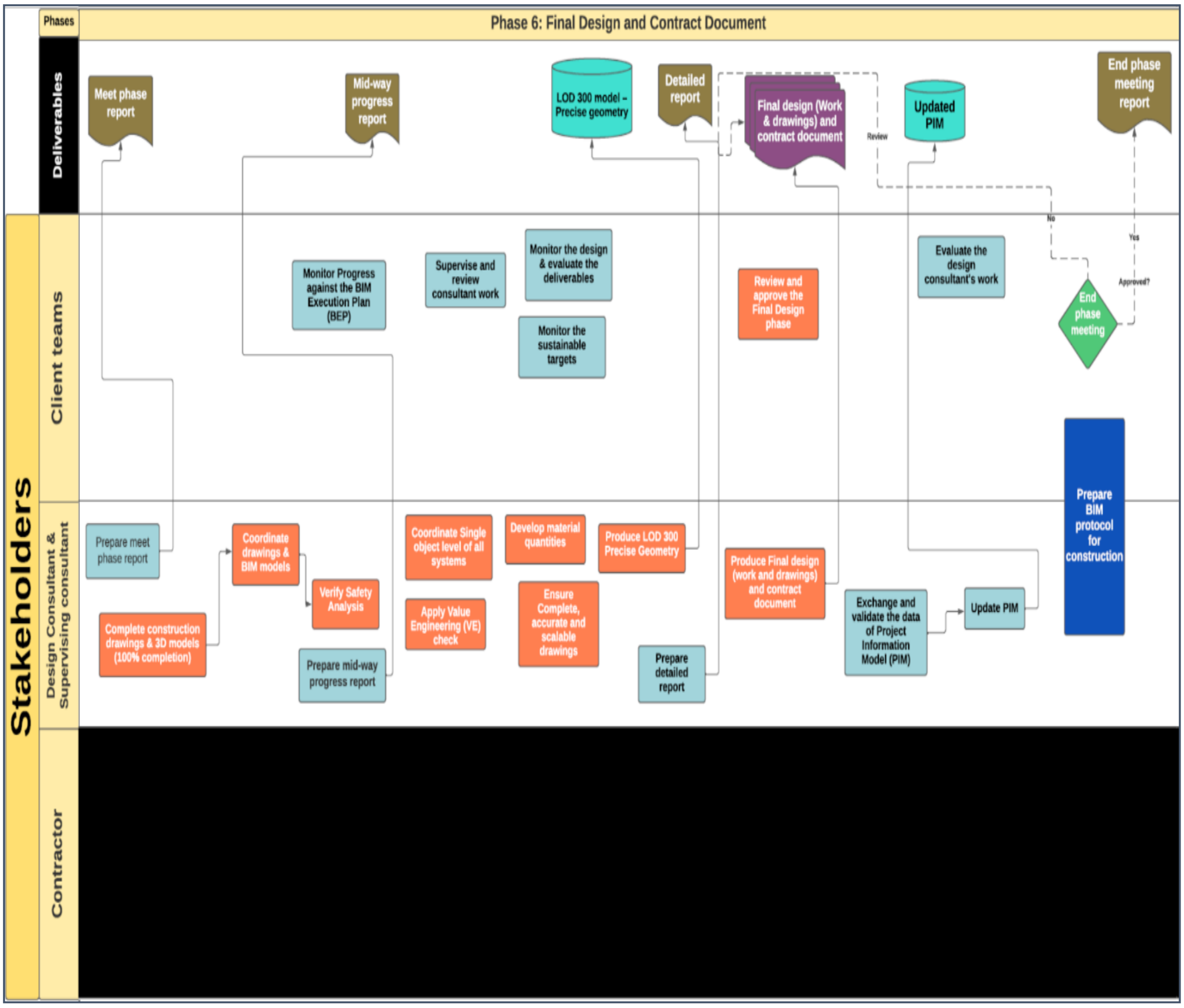


Figure 93: Phase 6: Final design & contract document

Minimum requirements to be met at this phase in order to move to the next phase:

- Final design (work and drawings) and contract document

Processes/Tasks:

- Prepare the meet phase report

- Complete the construction drawings & 3D models (100% completion)
- Coordinate the drawings & BIM models:
- Architectural, MEP-FP and structural – final clash detection
- Verify the safety analysis
- Prepare the mid-way progress report
- Monitor progress against the BEP
- Apply a Value Engineering (VE) check
- Coordinate the single object level of all systems
- Ensure complete, accurate and scalable drawings
- Supervise and review the consultant’s work
- Monitor the sustainability targets
- Monitor the design & evaluate the deliverables
- Develop the material quantities
- Produce a LOD 300 model, precise geometry
- Prepare a detailed report
- Produce the final design (work and drawings) and contract document
- Review and approve the final design phase
- Exchange and validate the Project Information Model (PIM) data
- During the project development process, the PIM continues to develop in accordance with the Master Information Delivery Plan (MIDP).
- Update the PIM
- Evaluate the design consultant’s work
- Prepare a BIM protocol for construction
- End phase meeting

- Get approval for the final design

The outcomes at this stage:

- Production of a LOD 300 model, precise geometry
- Production of a BIM protocol for construction
- Production of the final design and contract document

7.10 Phase 7: Tendering phase - Appointing a contractor

At this stage, qualified contractors (bidders) will be invited to submit a construction Request for Information (RFI) to clarify drawings or specifications in response to the EIR/TOR provided by the client. They should submit technical and financial proposals along with the pre-contract BEP. Then, these proposals will be assessed by the client and his advisors. Finally, a winning contractor will sign the agreement and proceed to the construction phase (Figure 94)[2].

Before starting this phase:

The following are prerequisites:

- BIM LOD 300
- A list of suppliers and sub-contractors
- Final BEP

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[2] **Note:** A contractor should have a BIM consultant in his team either in-house or outsourced.

- Approval of the final design
- PIM

Participants:

    - Client representatives
    - Design consultant
    - Contractors (bidders)

Submitted documents by the bidders:

- Financial proposals
- Technical proposals
- Pre-contract BEPs

Key high-level objective:

    - Is the bidder suitable for the project?

Deliverables from the winning bidder (contractor)

- Construction approval

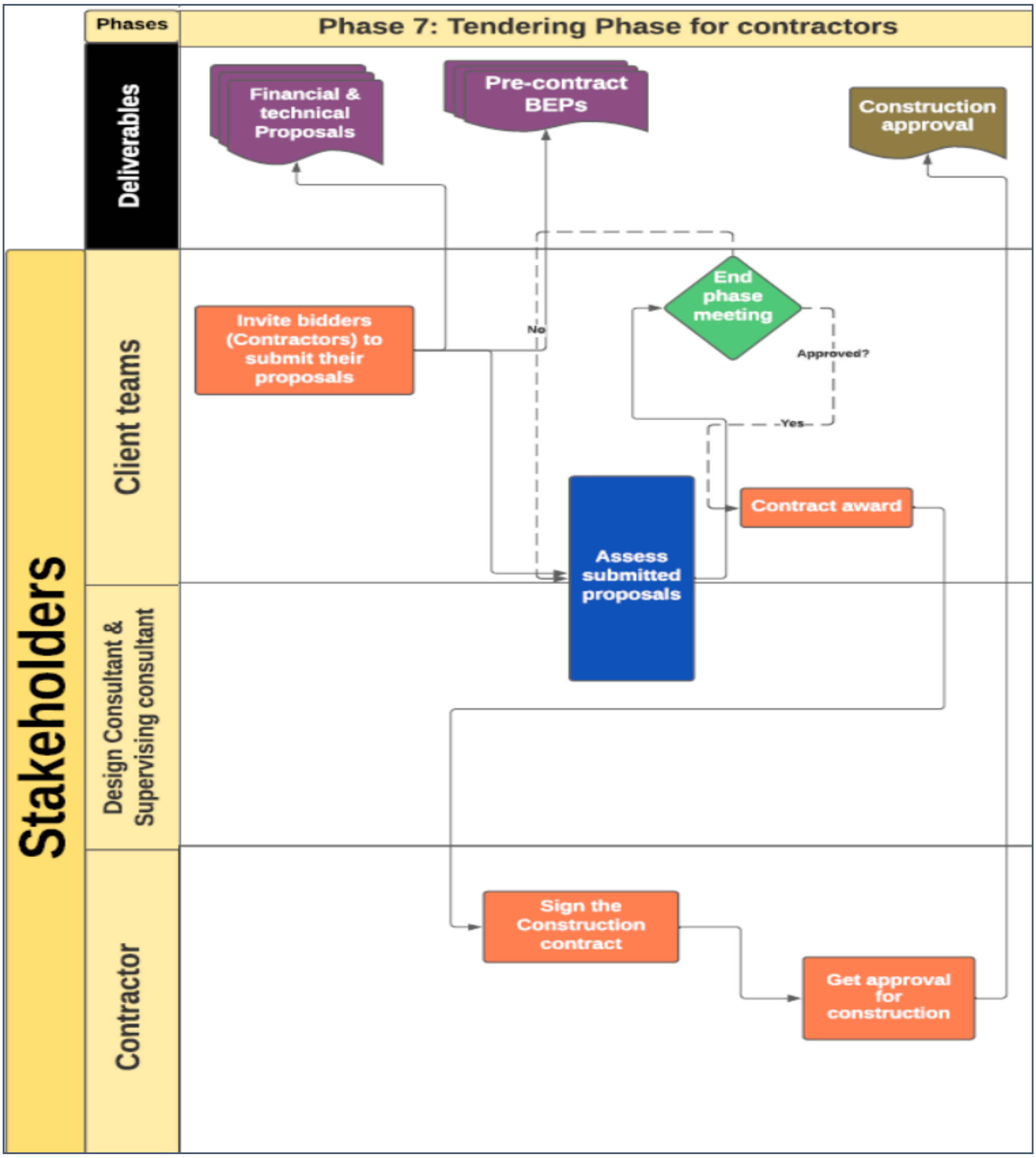

Figure 94: Phase 7: Tendering phase for contractors

Processes/tasks:

- Invite bidders (contractors) to submit their proposals
- Contractors will be invited to submit a construction Request For Information (RFI) to clarify drawings or specification proposals in response to the EIR/TOR

provided by the client.

- Contractors (bidders) will submit their proposals (financial and technical) and pre-contract BEP in response to the EIR/TOR provided by the client.
- Assess submitted proposals
- End phase meeting
- Contract award
- Select the winning bidder (winning contractor)
- Sign the construction contract
- Get approval for construction
- Get approval for construction from local authorities.

The outcome of this stage:

- Appointing the contractor.

7.11 Phase 8: Manufacturing and Construction Phase

In this phase, the contractor team will finalise the BIM model and produce the LOD 350/400 model. After that, construction will begin and the shop drawings will be handed over to sub-contractors for fabrication. A supervision team involving a design consultant will monitor the contractor's work and give technical support (if needed). The client team will monitor the contractor's progress and evaluate the work of the consultant and contractor (Figure 95).

Before starting this phase:

The following are prerequisites:

- Pre-contract BEP

- Approval from local authorities
    - The contractor should get approval for construction

Participants:

- Client representatives
- Design consultants
- Contractor (winning bidder)

Key high-level objective:

- How will we deliver and manage the project?

Deliverables

- Post-contract BEP
- Shop drawings & coordinated model
- QA & QC strategies
- Mock-up meeting feedback
- Weekly & monthly progress reports
- Waste management strategy
- LOD 350-400 model
- PIM (updated)
- Final BEP for FM
- AIM
- End phase meeting report

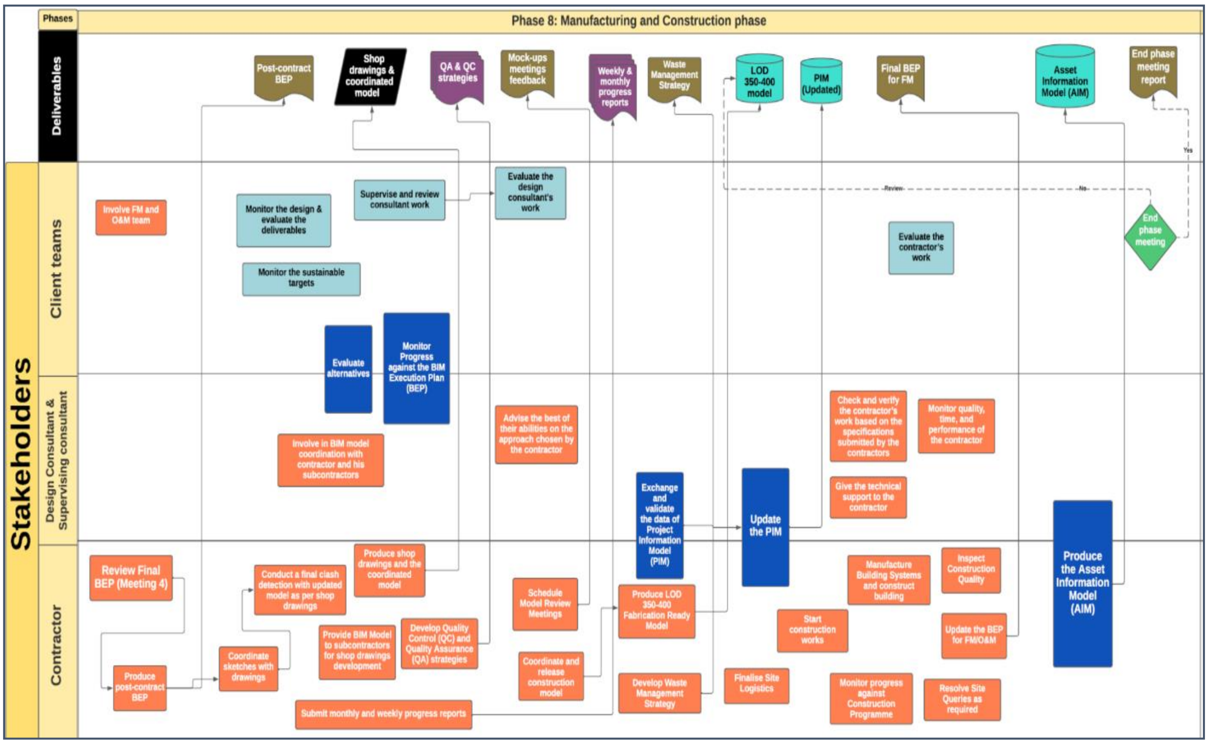

Figure 95: Phase 8: Manufacturing and Construction phase

Minimum requirements to be met at this phase in order to move to the next phase:

- Shop drawings and a coordinated model.
- PIM

Processes/Tasks:

- Involve the FM and O&M teams
- Review the final BIM Project Execution Plan (BEP) (Meeting 4)
- Review the draft BIM Project Execution Plan
- Create the project controls systems
- Define the procedure for the formal adoption of the BIM Project Execution Plan and monitoring process
- Agree on the tasks ahead and who is responsible for each
- Prepare the final BEP

- Produce a post-contract BEP
- Coordinate the sketches with drawings
- Conduct a final clash detection with an updated model as per the shop drawings
- Contractor and subcontractors involvement in the BIM model coordination
- Produce shop drawings and the coordinated model
- Coordinate and update the model as per the shop drawings
- Provide a BIM Model to subcontractors for the development of shop drawings
- Develop Quality Control (QC) and Quality Assurance (QA) strategies
- Schedule model review meetings
- Using virtual mock-ups
- Should be attended by all project parties
- Submit monthly and weekly progress reports
- Monitor the design & evaluate the deliverables
- Monitor the sustainability targets
- Evaluate alternatives
- Does this have a significant impact on either sustainable design targets or design quality
- Monitor progress against the BEP
- Advise on the approach chosen by the contractor
- Supervise and review the consultant’s work
- Evaluate the supervision consultant’s work
- Coordinate and release the construction model
- Produce an LOD 350-400 fabrication ready model
- Exchange and validate the Project Information Model (PIM) data

- During the project development process, the PIM continues to develop in accordance with the Master Information Delivery Plan (MIDP).
- Develop a waste management strategy
- Update the PIM
- Finalise the site logistics
- Start the construction works
- Manufacture the building systems and construct the building
- Monitor progress against the construction programme
- Inspect the construction quality
- Resolve site queries as required
- Give technical support to the contractor
- Check and verify the contractor’s work against the specifications submitted by the contractors
- Monitor the quality, time, and performance of the contractor
- Evaluate the contractor’s work
- Update the BEP for FM/O&M
- Produce the Asset Information Model (AIM)
- End phase meeting

The outcome of this stage:

- Coordinated BIM model
- Asset Information Model (AIM)
- Production of the practical completion certificate

7.12 Phase 9: Delivery and O&M or FM Phase (optional)

This phase is optional because it requires the implementation of Facility Management (FM). However, an FM department is not available in every client organisation. Therefore, it can be used for large-scale projects that require an FM phase and an LOD 500 model (Figure 96).

Before starting this phase:

The following are prerequisites:

- BIM LOD 350-400 model
- Final BEP
- AIM

Participants:

- o Client representatives including the FM team
- o BIM consultant
- o Design consultant
- o Contractor

Key high-level objective:

- o Is the building working as designed? How do we use the building?

Deliverables:

- LOD 500 model
- Asset Information Model (AIM) (updated)
- Building manual
- As-built drawings

- Practical completion certificate
- End phase meeting report

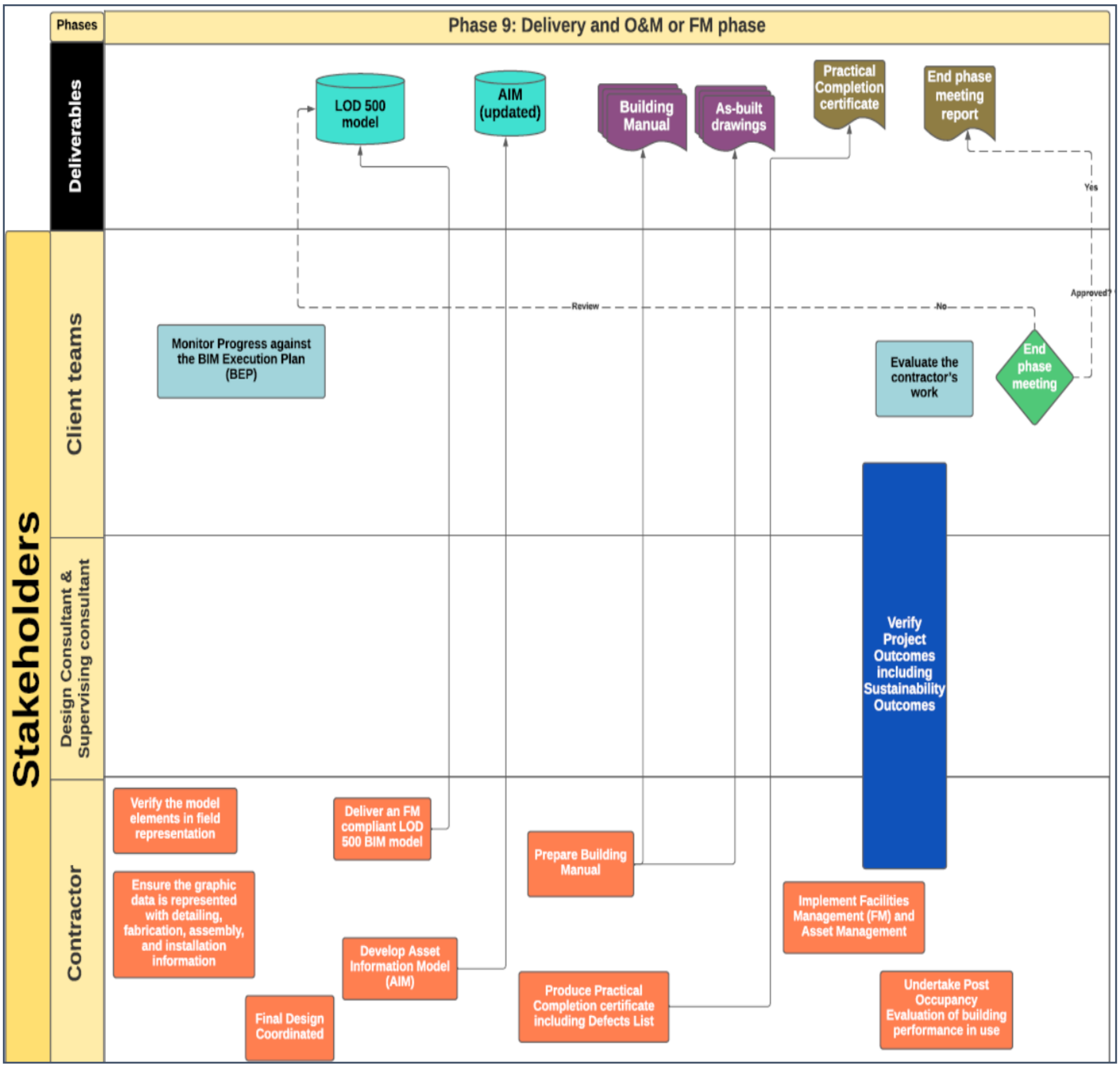

Figure 96: Phase 9: Delivery and O&M or FM phase

Minimum requirements to be met at this phase in order to move to the next phase:

- LOD 500 model
- AIM

Processes/Tasks:

- Verify the model elements in the field representation
- Ensure the graphic data is represented with detailing, fabrication, assembly, and installation information
- Final design coordinated
- Monitor progress against the BEP
- Deliver an FM compliant LOD 500 BIM model (as-built drawings)
- Develop an Asset Information Model (AIM)
- Prepare a building manual
- Produce as-built drawings
- Undertake the commissioning of building
- Produce O&M manuals
- Produce all references for the equipment
- Catalogue or maintenance manuals
- Produce a practical completion certificate including a defects list
- Implement the Facilities Management (FM) and asset management
- Undertake the post occupancy evaluation of the building performance in use
- Verify the project outcomes including the sustainability outcomes
- Evaluate the contractor's work
- End phase meeting

The outcome of this stage:

- Completion of the project
- Production of building manual

- Production of Asset Information Model (AIM)
- Implementation of facility management and asset management

7.13 Summary

In this chapter, the final BIM and Lean Construction process protocol/framework was described that aims to enhance the performance of the construction industry in Kuwait by applying BIM technology. It is based on BIM ISO 19650 Standards; and Lean principles and functions as a process flow framework that manages project information using BIM. This process begins by highlighting some of the key findings of the literature review, followed by the data collection to define the structure of this framework, the main processes, deliverables, participants, and phases. It was then modified by validation interviews to verify the applicability and suitability of the Lean and BIM process protocol in this field. In addition, since the research concentrates on one specific industry context, the results are not universally applicable across different sectors or in different countries. There is also the possibility that different sectors will have different product and process properties, which may affect the type, arrangement, and relationship between the elements of the framework, resulting in different outcomes from its use.

Chapter 8: Discussion, Conclusion and Recommendations

8.1 Introduction

The previous chapters of this thesis: Presented an overview of the literature that considered the problem to be investigated; identified the methodology used to achieve this; provided quantitative and qualitative results, and described the development of a process protocol that includes BIM and Lean Construction principles. This thesis completes the research circle by linking these steps to the five specific objectives mentioned in Chapter One.

The development of these five objectives was prompted by statistics concerning the performance of the construction industry in Kuwait. To evaluate this issue and the potential for BIM and Lean Construction to improve associated outcomes, this research first assessed existing literature by addressing the challenges facing the construction industry in Kuwait, including delays, cost overruns, and low productivity. Furthermore, the relevance of BIM and Lean Construction in enhancing the industry's performance outcomes was reviewed, highlighting the benefits of implementing these approaches to the industry. Finally, frameworks related to the integration of BIM and Lean Construction were examined, while different improvement construction process tools were explored to develop an improved framework that incorporates BIM and LC. The ultimate purpose of these five goals is to develop an improved Process Protocol/framework that supports the implementation of BIM technology and Lean principles within the public sector construction industry in Kuwait.

8.2 Achievement of the Research Aim and Objectives

To achieve the aim and objectives of this study, a mixed methods approach was applied using a questionnaire (n=136) and semi-structured interviews (n=10). Questionnaire data were analysed using descriptive statistics, univariate statistics, and content analysis (for open-ended questions) in order to develop a broad comprehension of the conditions and to gain insights into public sector construction industry in Kuwait. Thematic analysis was used to analyse interview data and generate a thorough understanding of the relevant conditions. Data from these two methods were analysed to understand current project management practices in public construction projects in Kuwait and to verify the relationship between BIM, Lean Construction and the performance of the industry in terms of time, money, and quality. Also, an integrated framework was developed for the use of BIM and LC in construction projects to address the challenges, evaluate the process protocol developed from experts' opinions, make recommendations based on best practice, and provide guidance for further research on the topic. The next sections explain how these steps achieved the five research objectives. The following section discusses the theoretical and practical contributions to knowledge. Finally, the limitations of the study and recommendations for further research are presented.

Objective 1: Identify challenges in the construction industry and their causes and consequenceses

This study evaluated construction projects in the public sector in Kuwait, the challenges facing this industry, and their causes and consequences. The survey results indicated that the industry faces several challenges, such as time and cost overruns, low collaboration between stakeholders, and a lack new, applied technologies, which result in underperformance and deficiencies in current project management practices. These findings reinforced literature analysis, which demonstrated that the industry has suffered from delays and cost overruns and there is a lack of BIM adoption which results in underperformance. The four main risks in the industry were found to be: delays, lack of communication and coordination between stakeholders, poor planning and control, and changes to orders. It is imperative to address these issues using advanced project management approaches, as the construction industry in Kuwait lacks any implementation of effective project management tools according to the questionnaire findings.

Objective 2: Review and identify improvement methods to overcome the challenges faced

In the literature review, improvement methods for project management practices were explored, such as Building Information Modelling (BIM) and Lean Construction (LC), as well as construction management process models and frameworks. These project management approaches have proven effective in enhancing the performance and productivity of the industry in many developed countries. However, analysis of the questionnaire data found a lack of effective project management practices applied in the construction industry in Kuwait. Despite implementing BIM, its adoption was inappropriate. Also, the industry lacks the awareness and application of Lean Construction and waste management techniques.

Objective 3: Establish and document general areas on Lean principles, BIM, and process protocols in the construction industry

In reviewing the literature, Lean principles, BIM and process protocols have been investigated. These approaches were found to improve the construction industry in many developed countries, as BIM is a process that fosters collaboration between various stakeholders using technologies, such as programs and software, while Lean Construction principles help reduce waste and add value for the client by creating a visual process of the entire project lifecycle. Several synergies between BIM and LC were mentioned in Chapter 2. Using a process protocol that employs BIM would optimise the performance of this sector and promote a high level of collaboration between project stakeholders.

Despite great awareness, according to the survey and interview results, the current implementation of BIM in the construction industry in Kuwait is inappropriate. This lack of implementation leads to further wasted time and money. Additionally, the low level of awareness of LC and waste management techniques in this industry has resulted in massive waste and prevented the industry from improving. Therefore, there is a substantial need for evolution in the construction industry in Kuwait through the adoption of new advanced construction management approaches and technologies.

Likewise, the interview findings revealed the inappropriate implementation of BIM technology in construction projects in Kuwait, and an absence of collaboration between project parties. For example, the designer produces a BIM model for the design phase without sharing it with the contractor, so the contractor redesigns the BIM model based on the shop drawings given by the client. This BIM model is subsequently developed by the contractor from LOD 300 to LOD 400, which is based on the agreement. Also, the contractor is responsible for coordination and clash detection. Yet, there is a lack of awareness and application of waste management techniques, such as Lean Construction, in the construction industry in Kuwait, as project stakeholders believe these methods only relate to material waste or design errors. In fact, Lean Construction focuses on optimising the construction processes, as all processes throughout the entire project lifecycle are monitored for optimisation in order to reduce waste and add value to the client.

Objective 4: Explore and identify the drivers and the challenges of implementing Lean principles and BIM in client organisations in the construction industry

The literature review explored the drivers for, and challenges of, implementing Lean Principles and BIM in construction projects around the world. A questionnaire was subsequently designed to examine these factors in the construction industry in Kuwait. The questionnaire findings revealed that "accurate construction sequencing", "improved design quality", and "reduced errors and avoided risks" are key drivers for BIM implementation in the industry. On the other hand, the most significant barriers to BIM adoption are organisational issues, a lack of skilled personnel, and a lack of BIM knowledge according to the survey results. The findings highlighted a lack of knowledge and experience in waste management methods, such as Lean Construction. Moreover, waiting, non-ulitised talents, and defects are the three main Lean wastes in construction projects in Kuwait. Thus, based on the interview results, there is misuse of BIM in the construction industry in Kuwait where there is a lack of collaboration and coordination among project stakeholders; a lack of experience, resources, and training, and no clear process protocol or best practice applied.

Objective 5: Develop and evaluate a framework for improving the performance of client organisations in the construction industry

After reviewing literature about BIM and Lean Construction frameworks, as well as construction process protocols, interviews were conducted to gather more information about processes, outputs, phases, and participants. This enabled the researcher to develop an improved process protocol for client organisations in the construction industry in Kuwait which embedded BIM technology and Lean Principles. This framework was verified through structured interviews in order to update and generate the final version that could be applied to the construction industry in Kuwait. In the validation process, generalisation was achieved using three different participants, two of whom were from different local client organisations, and the third was an international BIM consultant with experience in construction projects in the Middle East region and globally.

8.3 Expected Contribution to Knowledge and Practice

This research's contribution to knowledge is to improve the performance of the construction industry in Kuwait from a holistic perspective. Since the government launched the new Kuwait 2035 vision, the development of the construction industry has become one of the country's priorities. Moreover, the researcher has been encouraged by the public sector of the construction industry through its support for her postgraduate degree and funding of this study, which proposes a strategy-framework to employ BIM and LC in this sector. This framework will increase knowledge about Building Information Modelling (BIM) and Lean Construction (LC) in the industry with the aim of improving its performance by providing a visual process model that includes phases, processes/tasks, deliverables, and participants. This visual process model facilitates the monitoring of activities, evaluation and improvement of the entire process and the provision of guidance to employees. For example, the framework helps the client to prepare the project and BIM requirements for each phase. It also helps in detecting non-added value activities (waste) at each phase so that they can be eliminated.

Hence, bridging the knowledge gap in Lean Construction and Building Information Modelling would benefit various project stakeholders and create knowledge on implementing BIM through the application of the new international BIM standard (ISO 19650) alongside LC principles. This framework is the first to include the new international BIM standard ISO 19650 alongside the use of Lean principles for client organisations. For instance, BIM terms and requirements from the International BIM Standard ISO 19650 were included in different phases of the framework enable familiarisation amongst practitioners in the construction industry and support the effective implementation of BIM. Thus, awareness of BIM terms and requirements and their use will greatly enhance BIM adoption in the industry.

The contribution to practice by this research will influence the development of the construction industry by promoting modernisation through the adoption of advanced technologies that have been used globally to manage construction projects and overcome the challenges facing this industry. LC and BIM prevail as many developed countries already implement them; therefore, this study will support Kuwait’s new vision for the industry and help to introduce new methods that could digitise its practice. It will enhance the digitisation of the industry by providing a strategy with a visual tool that monitors and organises the entire project process, especially for client organisations. In addition, this process protocol can form the basis for creating a business model or system for public construction organisations. Globally, the development of a BIM and Lean Construction framework that uses the new international BIM standard will have a major impact on the construction industry. As this International BIM standard was intended for use in the Middle East region and globally to facilitate the implementation of BIM, and with its inclusion in the framework, it will fulfil its purpose.

8.4 Limitations of the Research and Recommendations for Further Research

Public sector construction projects in Kuwait represent a broad subject and include many authorities, stakeholders, departments, and practices. Therefore, it is impossible to cover all aspects of this sector in one study. Since the Kuwaiti government has sponsored the author to improve their initiatives, this research has focused on client organisations in public-sector construction projects, which include public facilities and commercial projects, such as hospitals and airport projects. This study focused on providing a framework/process protocol to improve the performance of Kuwait's construction industry through the inclusion of BIM and Lean Construction. The research has successfully achieved its aim and objectives. As no study is without limitations, it is important to highlight these, which are outlined as follows with some recommendations:

- The main restrictions of this study included time constraints and the accessibility of (potentially confidential) data from the departments of different organisations. In addition, participants refused to share all information, whilst language barriers may have affected the transfer of information and software usage.
- The generalisability of the process protocol/framework is a limitation. Although precise scientific approaches have been adopted in developing the process protocol, this research focuses on construction projects in Kuwait due to time constraints. Therefore, it is recommended that further research is undertaken on the applicability of this framework to the construction industry in various other countries and to identify similarities and differences.
- During the data collection stage, the researcher was unable to obtain a sufficient range

of important literature on BIM implementation, Lean Construction, and process protocols in the construction industry in Kuwait, or specific studies in this field of research. Also, some participants were unwilling to participate in the survey, which led to an increase in the duration of data collection stage.

- Mixed method research was adopted for this study by using a questionnaire and interviews to collect the primary data. Nevertheless, further research could implement other strategies, such as Action Research, in order to evaluate the implementation of the BIM and Lean Construction process protocol in the construction industry in Kuwait with the aim of reducing wasted time, money and effort, and thus improving performance.
- This study was restricted to large organisations, so future studies could investigate the development of medium and small organisations. Additionally, this research focused on public facilities and commercial projects, so further research could consider different types of project, such as specialised industrial and infrastructure construction projects.
- Finally, as this research focused on public construction organisations in Kuwait, future research could investigate the same subject in the private sector. This could enable a comparison between the results of the two studies.

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Appendix 1: Ethical Approval

Research, Innovation and Academic Engagement Ethical Approval Panel

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Manchester
M5 4WT

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30 July 2019

Manal Aladwani

Dear Manal

<u>RE: ETHICS APPLICATION STR1819-40 – T</u>o develop a process protocol to improve the performance of construction project lifecycle in the client organisation in Kuwait through applying LEAN construction principles and BIM technology.

Based on the information you provided, I am pleased to inform you that your application STR1819-40 has been approved.

If there are any changes to the project and/ or its methodology, please inform the Panel as soon as possible by contacting S&T-ResearchEthics@salford.ac.uk

Yours sincerely,

Dr Devi Prasad Tumula
Deputy Chair of the Science & Technology Research Ethics Panel

Appendix 2: Conceptual framework

		Project Information Model (PIM)								Asset Information Model (AIM)
		Design Process					Building Life Cycle			
			Pre-Design	Concept Design Modelling	Design Development	Final Design (Accurate modelling & shop drawings)	Fabrication & Assembly			Maintenance & Building Operations
	Level of Development (LOD)		LOD 000	LOD 100	LOD 200	LOD 300	LOD 400			LOD 500
		Pre-Construction Phase		Design Phase			Pre-Construction Phase		Construction	Post-Construction Phase
		Phase 0	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8
		Strategic Definition	Preparation and Brief	Concept Design	Design Development	Technical Design	Production information	Tendering Phase	Construction	Operation & Maintenance (FM)
Government/ Client Units	Strategic Planning and designing department	Develop Project Business Case/ Appoint the consultant	Develop Project Brief / Terms of References " TOR"/ Develop EIR				Preparing BOQ/ EIR			
	BIM Management	BIM Business Case: Identify BIM capabilities/ Define General BIM Guidelines/ Setting the Procurement & BIM Strategy/ Determine the Info Management & CDE Strategy	BIM Execution Plan (BEP)			BIM Execution Plan (BEP)	BIM Execution Plan			
	Execution department / Project Management (PM)									
	Contracts and Legal Dept.		Develop Procurement Plan							
	FM. Dept.									
	Local Authority	Budget approval	Project Plan approval							
Project Stakeholders	Design Consultants "Design team and MEP engineers"		Initial Responsibility Matrix			Preparing BOQ				
	BIM Consultant/ PM									
	Contractor									
	Sub-Contractors									

Appendix 3: Questionnaire Questions

Research Ethics Application Form

University of Salford MANCHESTER

APPENDIX 2
Draft Questionnaire

Subject: An invitation to take part in a questionnaire survey (Development of a Process Protocol for the implementation of BIM-driven Lean Construction Principles in the Kuwaiti Construction Industry: A Client Perspective)

Dear Participant,
You are invited to participate in a research study on titled "Development of a Process Protocol for the implementation of BIM-driven Lean Construction Principles in the Kuwaiti Construction Industry: A Client Perspective". This study is being conducted by Manal Al-Adwani and her research committee from the Department of Research at the University of Salford in the United Kingdom. This work aims to support the existing research available concerning the challenges and problems facing the construction projects in Kuwait, the existence of new advanced project management techniques such as Lean Construction (LC) and Building Information Modelling (BIM), their level of maturity, and the impacts of integrating them together. Also, the benefits, challenges of implementing BIM will be examined besides the existence of a framework to manage the lifecycle of a project. The aim of this research is to develop a process protocol to improve the performance of the construction project lifecycle in client organisation in Kuwait through applying LEAN construction principles and BIM technology.
It is expected that this process protocol would help to improve the awareness and understanding of the individuals and organisational level about the adoption of Lean Principles and BIM and its impact on project performance. The research will focus on the public sector construction projects, as it shows many challenges in terms of cost and time performance.
In this study, you will be asked to complete an electronic survey. Your participation in this study is voluntary and you are free to withdraw your participation from this study at any time. The data collected, and the anonymity are secured and guaranteed. The survey should take only 15 minutes to complete.
This survey has been approved by the Institutional Review Board of the University of Salford. There are no risks associated with participating in this study. Your survey response will be kept confidential, and data from this research will be reported only collectively. All of the response in the survey will be recorded anonymously.
While you will not experience any direct benefits from participation, information collected in this study may help in providing a background to the problems in this industry, Lean Construction and BIM status and their impacts on the construction projects, therefore, developing a solution to improve the performance of this industry.
If you have any questions regarding the survey of this research project in general, please contact me or my supervisor Mr. Andrew Fleming at his Email:
A.J.Fleming@salford.ac.uk
By completing and submitting this survey, you are indicating your consent to participate in the study. Your participation is appreciated.

Kind Regards,
Manal Al-Adwani
M.M.H.M.A.Al-Adwani@edu.salford.ac.uk

I agree that the information I provide may be used in the way described in the Participant Information Form.
أوافق على ان المعلومات التي سأقدمها سوف تستخدم كما وصفت في نموذج معلومات المشارك

- I agree (انا أوافق)

General questions:

1. You are representing: (انت تمثل)
   - Owner-representative/ Client (الموكل/ الوزارة الحكومية)
   - Contractor (مقاول)
   - Consultant (استشاري)
   - Educational institution/ University/ College (المؤسسة التعليمية / الجامعة / الكلية)

2. Please Mark on your years of experience: (يرجي وضع علامة علي عدد سنوات خبرتك)
   - Less than 5 years (اقل من ٥ سنوات)
   - 5 – 10 years (من ٥ الى ١٠ سنوات)
   - 11 – 15 years (من ١١ الي ١٥ سنه)
   - More than 15 years (اكثر من ١٥ سنة)

3. What role do you perform within your company/organisation / ما هو الدور الذي تقوم به داخل شركتك مؤسستك/ الوزارة?
   a. Civil Engineer مهندس مدني
   b. Architect معماري
   c. Quantity Surveyor مساح الكميات
   d. Mechanical Engineer مهندس ميكانيكي
   e. Electrical Engineer مهندس كهربائي
   f. Project Manager مدير مشروع
   g. Other أخرى : ……..
4. Do you work in the government project(s)?هل تعمل في مشاريع حكومية
   a. YES نعم
   b. NO لا

Questions related to the challenges facing the construction industry in Kuwait, especially the public sector construction projects: الأسئلة المتعلقة بالتحديات التي تواجه صناعة البناء والتشييد في الكويت ، وخاصة المشاريع الإنشائية الحكومية (القطاع العام):

5. In your career to date what percentage of projects have run في حياتك المهنية حتى الآن ما هي النسبة المئوية للمشاريع التي تديرها:

5a. In your career to date what percentage of projects have run "on time"? في حياتك المهنية حتى الآن ما هي النسبة المئوية للمشاريع التي تم تشغيلها في الوقت المحدد
(0-25%, 25-50%, 50-75%, 75-100%)

5b. In your career to date what percentage of projects have run "on budget"? في حياتك المهنية حتى الآن ما هي النسبة المئوية للمشاريع التي تم تشغيلها على الميزانية المحددة
(0-25%, 25-50%, 50-75%, 75-100%)

6. In your Opinion, do you think by preventing delays in construction projects, cost overrun could be avoided? في رأيك ، هل تعتقد أنه من خلال تجنب التأخير في المشاريع الانشائية، يمكن تجنب تجاوز التكلفة المحددة للمشروع؟
   a. YES نعم
   b. NO لا
   c. Maybe/not sure ربما/ لست متأكداً

7. What are the challenges/ problems facing the (Public Projects) Government construction Projects in Kuwait? ما هي التحديات / المشكلات التي تواجه مشاريع البناء الحكومية (المشاريع العامة) في الكويت

Challenges/ Problems التحديات/ المشاكل	Strongly Disagree اعترض بشده	Disagree اعترض	Neutral / not sure محايد/ لست متأكدا	Agree أوافق	Strongly Agree أوافق بشده
1. Time overrun/ delays تجاوز الوقت / التأخير					
2. Cost overrun تجاوز التكلفة					
3. Waste in Construction materials تبذير او هدر في مواد البناء					
4. Lack of communication and coordination between project parties نقص في التواصل والتنسيق بين الأطراف المشاركة في المشروع					
5. Low Productivity انخفاض الانتاجية					
6. Construction accident حوادث اثناء البناء					
7. Inadequate Project Management Practice and poor site management عدم كفاية ممارسة إدارة المشاريع وسوء إدارة الموقع					
8. Lack of experience and qualifications قلة الخبرة والمؤهلات					
9. Lack of adopting new technologies عدم تبني تقنيات جديدة					
10. Poor Planning and control سوء التخطيط والرقابة					
11. Change in orders/ decisions initiated by clients تغيير في أوامر / القرارات التي بدأها العملاء					

Other (If it is not above) غير ذلك (إذا لم يكن أعلاه:.........

8. Does your organisation follow any project management approach (protocol, framework, guidance, etc.) that addresses the problems and challenges facing the construction projects? هل تتبع مؤسستك أي نهج لإدارة المشروع (البروتوكول، الإطار، التوجيه ، إلخ) يعالج المشكلات والتحديات التي تواجه المشاريع الانشائية؟
   a) YES نعم
   b) No لا
   c) Not sure / I don't know لست متأكداً/ لا اعلم

Lean Construction Questions:

Lean Construction: is a technique to design production systems to reduce waste of materials, time, and effort to generate the maximum possible amount of value.

البناء اللّيّن "الرشيق": هو منهج في إدارة الإنتاج يهدف للتحسين عبر التحسين المستمر وإزالة الشوائب أو الهدر فهي تقنية لتصميم أنظمة الإنتاج لتقليل هدر المواد والوقت والجهد لتوليد أكبر قدر ممكن من القيمة. فالنتيجة قطاع انشائي خالي من الهدر

9. Are you familiar with the term "waste" or "non-added value" هل أنت على دراية بمصطلح "التبذير / الهدر " أو "القيمة غير المضافة"؟"?
   h. YES نعم
   i. NO لا

10. Do you know any construction firm in Kuwait applies approaches or tools to eliminate "non-added value" or "waste" in their projects هل تعرف أي شركة بناء في الكويت تطبق أساليب أو أدوات للقضاء على "القيمة غير المضافة" أو "التبذير" في مشاريعها?
    j. YES (نعم)
    k. NO (لا)
11. Have you heard about the Lean philosophy or the Toyota Production Systems (TPS) philosophy?
هل سمعت عن فلسفة او التفكير اللّيّن "الرشيق"؟ او فلسفة نظام انتاج تويوتا؟
    a. YES نعم
    b. NO لا
12. Do you know of any construction company in Kuwait that applies Lean Construction?
هل تعرف أي شركة بناء في الكويت تطبق البناء اللّيّن؟
هل تعرف أي شركة بناء في الكويت تطبق Lean Construction
    a. YES
    b. NO

If YES, please select the type of project(s) that applied Lean Construction:
إذا كانت الإجابة بنعم ، يرجى تحديد نوع المشروع (المشاريع) التي طبقت تطبيق Lean Construction

- Residential projects مشاريع سكنية
- Airport المطار
- Commercial تجاري
- Schools مدارس
- Universities جامعات
- Hospitals مستشفيات
- Others … أخرى

The following questions related to the 8 waste of Lean **الأسئلة التالية المتعلقة بال ٨ أشكال للهدر / التبذير**

13. How often the following waste occurred in construction projects كم مره حدث او ظهر هذا الهدر او التبذير في المشاريع الانشائية?

The 8 waste of Lean ٨ أشكال للنفايات/الهدر/التبذير	Never لم يحدث ابداً	Rarely نادراً	Sometimes أحياناً	Frequently كثير من الاحيان	Always دائماً
Defects العيوب التي تتطلب إعادة صياغة (e.g. Rework, Scrap, Design error, incomplete design, incorrect information, Inconsistency between contract documents) على سبيل المثال ، إعادة صياغة ، خردة ، خطأ في التصميم ، تصميم غير كامل ، معلومات غير صحيحة ، عدم التوافق (بين مستندات العقد) **العيوب التي تتطلب إعادة صياغة** (على سبيل المثال ، إعادة صياغة ، خردة ، خطأ في التصميم ، تصميم غير كامل ، معلومات غير صحيحة ، عدم التوافق بين مستندات العقد)					
Over Production فرط الإنتاج (Production that is more than needed or before it is needed) الإنتاج أكثر من اللازم أو قبل الحاجة **فرط الإنتاج** (الإنتاج أكثر من اللازم أو قبل الحاجة)					
Waiting وقت الانتظار (wasted time waiting for the next step in a process, such as long documentary cycle, long					

approval procedures) الوقت الضائع في انتظار الخطوة التالية في العملية ، مثل الدورة الوثائقية الطويلة وإجراءات الموافقة الطويلة **وقت الانتظار** (الوقت الضائع في انتظار الخطوة التالية في العملية ، مثل الدورة الوثائقية الطويلة وإجراءات الموافقة الطويلة)					
Non-utilized talents المواهب غير المستخدمة(underutilizing people's talents, skills, & knowledge) قلل من استغلال مواهب الناس ومهاراتهم ومعرفتهم **المواهب غير المستخدمة** (قلل من استغلال مواهب الناس ومهاراتهم ومعرفتهم)					
Transportation (Materials) النقل والصيانة الغير ضرورية(Unnecessary movements of products & materials) الحركات غير الضرورية للمنتجات والمواد **(النقل والصيانة الغير ضرورية (المواد** (الحركات غير الضرورية للمنتجات والمواد)					
Inventory زيادة المخزون (Excess products and materials being processed) المنتجات والمواد الزائدة التي تتم معالجتها **زيادة المخزون** (المنتجات والمواد الزائدة التي تتم معالجتها)					
Motion (People) التنقل العبثي (unnecessary movements by people "e.g. walking") **تحريك لا لزوم له للمواد أو للأشخاص** **التنقل العبثي (تحريك لا لزوم له للمواد أو للأشخاص)** (الحركات غير الضرورية التي يقوم بها الأشخاص "مثل المشي")					
Extra Processing معالجة اضافية (i.e. pouring concrete where pre cast concrete would be more effective) أي صب الخرسانة حيث تكون الخرسانة مسبقة الصب "الخرسانة الجاهزة" أكثر فعالية **معالجة اضافية** (أي صب الخرسانة حيث تكون الخرسانة سابقة الصب أكثر فعالية)					

BIM Questions

Building Information Modelling (BIM) is the process of creating information models containing both graphical and non-graphical information in a Common Data Environment (CDE) (a shared repository for digital project information). The information that is created becomes ever more detailed as a project progresses with the complete dataset then handed to a client at completion to use in the building's In-Use phase and potentially on into a decommissioning phase.

نمذجة معلومات البناء: هي عملية توليد وإدارة بيانات المبنى خلال دورة حياته، هي عملية إنشاء نماذج معلومات تحتوي على كل من المعلومات الرسومية وغير الرسومية في بيئة بيانات مشتركة (مستودع مشترك لمعلومات المشروع الرقمي)، تصبح المعلومات التي تم إنشاؤها أكثر تفصيلاً مع تقدم المشروع مع مجموعة البيانات الكاملة ثم تسليمها إلى العميل عند الانتهاء لاستخدامها في مرحلة الاستخدام "قيد التشغيل" وربما إلى مرحلة إيقاف التشغيل" الهدم".

14. Have you heard about Building Information Modelling (BIM)?

هل سمعت عن نمذجة معلومات البناء (BIM)؟

   a. YES نعم
   b. NO لا

15. Do you know of any construction company in Kuwait that applies BIM?

هل تعرف أي شركة بناء في الكويت تطبقBIM ؟

   a. YES نعم
   b. NO لا

If Yes, please select the type of project(s) that implement BIM:

إذا كانت الإجابة بنعم، يرجى تحديد نوع المشروع (المشاريع) التي تنفذ:BIM

- Residential projects المشاريع الاسكانية
- Airport المطار
- Commercial تجاري
- Schools مدارس
- Universities جامعات
- Hospitals مستشفيات
- Others ... أخرى

16. What is your knowledge of BIM?

ما هي معرفتك بـBIM ؟

   A. None لا شيء (no knowledge/ no experience in BIM) (بدون معرفة / لا يوجد خبرة)

   B. Beginner مبتدئ (Basic knowledge but No experience in BIM project (المعرفة الأساسية ولكن لا يوجد خبرة)

   C. Intermediate متوسط (Good BIM knowledge and I am involving in a BIM project) (معرفة جيدة واعمل على مشروع يستخدم نظام نمذجة معلومات البناء)

   D. Advanced متقدم (Expert in BIM and has completed some BIM projects) (معرفة متقدمة واستكملت بعض المشاريع التي تستخدم نظام نمذجة معلومات البناء)

17. Are you a BIM user?

   هل أنت مستخدمBIM

   a. YES نعم
   b. NO لا

If NO, please ignore the next two questions (go to question number 20)

إذا كان الجواب بالنفي ، فيرجى تجاهل السؤالين التاليين (انتقل إلى السؤال رقم 15)

18. Select your years of experience in BIM

   حدد سنوات خبرتك فيBIM

   a. Less than 5 years (اقل من ٥ سنوات)
   b. 5 – 10 years (من ٥ الى ١٠ سنوات)
   c. 11 – 15 years (من ١١ الي ١٥ سنه)
   d. More than 15 years (اكثر من ٥ سنوات)

19. Select your BIM usage:
حدد استخدام BIM الخاص بك:.
    a. Design (Design Phase)(التصميم (مرحلة التصميم
    b. Detailing (Design Phase)(التفاصيل (مرحلة التصميم
    c. Elements fabrication (Construction Phase)(تصنيع العناصر (مرحلة البناء
    d. Project management (Construction Phase)(إدارة المشروع (مرحلة البناء
    e. Facility Management (Use Phase)(إدارة المرافق (مرحلة الاستخدام
    f. Other أخرى : ....
20. Your BIM training:
تدريبك لBIM
    a. None لا يوجد
    b. Self-training تدريب ذاتي
    c. University/College الكلية/الجامعة
    d. In-house training program (by your company)(برنامج تدريبي داخلي (بواسطة شركتك
    e. Other آخر ......

BIM Maturity Levels Questions:

أسئلة مستويات نضوج:BIM

21. Please select the level of collaboration between project stakeholders in your organisation/company?
يرجى تحديد مستوى التعاون بين أصحاب المصلحة في المشروع في مؤسستك / شركتك.
    a. No collaboration لايوجد تعاون
    b. Low Collaboration تعاون منخفض
    c. Partial collaboration تعاون جزئي
    d. Full collaboration/integration التعاون الكامل/ التكامل

22. Please select how the project information is being produced in your organisation/company?
يرجى تحديد الكيفية التي يتم بها إنتاج معلومات المشروع في منظمتك / الشركة
    a. 2D using AutoCAD (باستخدام أوتوكاد 2D)
    b. Combination of 2D & 3D within a common data environment (AutoCAD/Autodesk Revit/ArchiCAD) but without integrating finance and cost management packages with the CAD)
    (مزيج من ثنائية وثلاثية الأبعاد داخل بيئة بيانات مشتركة (أوتوكاد / Autodesk Revit / ArchiCAD) ولكن دون دمج حزم التمويل وإدارة التكاليف معCAD)
    c. 4D/ 5D (which means the integration of 3D design model with planning, Project Management, and Cost Management).
    4D / 5D وهو ما يعني دمج نموذج التصميم ثلاثي الأبعاد مع التخطيط وإدارة المشاريع وإدارة التكلفة
    d. 6D (it means full lifecycle integration (4D+5D) considering Maintenance and Operation/Facility Management "FM". Focused on Assets Management).
    6D يعني التكامل الكامل لدورة الحياة (4D + 5D) مع الأخذ في الاعتبار الصيانة والتشغيل / إدارة المرافق "FM". يركز على إدارة الأصول
    يعني التكامل الكامل لدورة الحياة (نموذج رباعي وخماسي الابعاد) مع الأخذ في الاعتبار الصيانة والتشغيل / إدارة المرافق الذي يركز على إدارة الأصول

23. Please select what is the type of information sharing tool that is used in your organisation to share project information amongst the project team? الرجاء تحديد نوع أداة مشاركة المعلومات المستخدمة في مؤسستك لمشاركة معلومات المشروع بين فريق المشروع؟

a. Papers and printouts, or digitally via PDF, essentially separate sources of information covering basic asset information. (CAD format/ PDF files) الأوراق والمطبوعات او رقمياً عبر ملفات بي دي اف تفصل مصادر المعلومات التي تغطي معلومات الأصول الأساسية

b. File-based collaboration (electronic sharing of data is carried out from a common data environment "CDE") (CAD/RVT file format) but without integrating finance and cost management packages with CAD. التعاون القائم على الملفات بحيث تتم المشاركة الإلكترونية للبيانات من بيئة بيانات مشتركة ولكن دون دمج حزم التمويل وإدارة التكلفة في نفس البرنامج (الاوتوكاد/الريفيت)

c. File-based collaboration and Library management (IFC or COBie file formats). Managed 3D environment with commercial data attached and this data managed by enterprise resource planning software, integrated by proprietary interfaces or bespoke middleware. التعاون القائم على الملفات وإدارة المكتبات (تنسيق الملفات التجارية مرفقة وهذه البيانات مدارة بواسطة برنامج تخطيط وموارد المؤسسة مدمجة بواسطة واجهات خاصة أو برامج وسيطة مخصصة

بيئة ثلاثية الأبعاد مُدارة مع بيانات تجارية مرفقة وهذه البيانات .(IFC أو COBie التعاون القائم على الملفات وإدارة المكتبة (تنسيقات ملفات مُدارة بواسطة برنامج تخطيط موارد المؤسسة ، مدمجة بواسطة واجهات خاصة أو برامج وسيطة مخصصة

d. Integrated web services (Cloud-based environment) (iBIM)

(البيئة المستندة إلى مجموعة النظراء) خدمات الويب المتكاملة

BIM achieving Lean Principles questions:

أسئلة مختصة في ان BIM يحقق مبادئ Lean

24. Determine your level of agreement of the following BIM functions to achieve Lean Principles:

determine your level of agreement with the following statements حدد مستوى اتفاقك مع العبارات التالية

حدد مستوى موافقتك على وظائف BIM التالية لتحقيق مبادئ Lean

BIM functions and its interaction with Lean Principles وظائف BIM وتفاعلها مع مبادئ Lean	Strongly Disagree أعترض بشدة	Disagree أعترض	Neutral محايد	Agree أوافق	Strongly Agree أوافق بشدة
1. Clash detection function during design phase will eliminate waste in time, money, materials, and efforts. وظيفة الكشف عن الصدام أثناء مرحلة التصميم سوف تقضي على الهدر في الوقت والمال والمواد والجهود					
2. The existence of alternative designs to determine the most appropriate design will eliminate waste in time, money, materials, and efforts.					

وجود تصميمات بديلة لتحديد أنسب تصميم سيؤدي إلى التخلص من النفايات/الهدر في الوقت والمال والمواد والجهود.					
3. Performance simulations for the most efficient energy solution will eliminate waste in time, money, materials, and efforts. تفعيل عملية المحاكاة لطاقة أكثر فعالية سيؤدي إلى التخلص من الهدر في الوقت والمال والمواد والجهود					
4. Visualization of solution that ensures a clear understanding of the model will improve client value (achieving client' requirements) تصور الحل الذي يضمن فهم واضح لنموذج من شأنها تحسين قيمة العميل (تحقيق متطلبات العميل)					
5. Using analysis for the best result will improve client value (achieving client' requirements) استخدام التحليل للحصول على أفضل نتيجة سيؤدي إلى تحسين قيمة العميل (تحقيق متطلبات العميل(					
6. The understanding between client and supplier by use of 3D models and walkthroughs will improve client value (achieving client' requirements) التفاهم بين العميل والمورد عن طريق استخدام النماذج ثلاثية الأبعاد والإرشادات التفصيلية سيحسن من قيمة العميل (تحقيق متطلبات العميل(					
7. Automated generation of changes and material schedules and quantities will improve client value (meet client requirements) سيؤدي التوليد الآلي للتغييرات وجداول المواد وكمياتها (إلى تحسين قيمة العميل (تلبية متطلبات العميل					
8. Provide accurate information to Pre-fabrication (for Pre-cast concrete, etc.) will improve client value (meet client requirements) تقديم معلومات دقيقة لعملية التصنيع المسبق (للخرسانة مسبقة الصب ، إلخ) ستعمل على تحسين قيمة العميل (تلبية متطلبات العميل)					
9. Visualizing of work flow to check for process conflicts (team and tasks) will improve client value (meet client requirements) تصور سير العمل للتحقق من تعارضات العملية (الفريق والمهام) سيؤدي إلى تحسين قيمة العميل (تلبية متطلبات العميل)					
10. Making detailed schedules of tasks and materials delivery times will facilitate the workflow of the project عمل جداول زمنية مفصلة للمهام ومواعيد تسليم المواد سوف يسهل سير العمل في المشروع					
11. Working concurrently on the same design solution by different teams using BIM approach will achieve collaboration and coordination between all project parties العمل في وقت واحد على نموذج التصميم نفسه من قبل فرق مختلفة باستخدام نهج نمذجة معلومات البناء سيحقق التعاون والتنسيق بين جميع أطراف المشروع					

BIM benefits/ drivers:

25. Please select your level of agreement of the following BIM benefits on the Projects:

BIM Drivers/ Benefits فوائد ومحركات تنفيذ نمذجة المعلومات BIM	Strongly Disagree أعترض بشدة	Disagree أعترض	Neutral محايد	Agree أوافق	Strongly Agree أوافق بشدة
1. Cost savings through reduced re-work and RFI's (Requests for Information) توفير في التكاليف من خلال تخفيض إعادة العمل و RFI (طلبات المعلومات)					
2. Improve design quality تحسين جودة التصميم					
3. Accurate construction sequencing دقة تسلسل البناء					
4. Improve built output quality تحسين جودة الانتاج					
5. Improve capacity to provide whole life value to client تحسين القدرة على توفير قيمة كاملة للعميل					
6. Streamline design activities تبسيط أنشطة التصميم					
7. Time savings توفير الوقت					
8. Improve communication to operative تحسين الاتصالات					
9. Facilitate increased pre-fabrication تسهيل زيادة عمليات قبل التصنيع					
10. Design health and safety into the construction process تصميم الصحة والسلامة في عملية البناء					
11. Facilitate facilities management activities تسهيل أنشطة إدارة المرافق					
12. Reduce waste تقليل النفايات/الهدر 13. Smooth and clear flow تدفق سلس وواضح 14. Reduce errors and avoid risks تقليل الأخطاء وتجنب المخاطر 15. Collaborative environment خلق بيئة تعاونية					
16. Increased productivity زيادة الإنتاجية 17. Reduced project costs تقليل تكلفة المشروع 18. Better communication across stakeholders تحسين التواصل بين أصحاب المصلحة 19. Less defective work on site عيوب واخطاء اقل في الموقع 20. Improved site layouts تحسين تخطيطات الموقع					

21. Improved construction and procurement program تحسين برنامج البناء والمشتريات 22. Improved on site health and safety تحسين الصحة والسلامة في الموقع					

BIM challenges/barriers: تحديات او حواجز تواجه تنفيذ نمذجة المعلومات

26. Please select your level of agreement of the following challenges or Barriers of BIM implementation:
يرجى تحديد مستوى موافقتك على التحديات أو عوائق تنفيذ BIM التالية:

BIM Challenges/barriers	Strongly Disagree أعترض بشدة	Disagree أعترض	Neutral محايد	Agree أوافق	Strongly Agree أوافق بشدة
1. Lack of national BIM standard for the industry عدم وجود معيار محلي لنمذجة المعلومات في هذه الصناعة 2. Lack of skilled personnel (e.g. BIM experts) نقص الموظفين المهرة (مثل خبراء BIM) 3. Organisational issues (Process problems, learning curve, lack of senior support ownership) القضايا التنظيمية (مشاكل عملية، ومنحنى التعلم، وعدم وجود ملكية دعم العليا) 4. Legal issues (responsibility for inaccuracies licensing problems, copyright protection for ownership data, privacy etc.) المشكلات القانونية (المسؤولية عن مشاكل عدم دقة الترخيص، وحماية حقوق النشر لبيانات الملكية والخصوصية وما إلى ذلك) 5. Time needed for hiring/training people to use BIM الوقت اللازم لتوظيف / تدريب الناس على استخدام BIM 6. Cost of hiring or training people to use BIM تكلفة توظيف أو تدريب الناس على استخدام BIM 7. Lack of businesses desire to change to BIM processes/ or against change عدم رغبة الشركات في التغيير إلى عمليات BIM / أو ضد التغيير 8. Complexity of BIM system تعقيد نظام BIM 9. Information lost between different software المعلومات المفقودة بين البرامج المختلفة 10. Issues for collaborating with multiple Stakeholders مشاكل في التعاون بين أصحاب المصلحة المتعددين					
11. Risks allocation issues قضايا تخصيص المخاطر					
12. Absence of trust غياب الثقة					
13. Lack of client demand عدم وجود طلب من العميل 14. Cost of investing in software and equipment تكلفة الاستثمار في البرامج والمعدات .					

15. Lack of knowledge about BIM نقص المعرفة حول BIM 16. Misuse of BIM سوء استخدام BIM					

27. Do you think by developing a protocol or a framework utilizing BIM approach that manages and controls the whole lifecycle of a project and minimise waste, will improve the performance of the construction industry (in terms of the time, cost, quality, and productivity) and it will solve the construction problems in Kuwait?

هل تعتقد أن تطوير بروتوكول أو إطار عمل باستخدام نهج نمذجة معلومات البناء الذي يدير ويتحكم في دورة حياة المشروع بأكملها، سوف يحسن أداء صناعة البناء (من حيث الوقت والتكلفة والجودة والإنتاجية) وسيحل مشاكل البناء في الكويت؟

a) YES نعم
b) No لا
c) Maybe/ not sure ربما/لست متأكداً

28. Who do you think should drive the adoption of this BIM-driven Lean Principles protocol/framework?

من برأيك يجب أن يقود اعتماد بروتوكول / إطار مبادئ اللّيْن المرتكز على تطبيق نمذجة معلومات البناء؟

a) Client/government العميل/ الحكومة
b) Consultant الاستشاري
c) Contractor المقاول

29. Any suggestions for improving the performance of the construction industry in Kuwait especially for the government construction projects? (optional)

(أي اقتراحات لتحسين أداء صناعة البناء والتشييد في الكويت خاصة لمشاريع البناء الحكومية؟ (اختياري ....

Appendix 4: Introductory email

Research Ethics Application Form

University of Salford MANCHESTER

APPENDIX 3

Introductory Email (Interview)

To the kind attention of ( )

I am a PhD Student in the School of the Built Environment, at the University of Salford. My research aim is to develop a framework to improve the performance of construction project lifecycle in client organisation in Kuwait through applying LEAN construction principles and BIM technology. It is expected that this process protocol would help to improve the awareness and understanding of individuals and organisational level about adopting Lean Principles and Building Information Modelling and its impact on project performance. The research will focus on the public sector construction projects, as it shows many challenges in terms of cost and time performance. This research is supervised by Dr. xxx xxxx and he can be contacted via xxx. I am therefore sending you this email since I feel your contribution to the study would be of significant value, given your relevant involvement within the topic area.

The contribution would only involve a short interview discussion, which would be strictly anonymous, which will be arranged and held at the most suitable time and date for you.

Please let me know if this is of interest to you, in which case, I will send additional information on the participation, including a Participant Consent Form and Information Sheet, as well as a Draft Interview Guide.

Should you wish to formally accept the collaboration, what I will kindly ask you to do is to let me know by replying to this email. Then I will send you the consent form and participant information sheet. After this, an interview will be arranged at your convenience.

I look forward to hearing from you and thank you for your consideration.

Kind regards,

(---signed---)

Project contact details:

Appendix 5: Participant Consent Form

Research Ethics Application Form

University of Salford MANCHESTER

APPENDIX 4

Participant Consent Form

Title of the Research Study:
Process Protocol for the implementation of BIM-driven Lean Construction Principles in the Kuwaiti Construction Industry: A Client Perspective

Additional Information:
PhD research at the University of Salford

By:

Supervisor:

Please tick the appropriate boxes	**Y**	**N**
1 - Taking Part		
I have read and understood the Project Information Sheet.	☐	☐
I agree to take part in the project. Taking part in the project will include being interviewed and audio-recorded.	☐	☐
I understand that I take part as a volunteer: hence, I can withdraw from the study at any time and I do not have to give any reasons for why I no longer want to be involved.	☐	☐
2 - Use of data in the project		
I understand that my personal details will not be revealed to people outside the project, and my name kept anonymous.	☐	☐
I understand that my words may be quoted in publications, reports, web pages, and other research outputs.	☐	☐

________________________ ________________________ __________
Name of participant [printed] Signature Date

________________________ ________________________ __________
Researcher [printed] Signature Date

Project contact details:

Appendix 6: Interviews questions

Draft Interview Questions

Title of the Research Study:
Process Protocol for the implementation of BIM-driven Lean Construction Principles in the Kuwaiti Construction Industry: A Client Perspective

Additional Information:
- PhD research at the University of Salford

By:

Supervisor:

The Client representatives Questions	
Category	Questions
Questions about phases, deliverables, and participants	1. Before Starting a project or starting a project planning (At the Pre-project phase or Strategic Definition Process) what are the client' responsibilities and who is responsible for what (I mean each department in the client organisation and their responsibilities)? And what are the reports/documents need to be produced in order to proceed to the next phase/ planning phase? 2. Is the design consultant (or any other consultants) involved at this phase? And what are the criteria for selecting a design consultant? 3. Do you think BIM should be considered at this phase? And do you think it should be outsourcing (appointing BIM consultant) or the client organisation should setup a BIM management department or unit within the organisation? 4. What do you think are the responsibilities of BIM management at this early stage? What type of document or report should they produce or prepare? 5. Do you think the type of procurement method (D-B-B or D &B) should be considered at this stage? And by who? 6. Do you think that obtaining Financial approval from the competent authorities should be done at this stage? And what are the requirements or the things that need to be done or produced before obtaining this approval? 7. In the planning phase, what are the client responsibilities? (I mean each department), and what are the reports and documents that needed to be produced before proceeding to the next phase (designing phase)? 8. What are the reports or documents or tasks that need to be prepared by the consultants (design & BIM) to proceed to the next phase? 9. At what phase should the following tasks be conducted (prepare project brief & definition & options appraisal, prepare quality assurance plan, define Facility Management requirements plan, develop final project brief, and setup the project team, prepare brief for specialised projects)? And who is responsible for each one?

	10. In the concept design phase or modelling phase, do you think that collaboration level between different project parties and value-added applications should be done at this stage? And who is responsible for that? The client or the consultant? Or both 11. In this phase, what are types of documents and reports that should be produced and by who? 12. What do you think the BIM consultant/management role should be at this stage? 13. What is the role of a design consultant and what are the documents needed to be produced at this stage by the design consultant? 14. What are the client's organisation responsibilities at this phase? 15. Do you think contract documents should be developed at this phase? Who is responsible for developing and reviewing them? 16. Who do you think should participate to develop Exchange Information Requirements (EIR), BIM Execution Plan (BEP), schematic design, and prepare contract documents, Request for Proposal (RFP) 17. Do you use different type of procurement system (rather than DBB)? And who is responsible for choosing this type and how? What's type of procurement methods do you use? (Design-Bid-Build), (Design & Build) (Management Contracting) 18. What's type of contract do you use in your projects? (lumpsum/ fixed price), (Cost plus) (Target Cost) 19. In the Tendering phase or (Partnering Awarding Phase), what are the processes or tasks that should be done by you (the client organisation)? And what are the documents or reports should be produced? And by who? (e.g. cost & value engineering plan, Advertise BIM tender partnership, prepare project brief implementation report) 20. Who should analyse tender submissions and decide? And who should select suppliers for the project? 21. What do you think of obliging the contractor to assign a BIM architect/ consultant for the project to work with the design team to develop the detailed design for the project? 22. What do you think of the contractor should hire a BIM consultant/Architect immediately after signing the contract? Do you think the client should approve the selection of this consultant? 23. In the Designing phase (detailed design) or (Early BIM partnering phase), what do you think of developing an integrated design by Client's BIM consultant & design consultant with the contractor's BIM management team? What are their responsibilities? And what is the client organisation role at this phase? 24. What are the documents or types of data that need to be prepared or produced at this stage? 25. What are the responsibilities of the Contractor's BIM Architect/Consultant? At this phase 26. What are the client responsibilities at this stage?

	27. What are responsibilities of the client design and BIM consultants at this phase? 28. Who do you think should get building permits from local authorities and at what phase? 29. In the Construction phase, what should be the client and the client's consultants responsibilities? 30. What are the responsibilities of the contractor and their BIM Architect and sub-contractors at this stage? 31. How does the client monitor the progress of the project and perform quality control at this stage? And which department should be responsible for that? 32. Who should be responsible for Quality Assurance and Quality Control of the project? And how? 33. At the Operation and Maintenance (O & M) or Facility Management (FM phase), what are the responsibilities of each project party at this stage? And what are the documents and reports need to be prepared or produced? 34. Do you think it is important to have a feedback loop for each phase to ensure improvements? Why? And who is responsible for it? 35. Do you think it is important to have an archive legacy to evaluate previous projects? (for continuous improvement)? And who is responsible for it?
Question about BIM & Lean Construction	36. What are your requirements for implementing BIM? 37. What are the challenges/problems/ difficulties facing you while requesting or implementing BIM? 38. Do you have BIM training? And who is responsible for this training? 39. How do you minimise waste and add more value for the client? Do you perform Lean construction techniques? Or any waste management approach? If yes at what phase? And what is it? And who is responsible for it?
BIM ISO 19650 terms	40. At what phase do you think the following should be prepared? And by who? a. Information Requirements (OIR, AIR, EIR) i. information requirements at the strategic level (OIR) ii. the information requirements at the operational level (AIR) iii. how it could be specified in the tender specification (EIR) b. Information Delivery (BEP, PIM, AIM) c. Information Exchange across project lifecycle by all project stakeholders
Coordination and Collaboration	41. Do you decide the level of collaboration and coordination between the project parties? If not, who do you think should be responsible for that?
BIM based applications	42. Do you use any BIM applications? If yes, what are they?

The Consultant (Design, PM, BIM) Questions	
Category	Questions
Questions about phases, deliverables, and participants	1. Before Starting a project or starting a project planning (At the Pre-project phase or Strategic Definition Process) what are the client' responsibilities and who is responsible for what (I mean each department in the client organisation and their responsibilities)? And what are the reports/documents need to be produced in order to proceed to the next phase/ planning phase? 2. Do you think BIM should be considered at this phase? And do you think it should be outsourcing (appointing BIM consultant) or the client organisation should setup a BIM management department or unit within their organisation? 3. What do you think are the responsibilities of BIM management at this early stage? What type of document or report should they produce or prepare? 4. Do you think the type of procurement should be considered at this stage? And by who? 5. Do you think that obtaining Financial approval from the competent authorities should be done at this stage? And what are the requirements or the things that need to be done or produced before obtaining this approval? 6. In the planning phase, what are the client responsibilities? and what are the reports and documents that needed to be produced before proceeding to the next phase (designing phase)? 7. What are the reports or documents or tasks that need to be prepared by the consultants (design & BIM) to proceed to the next phase? 8. At what phase should the following tasks be conducted (prepare project brief & definition & options appraisal, prepare quality assurance plan, define Facility Management requirements plan, develop final project brief, and setup the project team, prepare brief for specialised projects)? And who is responsible for each one? 9. In the concept design phase or modelling phase, do you think that collaboration level between different project parties and value-added applications should be done at this stage? And who is responsible for that? The client or the consultant? Or both 10. In this phase, what are types of documents and reports that should be produced and by who? 11. What do you think the BIM consultant/management role should be at this stage? 12. What is the role of a design consultant and what are the documents needed to be produced at this stage by the design consultant? 13. What are the client's organisation responsibilities at this phase? 14. Do you think contract documents should be developed at this phase? Who is responsible for developing and reviewing them?

15. Who do you think should participate to develop Exchange Information Requirements (EIR), BIM Execution Plan (BEP), schematic design, and prepare contract documents, Request for Proposal (RFP)

16. Do you use different type of procurement system (rather than DBB)? And who is responsible for choosing this type and how? What's type of procurement methods do you use? (Design-Bid-Build), (Design & Build) (Management Contracting)
17. What's type of contract do you use in your projects? (lumpsum/ fixed price), (Cost plus) (Target Cost)

18. In the Tendering phase or (Partnering Awarding Phase), what are the processes or tasks that should be done by the consultant? And what are the documents or reports should be produced? And by who? (e.g. cost & value engineering plan, Advertise BIM tender partnership, prepare project brief implementation report)

19. Who should analyse tender submissions and decide? And who should select suppliers for the project?
20. What do you think of obliging the contractor to assign a BIM architect/ consultant for the project to work with the design team to develop the detailed design for the project?
21. What do you think of the contractor should hire a BIM consultant/Architect immediately after signing the contract? Do you think the client should approve the selection of this consultant?
22. What do you think should be the responsibilities of the Contractor's BIM consultant/ Architect?

23. In the Designing phase (detailed design) or (Early BIM partnering phase), what do you think of developing an integrated design by Client's BIM consultant & design consultant with the contractor's BIM management team? What are their responsibilities? And what is your role at this phase?
24. What are the documents or types of data that need to be prepared or produced at this stage?
25. What are the responsibilities of the Contractor's BIM Architect/Consultant? At this phase
26. What do you think are the client responsibilities at this stage?
27. What are responsibilities of the client design and BIM consultants at this phase?
28. Who do you think should get building permits from local authorities and at what phase?
29. In the Construction phase, what should be the client and the client's consultants' responsibilities?
30. What are the responsibilities of the contractor and their BIM Architect and sub-contractors at this stage?
31. How do you monitor the progress of the project and perform quality control at this stage? And which department should be responsible for that?

	32. Who should be responsible for Quality Assurance and Quality Control of the project? And how? 33. At the Operation and Maintenance (O & M) or Facility Management (FM phase), what are the responsibilities of each project party at this stage? And what are the documents and reports need to be prepared or produced? 34. Do you think it is important to have a feedback loop for each phase to ensure improvements? Why? And who is responsible for it? 35. Do you think it is important to have an archive legacy to evaluate previous projects? (for continuous improvement)? And who is responsible for it?
Question about BIM & Lean Construction	36. What are your requirements for implementing BIM? 37. What are the challenges/problems/ difficulties facing you while requesting or implementing BIM? 38. Do you have BIM training? And who is responsible for this training? 39. How do you minimise waste and add more value for the client? Do you perform Lean construction techniques? Or any waste management approach? If yes at what phase? And what is it? And who is responsible for it?
BIM ISO 19650 terms	43. At what phase do you think the following should be prepared? And by who? d. Information Requirements (OIR, AIR, EIR) i. information requirements at the strategic level (OIR) ii. the information requirements at the operational level (AIR) iii. how it could be specified in the tender specification (EIR) e. Information Delivery (BEP, PIM, AIM) f. Information Exchange across project lifecycle by all project stakeholders
Coordination and Collaboration	40. Do you decide the level of collaboration and coordination between the project parties? If not, who do you think should be responsible for that?
BIM based applications	41. What are the applications/ software you use it in each phase? (planning, design, thermal analysis, site inception, site analysis, etc.) 42. What is the level of collaboration for each project phase between project parties? (low, partial, integrated/full)? 43. Do you have BIM standards? What is it? 44. How do you use BIM? 45. What are the requirements of implementing BIM? 46. When should be the training of using BIM? And for who? 47. Who do you think should prepare BIM strategy and at what phase?

The Contractor Questions	
Category	Questions
Questions about phases, deliverables, and participants	1. In the Tendering phase or (Partnering Awarding Phase), What do you think of obliging the contractor to assign a BIM architect/ consultant for the project to work with the design team to develop the detailed design for the project? 2. What do you think of the contractor should hire a BIM consultant/Architect immediately after signing the contract? Do you think the client should approve the selection of this consultant? and at what phase you should hire or assign a BIM consultant? 3. What do you think should be the responsibilities of the Contractor's BIM consultant/ Architect? 4. In the Designing phase (detailed design) or (Early BIM partnering phase), what do you think of developing an integrated design by Client's BIM consultant & design consultant with the contractor's BIM management team? What are their responsibilities? And what is your role at this phase? 5. What are the documents or types of data need to be prepared or produced at this stage? 6. What are the responsibilities of the Contractor's BIM Architect/Consultant? At this phase 7. What do you think are the client responsibilities at this stage? 8. What are responsibilities of the client design and BIM consultants at this phase? 9. Who do you think should get the building permits from local authorities and at what phase? 10. In the Construction phase, what should be the client and the client's consultants responsibilities? 11. What are the responsibilities of the contractor and their BIM Architect and sub-contractors at this stage? 12. How do you monitor the progress of the project and perform quality control at this stage? And which department should be responsible for that? 13. Who should be responsible for Quality Assurance and Quality Control of the project? And how? 14. At the Operation and Maintenance (O & M) or Facility Management (FM phase), what are the responsibilities of each project party at this stage? And what are the documents and reports need to be prepared or produced? 15. Do you think it is important to have a feedback loop for each phase to ensure improvements? Why? And who is responsible for it? 16. Do you think it is important to have an archive legacy to evaluate previous projects? (for continuous improvement)? And who is responsible for it?
Question about BIM & Lean Construction	17. What are your requirements for implementing BIM? 18. How do you prepare for BIM when the client asked you to use BIM? 19. How do you use BIM? 20. What is your opinion about early team involvement?

	21. What are the challenges/problems/ difficulties facing you while implementing BIM? 22. How do you think BIM should be implemented? 23. Do you use any prefabricated units? Or precast concrete? 24. How do you minimise waste and add more value for the client? Do you use Lean construction techniques? Or any waste management approach?
Coordination and Collaboration	25. Do you decide the level of collaboration and coordination between the project parties? If not, who do you think should be responsible for that?
BIM based applications	26. What are the applications/ software you use it in each phase? (planning, design, thermal analysis, site inception, site analysis, etc.) 27. What is the level of collaboration for each project phase between project parties? (low, partial, integrated/full)? 28. Do you have BIM standards? What is it? 29. How do you use BIM? 30. What are the requirements of implementing BIM? 31. When should be the training of using BIM? And for who? 32. Who do you think should prepare BIM strategy and at what phase?

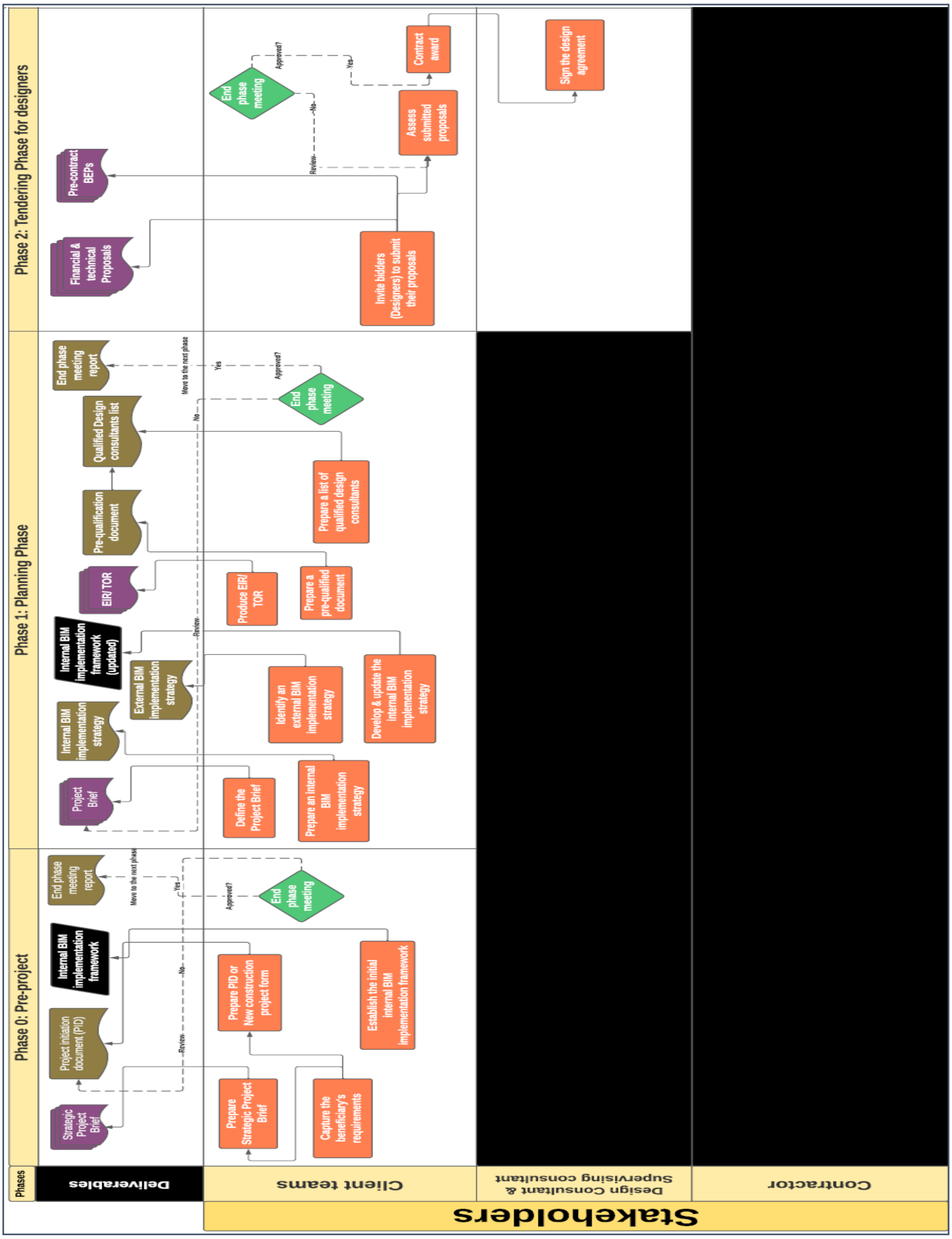
Appendix 7: Feedback template for validation

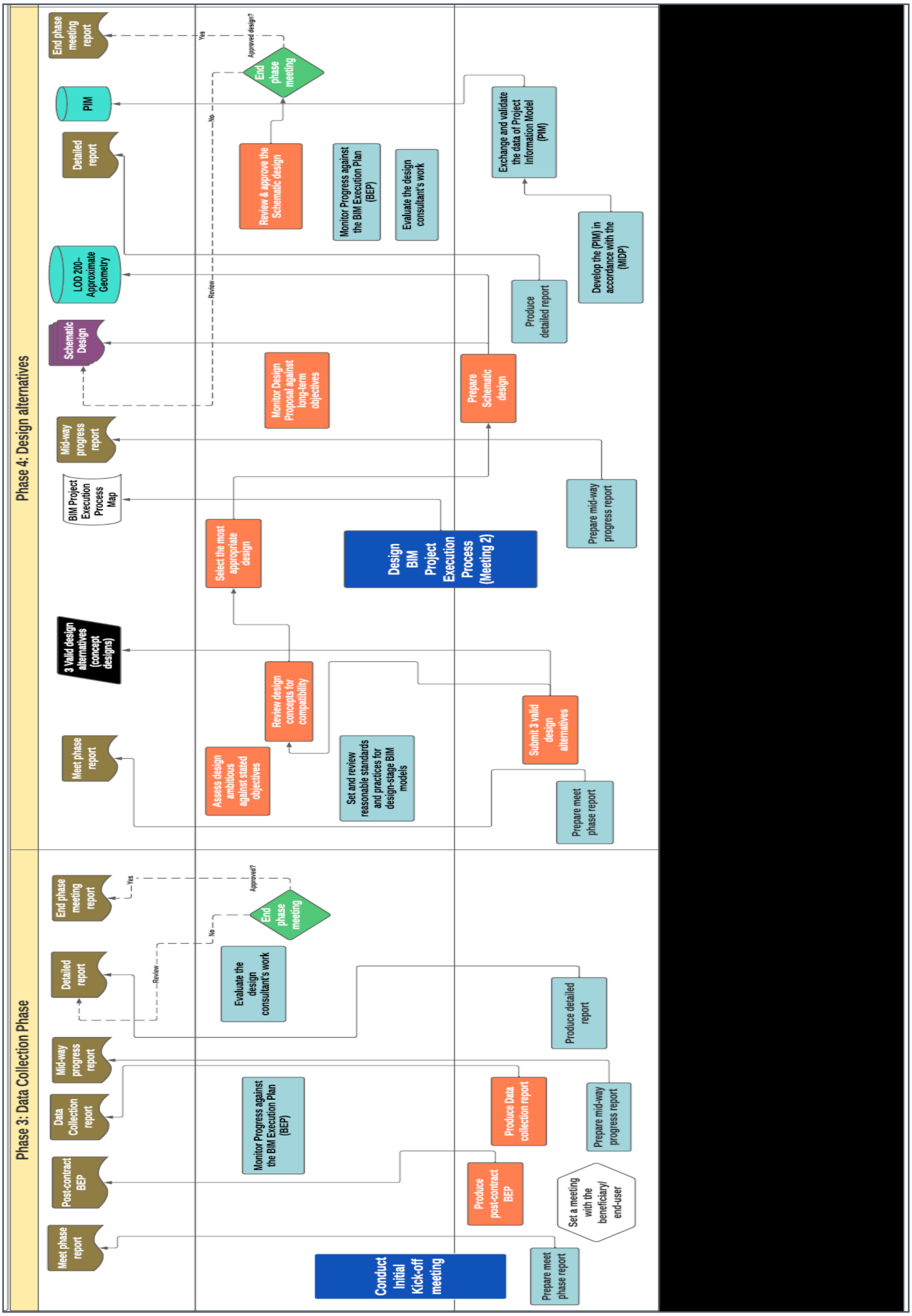
Feedback template for the interviewee:

Level of agreement to the following statements						
Category	Statements (Please tick where necessary)	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Correctness	The 4 parts of the framework (What, how, who, and when) provide a complete framework for drafting a process protocol. توفر الأجزاء الأربعة للإطار (ماذا وكيف ومن ومتى) إطارًا كاملاً لصياغة بروتوكول العملية					
Completeness	The framework/ Process Protocol covers the essential requirements of BIM implementation and Lean construction. يغطي بروتوكول الإطار / العملية المتطلبات الأساسية لتنفيذ نمذجة معلومات البناء (بيم) والبناء الخالي من الهدر.					
Simplicity	Implementing BIM within the framework is convenient for its simplicity when presented to the client organisation. يعد تنفيذ نمذجة معلومات البناء (بيم) في إطار العمل مناسبًا لبساطته عند تقديمه إلى منظمة العميل					
Statements (Please tick where necessary)		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Flexibility	The Process Protocol/ framework should fit perfectly with any public organisation in Kuwait and not in a specific sector. يجب أن يتلاءم بروتوكول / إطار العمل تمامًا مع أي منظمة عميلة في الكويت وليس في قطاع معين					
Understanding	The presented Process Protocol was easy to understand and demonstrated the implementation of BIM for the client organization. كان بروتوكول العملية المقدم سهل الفهم وأظهر تنفيذ نمذجة معلومات البناء (بيم) للمنظمة العميلة					
Overall Quality	The proposed Process Protocol will meet the client organisation's vision for the implementation of BIM. سيلبي بروتوكول العملية المقترح رؤية المؤسسة العميلة لتنفيذ نمذجة معلومات البناء (بيم)					
Overall feedback	The Process Protocol meets your expectations in the BIM implementation and Lean Construction. يلبي بروتوكول العملية توقعاتك في تنفيذ نمذجة معلومات البناء (بيم) والبناء الخالي من الهدر					
	Client organisation will benefit from this Process Protocol. ستستفيد منظمة العميل من بروتوكول العملية هذا.					

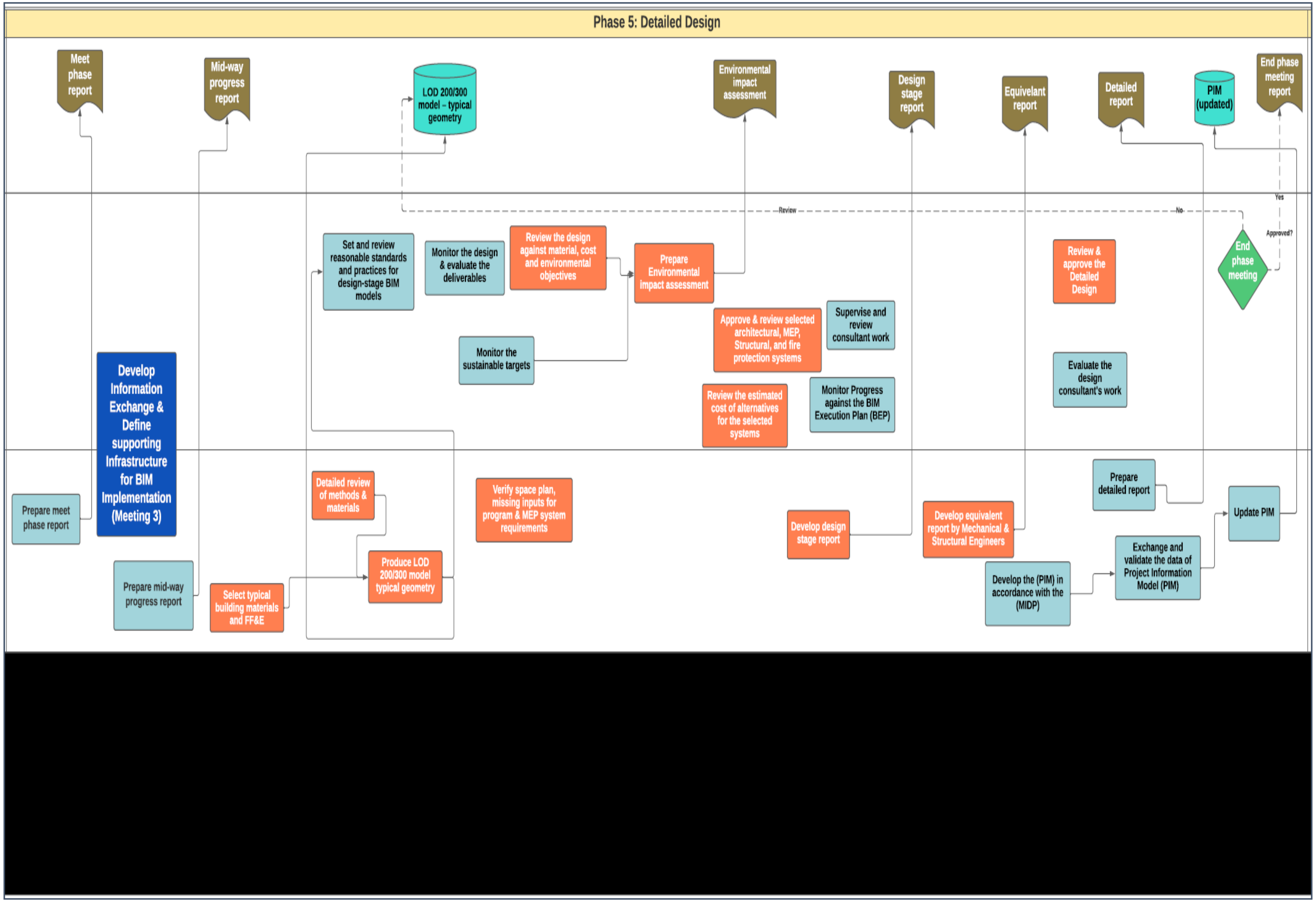
	The Performance levels within the client organisation could be improved and reflected positively by introducing the framework to them. يمكن تحسين مستويات الأداء داخل المؤسسة العميلة وعكسها بشكل إيجابي من خلال تقديم إطار العمل لهم.					
Further comments	Do you have any further comments to add? هل لديك أي تعليقات أخرى لتضيفها؟	YES			NO	
	If yes then what are they? إذا كانت الإجابة بنعم فما هي؟					

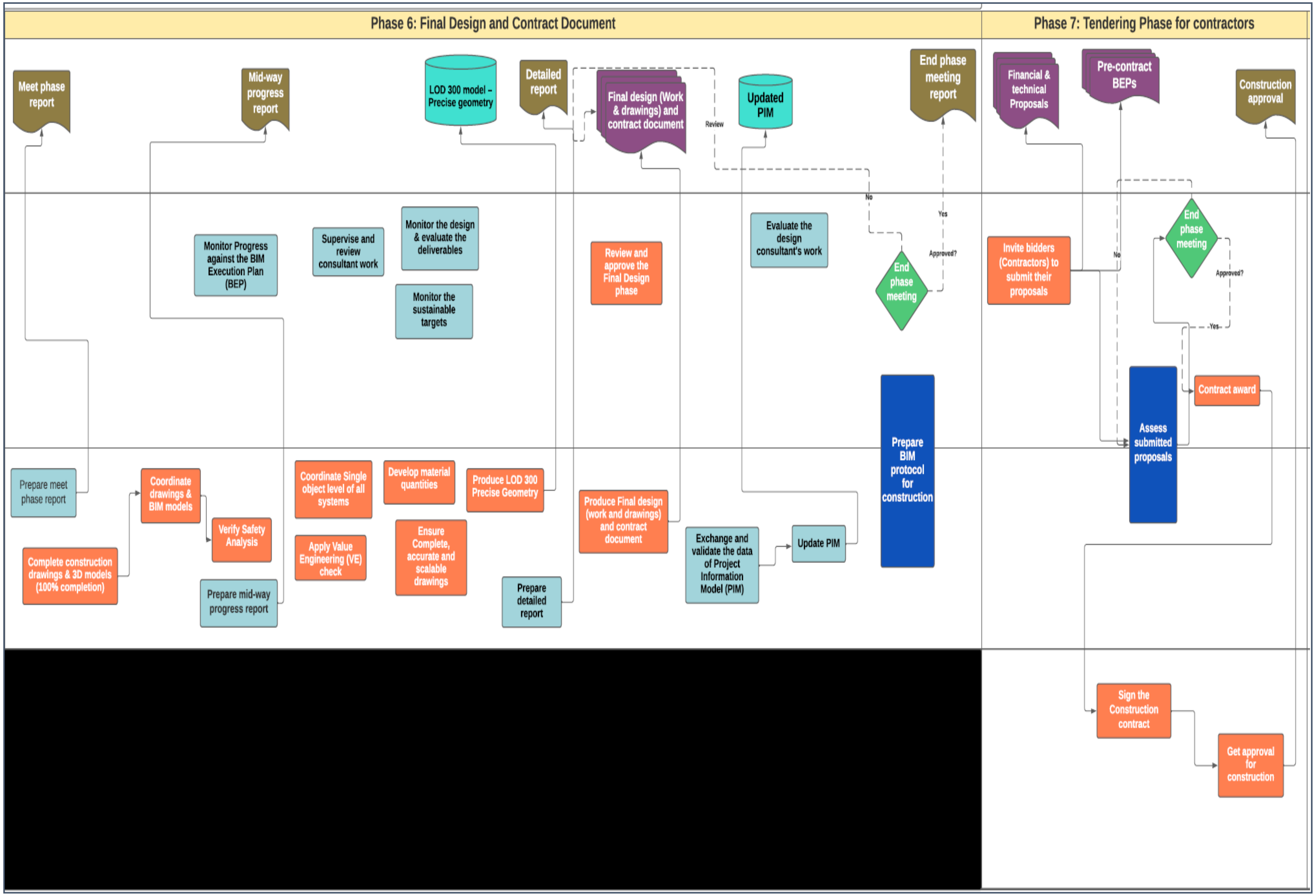
Appendix 8: Final BIM and Lean Construction Process Protocol



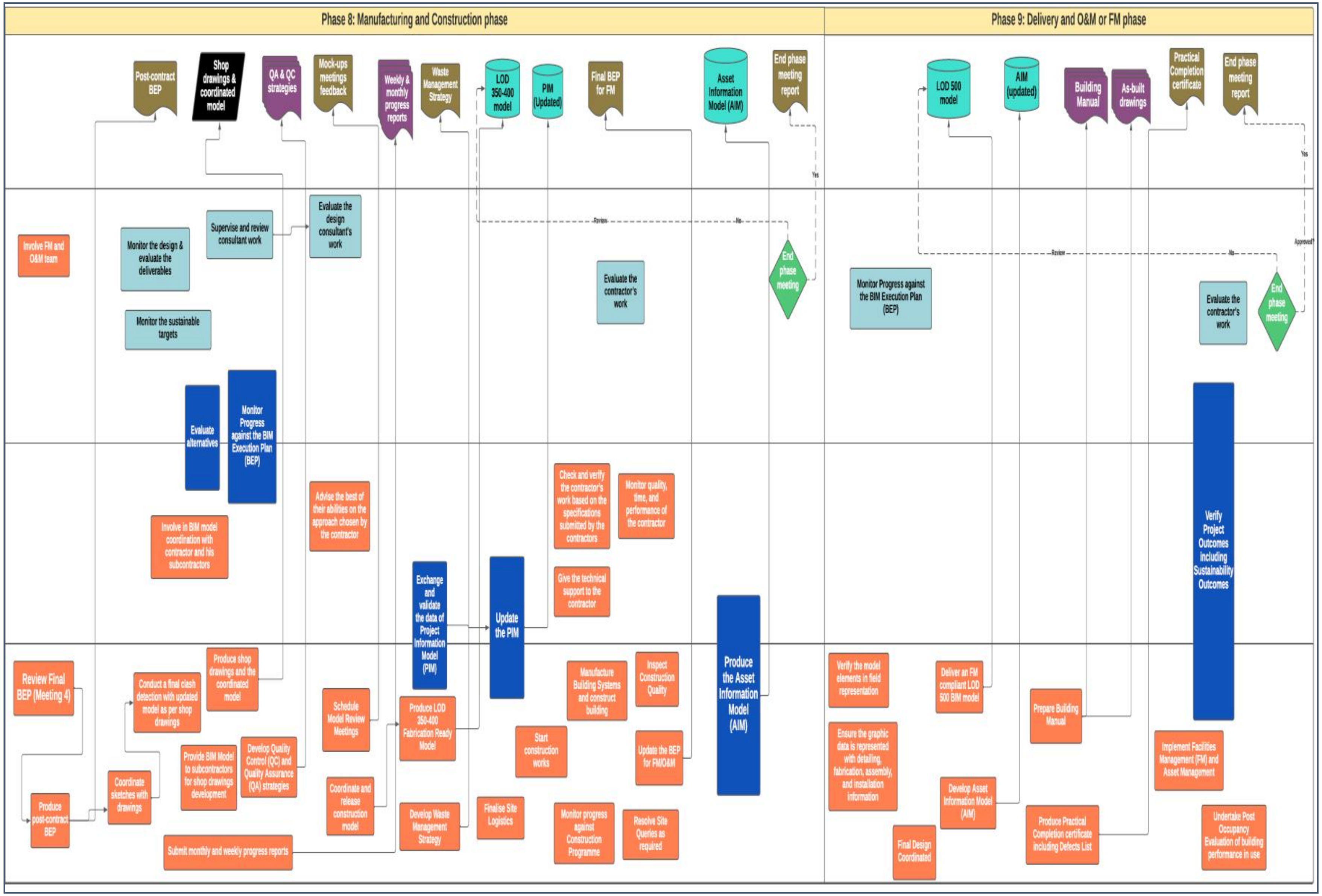


Phase 3: Data Collection Phase
Meet phase report
Post-contract BEP
Data Collection report
Mid-way progress report
Detailed report
End phase meeting report
Conduct Initial Kick-off meeting
Monitor Progress against the BIM Execution Plan (BEP)
Evaluate the design consultant's work
End phase meeting
Approved?
Yes
No
Review
Produce post-contract BEP
Produce Data collection report
Produce detailed report
Set a meeting with the beneficiary/ end-user
Prepare meet phase report
Prepare mid-way progress report
Phase 4: Design alternatives
Meet phase report
3 Valid design alternatives (concept designs)
BIM Project Execution Process Map
Mid-way progress report
Schematic Design
LOD 200- Approximate Geometry
Detailed report
PIM
End phase meeting report
Assess design ambitious against stated objectives
Review design concepts for compatibility
Select the most appropriate design
Monitor Design Proposal against long-term objectives
Review & approve the Schematic design
End phase meeting
Approved design?
Yes
No
Review
Set and review reasonable standards for design-stage BIM models
Design BIM Project Execution Process (Meeting 2)
Monitor Progress against the BIM Execution Plan (BEP)
Evaluate the design consultant's work
Prepare meet phase report
Submit 3 valid design alternatives
Prepare mid-way progress report
Prepare Schematic design
Produce detailed report
Develop the (PIM) in accordance with the (MIDP)
Exchange and validate the data of Project Information Model (PIM)


Phase 5: Detailed Design
Meet phase report
Mid-way progress report
LOD 200/300 model – typical geometry
Environmental impact assessment
Design stage report
Equivelant report
Detailed report
PIM (updated)
End phase meeting report
Review
No
Yes
Approved?
Set and review reasonable standards and practices for design-stage BIM models
Monitor the design & evaluate the deliverables
Review the design against material, cost and environmental objectives
Prepare Environmental impact assessment
Monitor the sustainable targets
Approve & review selected architectural, MEP, Structural, and fire protection systems
Supervise and review consultant work
Review the estimated cost of alternatives for the selected systems
Monitor Progress against the BIM Execution Plan (BEP)
Review & approve the Detailed Design
Evaluate the design consultant's work
End phase meeting
Develop Information Exchange & Define supporting Infrastructure for BIM Implementation (Meeting 3)
Prepare meet phase report
Prepare mid-way progress report
Select typical building materials and FF&E
Detailed review of methods & materials
Produce LOD 200/300 model typical geometry
Verify space plan, missing inputs for program & MEP system requirements
Develop design stage report
Develop equivalent report by Mechanical & Structural Engineers
Develop the (PIM) in accordance with the (MIDP)
Prepare detailed report
Exchange and validate the data of Project Information Model (PIM)
Update PIM
[redacted]



Phase 6: Final Design and Contract Document
Phase 7: Tendering Phase for contractors
Meet phase report
Mid-way progress report
LOD 300 model – Precise geometry
Detailed report
Final design (Work & drawings) and contract document
Review
Updated PIM
End phase meeting report
Financial & technical Proposals
Pre-contract BEPs
Construction approval
Monitor Progress against the BIM Execution Plan (BEP)
Supervise and review consultant work
Monitor the design & evaluate the deliverables
Monitor the sustainable targets
Review and approve the Final Design phase
Evaluate the design consultant's work
No
Yes
Approved?
End phase meeting
Invite bidders (Contractors) to submit their proposals
Yes
Contract award
Assess submitted proposals
Prepare BIM protocol for construction
Prepare meet phase report
Complete construction drawings & 3D models (100% completion)
Coordinate drawings & BIM models
Verify Safety Analysis
Prepare mid-way progress report
Coordinate Single object level of all systems
Apply Value Engineering (VE) check
Develop material quantities
Ensure Complete, accurate and scalable drawings
Produce LOD 300 Precise Geometry
Prepare detailed report
Produce Final design (work and drawings) and contract document
Exchange and validate the data of Project Information Model (PIM)
Update PIM
Sign the Construction contract
Get approval for construction


Phase 8: Manufacturing and Construction phase
Phase 9: Delivery and O&M or FM phase
Post-contract BEP
Shop drawings & coordinated model
QA & QC strategies
Mock-ups meetings feedback
Weekly & monthly progress reports
Waste Management Strategy
LOD 350-400 model
PIM (Updated)
Final BEP for FM
Asset Information Model (AIM)
End phase meeting report
Involve FM and O&M team
Monitor the design & evaluate the deliverables
Supervise and review consultant work
Evaluate the design consultant's work
Monitor the sustainable targets
Evaluate the contractor's work
End phase meeting
Review
No
Yes
Evaluate alternatives
Monitor Progress against the BIM Execution Plan (BEP)
Involve in BIM model coordination with contractor and his subcontractors
Advise the best of their abilities on the approach chosen by the contractor
Exchange and validate the data of Project Information Model (PIM)
Update the PIM
Check and verify the contractor's work based on the specifications submitted by the contractors
Monitor quality, time, and performance of the contractor
Give the technical support to the contractor
Produce the Asset Information Model (AIM)
Review Final BEP (Meeting 4)
Produce post-contract BEP
Coordinate sketches with drawings
Conduct a final clash detection with updated model as per shop drawings
Produce shop drawings and the coordinated model
Provide BIM Model to subcontractors for shop drawings development
Develop Quality Control (QC) and Quality Assurance (QA) strategies
Submit monthly and weekly progress reports
Schedule Model Review Meetings
Coordinate and release construction model
Produce LOD 350-400 Fabrication Ready Model
Develop Waste Management Strategy
Finalise Site Logistics
Start construction works
Manufacture Building Systems and construct building
Inspect Construction Quality
Update the BEP for FM/O&M
Monitor progress against Construction Programme
Resolve Site Queries as required
LOD 500 model
AIM (updated)
Building Manual
As-built drawings
Practical Completion certificate
End phase meeting report
Approved?
Monitor Progress against the BIM Execution Plan (BEP)
Evaluate the contractor's work
End phase meeting
Verify Project Outcomes including Sustainability Outcomes
Verify the model elements in field representation
Ensure the graphic data is represented with detailing, fabrication, assembly, and installation information
Deliver an FM compliant LOD 500 BIM model
Final Design Coordinated
Develop Asset Information Model (AIM)
Prepare Building Manual
Produce Practical Completion certificate including Defects List
Implement Facilities Management (FM) and Asset Management
Undertake Post Occupancy Evaluation of building performance in use