CONCEPTUAL PROCUREMENT FRAMEWORK FOR BUILDING INFORMATION MODELLING UPTAKE TO ENHANCE BUILDINGS’ SUSTAINABILITY PERFORMANCE IN THE JORDANIAN PUBLIC SECTOR

By

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ABSTRACT

Jordan faces a variety of challenges, because of the lack of natural resources such as oil and water, and then combined with its rapid urbanisation and a significantly growing population due to cultural, economic and political reasons such as recurring forced immigration from neighbouring countries over the past 69 years. It imports 96.5% of its energy needs, equal to 83% of the total export gains. Buildings have been recognised as a significant consumer of natural resources as it represents nearly 70%, of the construction work in Jordan and accounts for 33% of the total energy consumption in the country. Public building projects in Jordan are vital to the building sector as the government is the major client and key mover for the construction buildings sector. However, a large portion of the public building projects in Jordan suffers from sustainability performance issues. Therefore, greening the public sector building becomes a key target and favourable option for the government.

Many studies have identified Building Information Modeling as one of the most promising approaches in terms of facilitating sustainable solutions and meeting the global need for sustainable buildings. The regulatory frameworks and in particular procurement approaches have been identified as a significant factor of the success of BIM implementation on building projects. However, there have been no precedent studies on BIM and the effect of procurement approaches on BIM uptake in the Jordanian context and typology of public building projects. Therefore, this research aims to develop a procurement framework to encourage the implementation of BIM in the Jordanian public sector for better sustainable building performance. In order to achieve the aim, this research firstly conducted a systematic literature review to investigate the importance of delivering sustainable public building projects in Jordan. Then, an investigation on the impact of adopting BIM on the design and delivery of sustainable building projects, and the impact of public procurement approaches on the uptake of BIM and delivery of sustainable buildings were undertaken. Subsequently, questionnaires and semi-structured interviews were distributed and conducted to investigate the current practice and common issues regarding BIM implementation in the Jordanian public building sector and the impact of the currently adopted procurement approaches on BIM implementation. Finally, a BIM-friendly procurement framework was developed based on the findings and was validated through semi-structured interviews with tender managers, project managers, BIM managers and construction managers working in the public building sector in Jordan.

This study has confirmed the need for BIM implementation in the public building sector in Jordan because of the several potential benefits including sustainability enhancement of new building projects. This study also found that procurement approaches have a significant impact on BIM

implementation and sustainability outcomes in the Jordanian public building sector in which more integrated procurement approaches have further potential for effective BIM implementation to achieve sustainable buildings. However, changing the traditional procurement approach for a collaborative one would be faced with many legal, cultural and technical issues. Therefore, the developed procurement framework was based on the traditional procurement approach. This framework aims to provide several solutions to overcome the barriers associated with the traditional procurement approach, and it facilitates the implementation of BIM, thus enhancing the sustainability performance of the new Jordanian public buildings. Finally, the procurement framework was validated as suitable and a good stepping stone towards better BIM implementation and achieving sustainability.

The content of this research should be of interest to public clients, and their consultants and contractors dealing with procurement and BIM implementation issues. It should also be of interest to researchers in the field as it provides a basis for future research and fills a knowledge gap in the area of BIM implementation and procurement issues to enhance the buildings' sustainability performance in the Jordanian public sector.

DECLARATION

Whilst registered as a candidate for the above degree, I have not been registered for any other research award. The results and conclusions embodied in this thesis are the work of the named candidate and have not been submitted for any other academic award.

Mohammad Alhusban

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In The Name Of God, the Most Gracious, the Most Merciful, the Lord of the worlds; and prayers and peace be upon Mohammad His servant and messenger.

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ACRONYMS AND ABBREVIATIONS

2D	Two-Dimensional
3D	Three-Dimensional
ACIF	Australian Construction Industry Forum
AEC	Architecture, Engineering And Construction Industry
AIA	American Institute Of Architects
ANME	Association Of Network Managers In Education
APCC	Australasian Procurement And Construction Council
Aps	Accredited Professionals
ARCOM	Association Of Researchers In Construction Management
BEAM	Building Environmental Assessment Method
BEP/ BxP	BIM Execution Plan
BIM	Building Information Modelling
BREEAM	Building Research Establishment's Environmental Assessment Method
BSI	British Standards Institution
CCD	Companies Control Department
CDE	Common Data Environment
CIB	Conseil International Du Bâtiment" (International Council For Building)
CIC	Construction Industry Council
CIFE	Centre For Integrated Facilities Engineering
CLP	Cost Led Procurement
CM	Construction Management
CMR	Construction Management At Risk
CO2	Carbon Dioxide
CPIM	Construction Process Improvement Methodology
CRC	Cooperative Research Centre
CURT	Construction Users Roundtable
DB	Design and Build
DBB	Design-Bid-Build
DETR	Department Of The Environment, Transport And The Regions
DRIVE	Define, Review, Identify, Verify And Execute
DSFEM	Development Strategy Formulation And Evaluation Methodology

DSS	Development Strategy Simulator
EBP	Early BIM Partnering
ECI	Early Contractor Involvement
ECTP	European Construction Technology Platform
EIR	Employer’s Information Requirement
FES	Friedrich-Ebert-Stiftung
FFEM	French Facility For Global Environment
FFWA	Federal Highway Administration
FIDIC	The International Federation Of Consulting Engineers (Fédération Internationale Des Ingénieurs-Conseils)
FTA	Free Trade Agreements
GCC	Gulf Cooperation Council
GCEP	General Corporation For Environmental Protection
GCS	Government Construction Strategy
GDP	Gross Domestic Product
GSA	General Services Administration
GSL	Government Soft Landings
GTD	Government Tenders Department
HoD	Head Of Department
HVAC	Heating, Ventilation, And Air Conditioning
ICAEN	Instituto Catalán De Energía
IFC	Industry Foundation Classes
IISD	International Institute For Sustainable Development
ISO	International Organization for Standardization
IPD	Integrated Project Delivery
IPI	Integrated Project Insurance
ISO	International Organization For Standardization
ITP	Inception Testing Procedure
JCCA	Jordanian Construction Contractors Association
JCI	Jordanian Construction Industry
JEA	Jordan Engineering Association
JREEEF	Jordan Renewable Energy & Energy Efficiency Fund
LACCD	The Los Angeles Community College District

LCC	Life Cycle Costing
LEED	Leadership In Energy And Environmental Design
LOD	Level Of Model Development
LOI	Level Of Information
MDGs	Millennium Development Goals
MEMR	Ministry Of Energy And Mineral Resources
MIDP	Master Information Delivery Plan
MMRAE	Ministry Of Municipal And Rural Affairs And Environment
MOE	Ministry Of Education
MOH	Ministry Of Health
Moict	Ministry Of Information, Communications And Technology
MOT	Ministry Of Transport
MOWI-WAK	Ministry Of Water And Irrigation
MPWH	Ministry Of Public Works And Housing
MWI	Ministry Of Water And Irrigation
NASA	The National Aeronautics And Space Administration
NBIMS	National BIM Standard
NBS	National Building Specification
NEAP	National Environmental Action Plan
NEP	National Executive Programme
NRC	National Research Council
NSDS	National Sustainable Development Strategy
PA	Project Alliancing
PAS	Publicly Available Specification
PCSA	Pre-Construction Services Agreement
PIP	Project Information Plan
PM	Project Manager
PS	Project Sponsor
RIBA	Royal Institute Of British Architects
ROI	Return On Investment
RSSJ	Royal Scientific Society Of Jordan
SBD	Sustainable Building Design
SDGs	Sustainable Development Goals

SMEs	Small And Medium-Sized Enterprises
TIDPs	Task Information Delivery Plans
TPA	The Port Authority
UKSDS	United Kingdom Sustainable Development Strategy
UN	United Nations
UNCSD	The United Nations Conference On Sustainable Development
UNDESA	United Nations Department Of Economic And Social Affairs
UNDG	United Nation Development Group
UNEP	United Nations Environment Programme
UNESCO	The United Nations Educational, Scientific And Cultural Organization
UNGASS	Un General Assembly Special Session
VNR	Voluntary National Review
WACOSS	Western Australia Council Of Social Services
WCED	World Commission On Environment And Development
WSSD	World Summit On Sustainable Development
WTO	World Trade Organization

LIST OF PUBLICATIONS

- Alhusban M., Al-Bizri S., Danso-Amoako M., Gaterell M. (2017). Building Information Modelling in the Public Sector in Jordan: An Exploration study. Journal of Civil Engineering and Architecture Research, Vol.4, No.5.
- Alhusban M., Al-Bizri S., Danso-Amoako M., Gaterell M. (2017) Procurement Route and Building Information Modelling (BIM) Implementation Effect on Sustainable Higher Education Refurbishment Projects. In: Dastbaz M., Gorse C., Moncaster A. (eds) Building Information Modelling, Building Performance, Design and Smart Construction. Springer, Cham.
- Alhusban M., Al-Bizri S. (2017). Procurement route and Building Information Modelling (BIM) implementation effect on achieving sustainable buildings in developing countries: a case study of Jordan. The Seventh Jordanian International Civil Engineering Conference (JICEC07)9-11 May 2017, Jordan Engineering Association.
- Alhusban M, Al-bizri S, Danso-Amoako M and Gaterall M (2016) Procurement route and building information modelling (BIM) implementation effect on sustainable higher education refurbishment projects In; Gorse C and Dastbaz M (Eds) International SEEDS Conference, 14-15 September 2016, Leeds Beckett University, UK, Sustainable Ecological Engineering Design for Society.

CHAPTER 1: INTRODUCTION

1.1 RESEARCH BACKGROUND

Current concerns about energy consumption, natural resources, increasing oil prices and other factors affecting the global environment have led to increasing pressure for all new developments to be sustainable. Issues pertaining to global warming and carbon emissions make sustainability a priority. Thus, sustainable development is now a field of evolving research (Sheth, 2011).

The construction industry has been widely recognised for its significant contribution to Jordan's socio-economic development and as being a major consumer of energy and natural resources. Buildings, in particular, have a substantial impact on the global environment. The building sector has been described as an energy intensive and profligate industry. Globally, 45% of the world's energy and 50% of the water are used in building construction (Willmott Dixon, 2010). Therefore, buildings are critical in delivering sustainable developments, which are important to everyone's quality of life (Burgan & Sansom, 2006; Morrell, 2010).

Building Information Modelling (BIM) has been identified as one of the most promising solutions in terms of improving sustainability and meeting the global need for sustainable buildings (Kumanayake and Bandara, 2012). This is due its ability to support the supply, management and integration of much-needed information throughout the lifecycle of a building (Häkkinen and Kiviniemi, 2008). BIM's sustainable solutions have started recently to realise their potential as the demand for both BIM and sustainability is increasing annually (Bynum, Issa & Olbina, 2013). Practitioners believe that BIM can achieve sustainable building outcomes more efficiently than non-BIM approaches (McGraw-Hill, 2010a), and that such benefits accrue in building projects across the globe. Mihindu and Arayici (2008) have reported that many pilots and live projects completed and documented in Finland, Sweden, Norway, Germany, France, Singapore and Australia demonstrate that BIM has a better outcome in terms of constructing sustainable buildings compared to non-BIM approaches.

The public sector has a primary role in BIM adoption (Cheng, 2015; Wong, Wong & Nadeem, 2009). Many countries around the globe have realised the vital role of the public authorities in promoting BIM, such as in the United States (US), Australia and the United

Kingdom (UK) (Won, 2013). Porwal and Hewage (2013) stated that the public sector has a pivotal role in initiating and driving BIM implementation. Cheng and Lu (2015) argued that the public sector should not only initiate and drive BIM implementation, but it should also act as a regulator. Therefore, governments in the US (Wong et al., 2009), Australia (BuildingSMART, 2012) and the UK (HM Government, 2012) have set a mandate and certain implementation strategies for the use of BIM in public construction projects.

Many studies have indicated that regulatory frameworks and, in particular, procurement approaches have a major impact on the success of BIM implementation in building projects (Holzer, 2015). This is because BIM is a collaborative platform; thus, deriving the maximum benefit from its implementation requires a collaborative environment within all the different parties involved. Clients are, therefore, likely to change the way that they procure buildings when implementing BIM to ensure a more integrated and collaborative working process (Foulkes, 2012). Different procurement approaches can achieve different collaboration levels by establishing the relationships between the involved parties and the tasks involved, which are connected to the building lifecycle (Laishram, 2011). This has led many governments around the world in countries such as the UK and Australia to require the deployment of collaborative procurement approaches (GCS, 2016), or the development of a new procurement approach for BIM implementation (Porwal and Hewage, 2013). On the other hand, developing a procurement approach for BIM implementation needs to be investigated in a specific context and certain typology of building project (Sebastian, 2011a).

1.2 STATEMENT OF PROBLEM

The geographic focus of this research is Jordan, which faces a variety of sustainability challenges shared with other developing countries, especially in the Middle East, such as increased levels of pollution and energy concerns (Ali and Al Nsairat, 2009). Jordan lacks natural resources, combined with a significantly growing population (MWI, 2016). Moreover, Jordan represents a different case from other countries in the Middle East as it is a non-oil producing country, and it imports 96.5% of its energy needs from neighbouring countries (MEMR, 2012). This consumes a considerable portion of the state’s annual budget, which is equal to 83% of the total export gains (ibid). Therefore, sustainability issues are of paramount importance for the future of Jordan

The Jordanian construction industry is the largest sector in the country, and it has been widely recognised as a significant consumer of energy and natural resources, and as making a considerable contribution to the socio-economic development (Dana, 2015). It contributes nearly 15% of the Jordanian economy to the Jordanian Gross Domestic Product (GDP) (JCCA, 2015). Buildings represent a large portion of the construction work in Jordan with nearly 70% of the total value (see Table 1.1).

Table 1.1: Type of construction work in Jordan (JCCA, 2015)

Type	Value (JD m)	Percentage
Buildings	514.5	70%
Electro-mechanical	83.02	11.2%
Roads	39.3	5.3%
Water supply and waste water	58.9	8%
Others	40.9	5.5%
Total	736.62	100%

Moreover, there is a high demand for buildings in Jordan, which makes it the fastest growing sector in the country. This is due to many trends such as the high rate of population growth on account of waves of recurring forced immigration from neighbouring countries over the past 69 years. According to the last national census conducted in November 2015, the total population in Jordan is 9.523 million. From this, Jordanian nationals equal to 6.6 million while around 2.9 million comprise the non-Jordanians who reside in the country (Ghazal, 2016). Moreover, rapid urbanisation has resulted in approximately 80% of the general population residing in urban areas, and 70% of this population living within 30 km of the capital, Amman (Kisbi, 2011). These issues have placed a large burden on the public buildings and built environment in Jordan.

The importance of the building sector comes from the fact that it accounts for 33% of the final energy consumption in Jordan (UNEP, 2007), and that it consumes a significant amount of the available water in a country that is considered to be one of the world's most water-stressed countries (Kisbi, 2011). Greening the building sector becomes a key target and favourable option (RSSJ and FES, 2013). However, raising awareness on energy and water consumption has been the main focus with regard to resource efficiency in Jordan. These are minor measures unless they are complemented by sustainable design practices and approaches throughout the buildings' lifecycle (RSSJ and FES, 2013; Reed, Fraser and Dougill, 2006).

Public buildings in Jordan are of utmost importance to the building sector. This is because the government in Jordan has always been "the major client for most important construction works that represent the major part of expenditure in the construction work" (Awni, 1983), and it is one of the Jordanian Construction Industry (JCI) key movers (Haddadin, 2014). Additionally, Jordan is primarily a service economy with a significant dependence on the public sector. However, a large portion of the public building projects suffer from sustainability performance issues (FFEM and ANME, 2010).

Despite the recognised potential of the BIM contribution on delivering sustainable buildings, very little research has been undertaken on BIM in Jordan (Al Awad, 2015; Matarneh, 2017). The first academic research study on BIM in the Jordanian context was by Al Awad (2015) on 'the uptake of advanced IT with specific emphasis on BIM by SMEs in the Jordanian Construction Industry'. He concluded that BIM is virtually non-existent in Jordan. Following this research, Matarneh (2017) conducted a study to identify certain BIM experiences, including the perceived benefits, values and challenges to BIM adoption and implementation in the construction industry in Jordan. The findings of her research revealed that in Jordan, BIM implementation is in its infancy. The crucial role of the public sector in Jordan and the public sector role in BIM implementation was not the focus in any of the above studies. This also shows the absence of research on the regularity frameworks (procurement approaches) and their effect on BIM implementation in the public sector in Jordan. There is, therefore, a need to explore the current BIM theory and regularity frameworks (procurement approaches) in the public building sector in Jordan.

1.3 RESEARCH MOTIVATION

The following describes the main motivation for conducting this research:

1. The preconstruction stage has been the focus of previous research in the field of delivering sustainable buildings, such as building design regulations, sustainable building design (SBD) and the tools for building sustainable assessments (Hama and Greenwood, 2009; Zanni, 2017; Bossink, 2007, Labuschagne and Brent, 2005; Wang, Chang and Nunn, 2010). However, in the last ten years, researchers have begun to investigate the delivery

of sustainable buildings through project management systems, which demonstrates a lack of studies in this area.

2. The government in Jordan was the first in the Middle East to take the BIM oath. This was through signing an agreement in 2011 between the Ministry of Public Works and Housing (MPWH) and the Jordan Engineering Association (JEA) with 'BuildingSMART' and 'the BIM Journal' to establish a BuildingSMART Forum in Jordan and to promote BIM adoption and implementation (Middle East Construction News, 2011). However, since signing the agreement, few studies have been conducted on BIM adoption and implementation in Jordan (Al Awad, 2015; Matarneh, 2017), with no precedent studies on BIM adoption and implementation in the public sector in Jordan.

3. Many researchers have identified the current procurement approaches as a challenge for BIM implementation (Becerik-Gerber and Kensek, 2010; Bolpagni, 2013; Sackey, Tuuli & Dainty, 2015). However, the literature is divided between two standpoints to overcome this challenge. The first position is that there is a need for profound changes in the adopted procurement approaches for BIM implementation, particularly to create the required collaborative environment to bring multiple stakeholders together over the project lifecycle (Foulkes, 2012; Volk, Stengel & Schultmann, 2014; Pcholakis, 2010; Laishram, 2011). Therefore, it is argued that clients should change the way they procure buildings when implementing BIM to ensure a fully integrated, collaborative BIM-enabled work process (Foulkes, 2012). The second argument is that the profound changes and radical transformation of the construction industry for BIM-enabled working practices are a challenging task (Howard and Bjork, 2008). Instead, researchers recommend developing a procurement framework that synchronises BIM implementation with the current work processes (Kim, 2014; London, Singh, Taylor, Gu & Brankovic, 2008; Porwal and Hewage, 2013). These viewpoints highlight the importance of investigating the current procurement approaches fitness for effective BIM implementation in a specific context and certain typology of building project (Sebastian, 2011a), and how to overcome this challenge. Therefore, the next section highlights the aim and objectives for this study trying to fill these gaps.

1.4 RESEARCH AIM AND OBJECTIVES

The overarching aim of this research is to develop a procurement framework to enhance the implementation of BIM in the Jordanian public sector for better sustainable building performance.

To satisfy this aim, the following objectives are pursued:

- To investigate the importance of delivering sustainable public building projects in Jordan.
- To investigate the impact of adopting BIM approaches on the design and delivery of sustainable building projects.
- To investigate the impact of procurement approaches on the uptake of BIM and delivery of sustainable buildings.
- To investigate the current BIM status, feasibility, benefits and barriers in the public sector in Jordan.
- To investigate the procurement approaches used in the Jordanian public sector, their effect on the adoption of BIM and the subsequent ability to deliver sustainable building projects.
- To develop a procurement framework to enhance the implementation of BIM in the Jordanian public sector for better sustainable building performance.
- To refine and validate the developed framework.

1.5 OUTLINE OF RESEARCH METHODLOGY

The research design is developed based on the research problem (see Section 1.3). The research problem influenced the selected methods of collecting the data and achieving the research objectives (see Table 1.2). In addition, it clarified the main steps in the research process (see Section 1.7). A mixed methods approach is adopted in this research; both quantitative and qualitative data collection and analysis will be used. Mixed method approaches allow "a more complete and synergistic utilisation of data than doing separate quantitative and qualitative data collection and analysis" (Wisdom & Creswell, 2013, p. 1). Questionnaires and interviews will be utilised to collect data from the major stakeholders in the public construction sector in Jordan. Chapter 5 will provide more in-depth detail about the research design employed in this research.

Table 1.2: Summary of key research objectives and outline of methods

LR: Literature Review; **QA:** Questionnaire Analysis; **IA:** Interview Analysis, **VIA**: Validation Interview Analysis			
Objective number	Research objectives	Method	Chapter
One	To investigate the importance of delivering sustainable public building projects in Jordan.	LR	2
Two	To investigate the impact of adopting BIM approaches on the design and delivery of sustainable projects.	LR IA	3 7
Three	To investigate the impact of procurement approaches on the uptake of BIM.	LR IA	4 7
Four	To investigate the current BIM status, feasibility, benefits and barriers in the public sector in Jordan.	QA IA	6 7
Five	To investigate the procurement approaches used in the Jordanian public sector, their effect on the adoption of BIM and the subsequent ability to deliver sustainable projects that perform over their whole life.	IA	7
Six	To develop a procurement framework to enhance the implementation of BIM in the Jordanian public sector for better sustainable building performance.	QA IA LR	8
Seven	To validate the developed framework.	VIA	8

1.6 RESEARCH PROCESS

The research design process is described in Figure 1.1 below. There are twenty main steps. The research started by identifying the research problem followed by setting the research aim and objectives (see steps 1, 2 & 3). Then, the secondary data were collected by the researcher to cover the literature review section, which is represented by step 4. This step reviewed the literature on sustainable buildings, BIM and its effect on delivering sustainable buildings, and the effect of procurement approaches on BIM and sustainability considerations. Therefore, the literature review was divided into three chapters in this thesis (see Chapters 2, 3 & 4). The fifth step looked at the research design (the research methodology), including the research philosophy and approach, research methods and techniques and research population and sampling methods (see steps 5, 6, 7 & 8). These steps are finalised in Chapter 5. The four phases of data collection are discussed in detail in the research design part (see Section 5.7). Phase 1 is represented in step 9 in view of the data collection, through distributing questionnaire surveys to key stakeholders in the public building sector in Jordan, and in step 10's statistical data analysis and discussion; these steps are concluded in Chapter 6. Phase 2 is represented by four steps. Step 11 identified potential interviewees that had the required experience, and then sent an invitation letter (see Appendix E), and step 12 organised the time and place for each interview. Step 13 was about the collection of data on the basis of face-to-face interviews. This was followed by step 14 to analyse the collected data; this final step includes the interview data transcriptions and the data analysis using the NVivo software. Steps 11, 12, 13 and 14 are concluded in Chapter 7. Phases 3 and 4 are represented by four steps. Step 15 developed a framework adopting the main principles of a problem-solving methodology using the literature, questionnaire analysis and interviews analysis; step 16 prepared for the data collection to validate the developed framework through semi-structured interviews. Step 17 examined the data collection, including the transcriptions, and step 18 revised and refined the developed framework. Phases 3 and 4 are concluded in Chapter 8. In the last two steps, step 19 drew certain research conclusions, and step 20 provided recommendations for future research. These steps are concluded in Chapter 9 of this thesis.

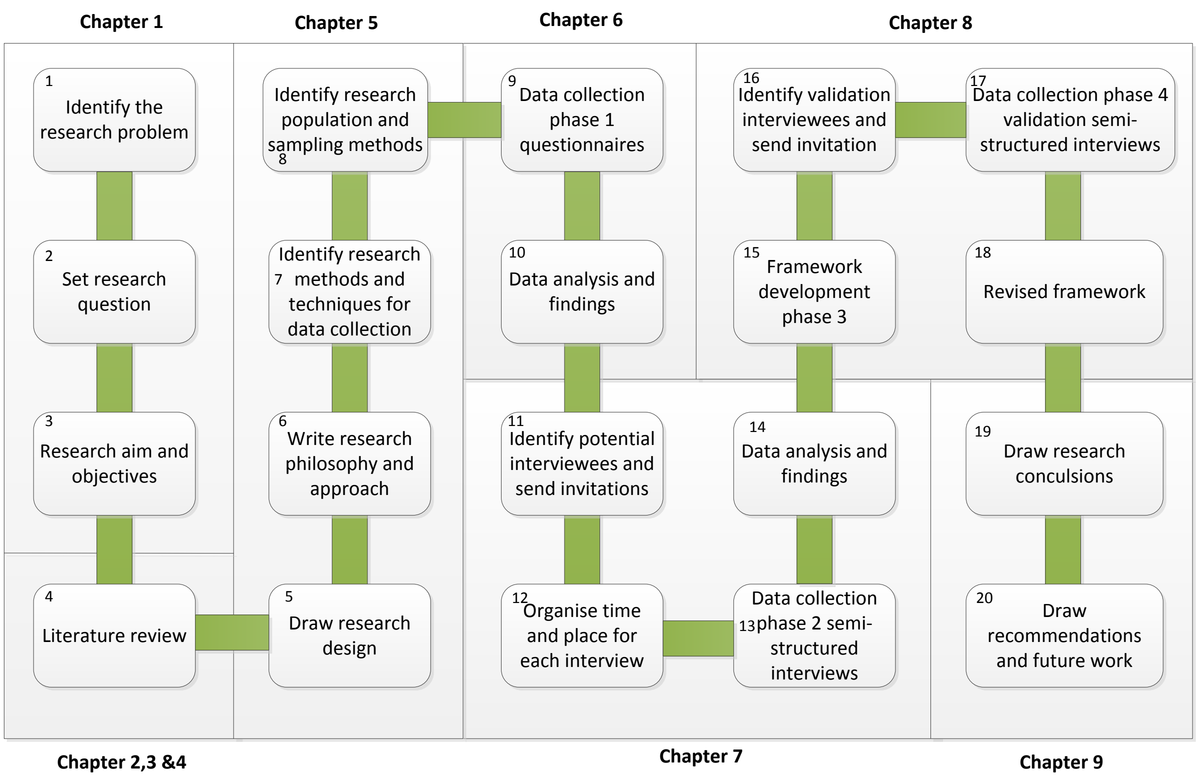


Figure 1.1: Research design process

1.7 THESIS STRUCTURE

The thesis is structured into nine chapters, as briefly described below. Figure 1.2 illustrates the links between the thesis chapters.

Chapter One: General Introduction

This chapter provides the research background, statement of problem, research motivation, aims and objectives, along with an outline of the research methodology and the research design process. The research motivation refers to the significant gap found in the literature. Finally, this chapter introduces the thesis structure.

Chapter Two: Sustainable development and built environment

This chapter provides a background to the concepts, principles, strategies and plans for sustainable development and sustainable construction worldwide and in Jordan. It also discusses the importance of delivering sustainable public buildings in Jordan and the issues associated with it. Finally, the chapter identifies the major sustainable building projects' stakeholders.

Chapter Three: BIM-enabled sustainable design and delivery

This chapter provides a contextual background for BIM worldwide and in the public sector in Jordan. It identifies the lack of research on BIM implementation in Jordan, particularly in the public sector. This chapter also provides a holistic understanding and critical reflection on the nexus between BIM and sustainable buildings, through reviewing the BIM support for the lifecycle of sustainable buildings and sustainable building analysis and assessment.

Chapter Four: The implication of construction procurement on BIM implementation and sustainability considerations

This chapter reviews the existing literature on the construction procurement definitions, classifications and processes. It also explores the impact of procurement approaches on BIM implementation and sustainability considerations. Moreover, a review of the construction procurement regime in the public sector in Jordan is provided. Finally, this chapter discusses the justifications for carrying out this research.

Chapter Five: Research methodology

This chapter presents the research methodology and research design to achieve the aim of this research. It reviews the relevant research philosophy, research approaches, strategies, methodologies and methods in construction and business research. Based on this review, this chapter illustrates the philosophical position of this research and justifies the selected approach, strategy, methodology and data collection techniques and analysis. Finally, the data validity and reliability and the ethical considerations of this research are discussed in this chapter.

Chapter Six: BIM feasibility study

This chapter, firstly, presents the general statistics regarding the questionnaire survey, including the questionnaire sampling, response rates and the different sections of the questionnaire. Then, it shows the findings and discussions on the main findings.

Chapter Seven: BIM, procurement and sustainability issues in the Jordanian public sector projects

This chapter discusses the main findings from conducting the interviews with BIM practitioners in the public sector in Jordan. It begins by stating the aim and objectives for conducting the interviews, followed by the sampling methods and analysis techniques for the interviews. Finally, it demonstrates the main findings and provides an analysis and discussion on these findings.

Chapter Eight: Framework development, validation and discussion

This chapter firstly discusses the framework design and development including the framework aim, framework development methodology, framework themes development and the framework structure. Following to this, it presents the main findings from the validation interviews. Finally, it discusses the framework strengths and barriers.

Chapter Nine: Conclusions, limitation and recommendations

This chapter presents the research conclusions, limitations and recommendations. It includes a summary of the main findings, specific contributions to the body of knowledge, limitations and challenges to the research and recommendations for future work.

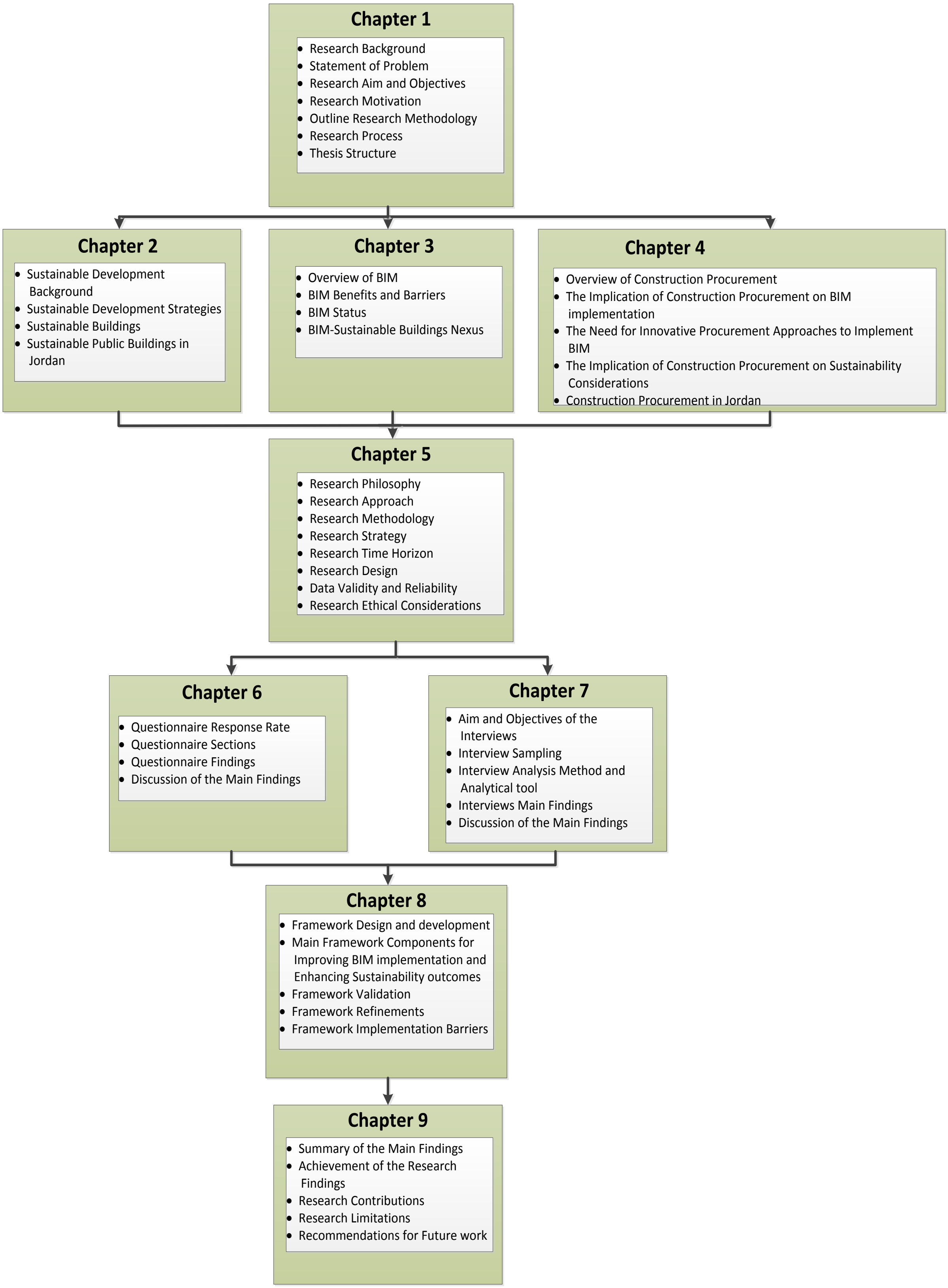


Figure 1.2: Thesis structure

CHAPTER 2: SUSTAINABLE DEVELOPMENT AND THE BUILT ENVIRONMENT

2.1 INTRODUCTION

Current concerns about energy consumption, increased oil prices, natural resources and climate change have increased the importance of making new developments sustainable (Sheth, 2011). Moreover, issues pertaining to carbon emissions and global warming make sustainability a priority area for research (ibid). In this chapter, sustainable development and sustainable construction will be investigated on a global level and in Jordan. This chapter is divided into four main sections, as follows:

- A background in sustainable development, which includes the definition of sustainability and sustainable development and the main three aspects of sustainable development.
- Strategies for sustainable development on a global level, which include the status of sustainable development strategies in different countries, the issues of such strategies and the principles of sustainable development.
- An overview of sustainable construction, including the importance of sustainable buildings on a global level, principles of sustainable building construction, sustainable building design, sustainable building assessment methods and achieving sustainable buildings through building management approaches.
- Sustainable building construction in Jordan, beginning with a review of the Jordanian construction industry (JCI) and the importance of the public construction sector; then, sustainable development and sustainable construction strategies are explored.

2.2 SUSTAINABLE DEVELOPMENT BACKGROUND

In the Cambridge online dictionary, sustainability has been defined as "the ability to continue at a particular level for a period of time" (Cambridge University Press, 2018). In the online 'Dictionary', it was defined as "the ability to be sustained, supported, upheld, or confirmed" (*Dictionary online*, 2018). Sustainability can also be defined as "a paradigm for thinking about the future in which economic, environmental, and social dimensions are intertwined and balanced in the pursuit of an improved quality of life" (UNESCO, 2012).

The most common sustainability model comprises three connected rings: social, economic and environmental (see Figure 2.1) (Hopwood, Mellor & O'Brien, 2005; Giddings, Hopwood & O'Brien, 2002).

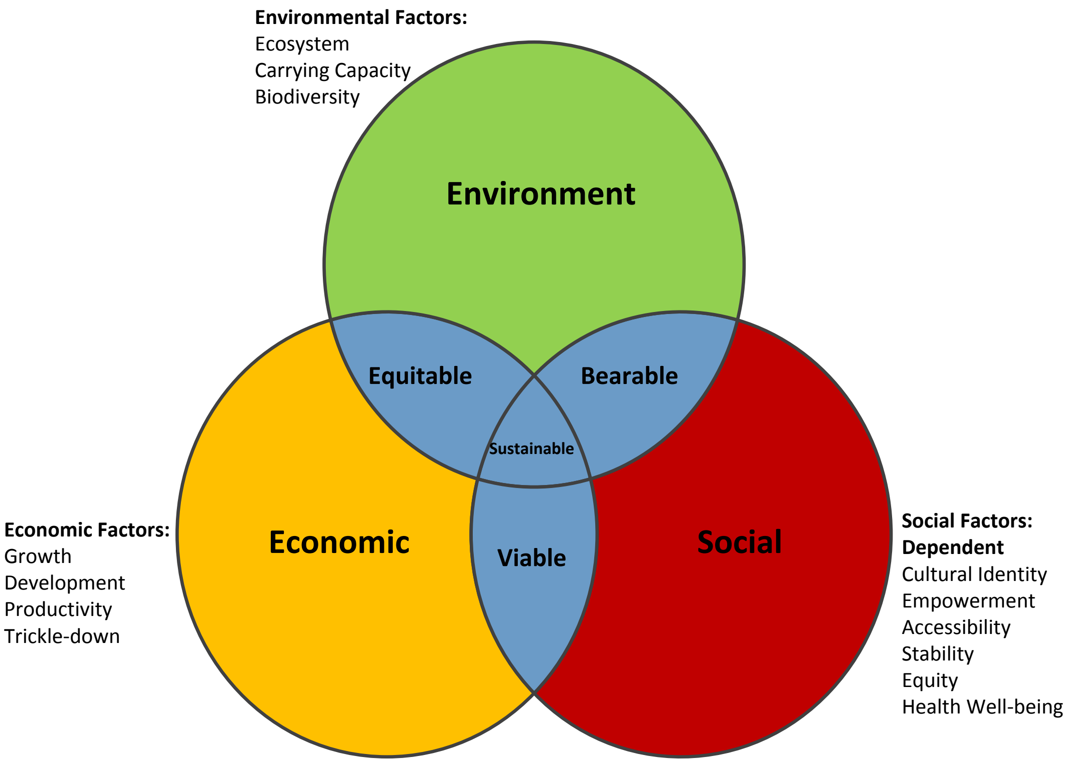


Figure 2.1: Common sustainability model (ICAEN, 2004)

Sustainable development is an ambiguous concept, with a contested and complicated meaning (Carter, 2007). Different groups such as from the area of business, academia and planning have defined, used and interpreted the concept of sustainable development in different ways to achieve their own goals (Redclift, 2005). The definition in 'the Brundtland Report' is the most frequently quoted: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987).

Three sustainable development aspects: environmental, economic and social have been recognised since the establishment of 'Our Common Future' report in 1987 by the World Commission on Environment and Development. These aspects are (Holmberg, 1992):

1. Environmental systems: the ability to deplete non-renewable resources, avoid overexploitation of renewable resource systems and maintain a stable resource base.

2. Economic system: the ability to avoid the extreme imbalances of sectors in which industrial production and agriculture could be damaged, the ability to maintain external debt and to produce services and goods on a continuing basis.
3. Social system: it must achieve political accountability, gender equity and adequate provision of social services, including education, health and distributional equity.

Sustainable development aims to bring together and balance the three sustainability dimensions, reconciling any potential conflict (Giddings et al., 2002; Halsnaes, 2002). However, different groups implementing sustainable development through distinct lenses might prioritise one of the dimensions at the expense of the others (Carter, 2007). This led to the emergence of 'strong' and 'weak' sustainability (Baker, 2006).

The argument for 'weak sustainability' is that the imbalance between the three dimensions can occur, such as the focus could be on the economic dimension through investing in man-made capital which can replace environmental damage and natural resource depletion (Lomborg, 2001; Neumayer, 1999). On the other side, the proponents of 'strong sustainability' have heavily criticised those views (Carter, 2007; Daly, 1993) in that man-made capital cannot reimburse natural resource losses. Even more pertinent, the green parties have added that natural systems, biodiversity and non-human species have values and rights in themselves (Carter, 2007; Redclift, 2005).

Whatever view is followed, sustainability is a contested area, and no single definition can capture all the varying aspects to this concept (Hill and Bowen, 1997). However, the core concept of sustainability development is to support the possibility of achieving economic growth without any trade-offs (Carter, 2007).

2.3 SUSTAINABLE DEVELOPMENT STRATEGIES

In the late 1960s and early 1970s, the governments in developed countries started to link the environment with decision-making processes through more comprehensive approaches (Hanf and Jansen, 1998; Janicke and Weidner, 1997). The World Commission on Environment and Development (WCED) published 'the Brundtland Report' or 'Our Common Future' (WCED, 1987). The concept of sustainable development was brought onto the international agenda by this report.

In 1992, the Rio Earth Summit was held to discuss how sustainable development can be achieved (Halliday, 2008). One of the outputs was Agenda 21, which is an action plan for achieving the sustainable development principles in the twenty-first century, and it was suggested that “a national strategy for sustainable development” should be prepared by all countries (UNCSD 1992, p. 67). The same suggestion was made in 1997, at the UN General Assembly Special Session (UNGASS), and in 2002, at the World Summit on Sustainable Development (WSSD).

A national sustainable development strategy (NSDS) can be defined as “a coordinated, participatory and iterative process of thoughts and actions to achieve economic, environmental and social objectives in a balanced and integrative manner” (UNDESA, 2002, p. 1). Five principles have been derived to determine what the NSDS is in further detail (UNDESA, 2002):

- Environment, social and economic policy integration across generation, sectors territories.
- Development of the necessary capacity and enabling environment.
- Focus on implementation and outcomes.
- Country commitment and ownership.
- Broad participation and effective partnerships.

Meadowcroft (2007) has presented a division of the world according to the general sustainable development strategies into three groups: European countries, industrialised countries and the rest of the world. In Europe, national sustainability strategies are well developed due to the significant number of strategies that have been adopted. Many factors contributed to this, such as the supra-national initiative effects, developed cross-national network exchange and well-developed environmental policies. However, despite the implementation of these sustainable development strategies, evidence shows that they typically remain minimal compared to a given government's core activities (Steurer and Martinuzzi, 2005; Swanson, Pinter, Bregha, Volkery & Jacob, 2004; Meadowcroft, 2000).

The first published NSDS in Europe and worldwide was by the UK government in 1994 (UKSDS, 2005). Following its national strategy in 1999, a document called ‘A better quality of life: A strategy for sustainable development in the UK’ was published by the government (DETR, 1999). In this strategy, a vision to deliver social, economic and environmental outcomes simultaneously was set. Moreover, the UK Government has set the world's first legally binding national target to reduce greenhouse emissions. Furthermore, in the Climate Change Act 2008, the UK government committed to reducing carbon emissions. In this act and under Section 1(1), "the Secretary of State for Energy and Climate Change" is responsible for the UK carbon account reduction by 34% by 2020 and 80% by 2050 against 1990 CO_2 emission levels. (UK Parliament, 2008).

Outside Europe, as seen in Table 2.1, the picture is mixed among different developed countries:

Table 2.1: NSDS in developed countries outside Europe (Meadowcroft, 2007)

Country	NSDS
Australia	An ecological, sustainable development national strategy was adopted in 1992; however, today this is essentially moribund.
New Zealand	The first strategy was completed in 2007.
Canada	No overall NSDS; however, at the federal level, it has a well-institutionalised system of departmental sustainable development strategies, and several provinces have produced plans.
The United States	Many guidelines and recommendations have been developed and published. However, there is still a lack sustainable development meaningful strategy.

Outside Europe and most of the developing countries, specifically poor and small countries have a lack of engagement with the sustainable development process. International organisations put pressure on these countries to produce a range of different documents and strategies (Meadowcroft, 2007). Finally, individuals, communities, organisations and countries, especially developing countries, must invest in developing and implementing innovative, alternative and more sustainable strategies.

2.4 SUSTAINABLE BUILDINGS

'Sustainable Built Environment' otherwise known as 'Sustainable Construction' is a division of sustainable development. It maintains ecological diversity while effectively integrating low-energy design materials (Edwards, 1998). Sustainable construction was defined by

Charles Kibert in the first International Conference on Sustainable Construction in Tampa 1994, as “the creation and operation of a healthy built environment based on resource-efficiency and ecological principles” (Kibert, 2008, p. 2). Sustainable construction was also defined by the International Council for Research and Innovation in Building and Construction (CIB) (2004) as “the sustainable production, use, maintenance, demolition, and reuse of buildings and constructions or their components”.

Despite the variances between different definitions, sustainable construction integrates at least three aspects that are widely accepted (Sourani, 2013):

1. The social dimension, which focuses on equality and diversity in the workplace, stakeholder involvement, employment opportunities and health and safety.
2. The economic dimension, which focuses on financial affordability for the intended beneficiaries, local economy support and whole life costing.
3. The environmental dimension, focusing on reducing pollution, the use of renewable resources and water and energy consumption reduction.

For sustainable buildings, the links between the building sector and sustainability development can be summarised in two points. For point one, buildings consume natural resources such as energy, materials, land and water. Secondly, buildings support comfort, health and economic development (Bourdeau, Halliday, Huovila & Richter, 1997). Sinha (2013) also confirmed the need to achieve the following objectives to deliver sustainable buildings; minimising consumption of matter and energy; reusability and recyclability of the material; minimum environmental impacts and embodied energy; and human satisfaction. However, the building sector has been described as an energy intensive and profligate industry. Globally, according to 2010 data, 45% of the world’s energy and 50% of the water are used in building construction. Table 2.2 represents the different resources used in building construction.

The operation phase for buildings also has a crucial role in sustainability as buildings present a unique case due to their long lifespan when compared to other industries. The lifespan of a building ranges between 80 and 100 years, which will have a long-term impact on the environment, the society and the economy (Sev, 2009). Therefore, it is crucial to consider sustainability principles throughout a building’s lifecycle from planning to demolition to achieve high-performance, sustainable buildings (Son, Kim, Chong & Chou, 2011; Pearce, 2006). Moreover, the buildings’ operational energy consumption has the single largest impact on the environment (Operational

Energy Use, n.d). Table 2.3 represents the estimated global pollution that can be attributed to the building operations.

The design phase of a building delivery plays a significant role in reducing the impact of the construction and operations on the environment as the most effective decisions are those made in this phase (Shoubi, Bagchi & Barough, 2015). On the other hand, the decisions made after this stage lead to the expensive and inefficient process of retroactively changing the building design to achieve a set of performance criteria (Schueter and Thessling, 2008).

Table 2.2: Estimation of global resources used in buildings (Willmott Dixon, 2010)

Resource	**(%)**
Energy	45–50
Water	50
Materials for buildings and roads (in bulk)	60
The agricultural land loss to buildings	80
Timber products for construction	60 (90% of hardwoods)
Coral reef destruction	50 (indirect)
Rainforest destruction	25 (indirect)

Table 2.3: Estimation of global pollution that can be attributed to buildings (Willmott Dixon, 2010)

Pollution (%)	**(%)**
Air quality (cities)	23
Greenhouse gas production	50
Climate change gases	50
Drinking water pollution	40
Landfill waste	50
Ozone depletion	50

As discussed above, buildings consume more energy than any other single sector; therefore, it is expected that the greatest cuts should be achieved from this sector (Roaf, Crichton & Nicol, 2009). For this reason, sustainable buildings are the focus of this research.

2.4.1 Principles of Sustainable Buildings

Traditional construction approaches emphasise cost, time and quality performance goals (Latham, 1994). Moving to sustainable buildings expands the goals to creating a healthy and comfortable built environment while minimising resource consumption, environmental degradation, waste generation and air emissions (see Figure 2.2) (Huovila & Koskela, 1998).

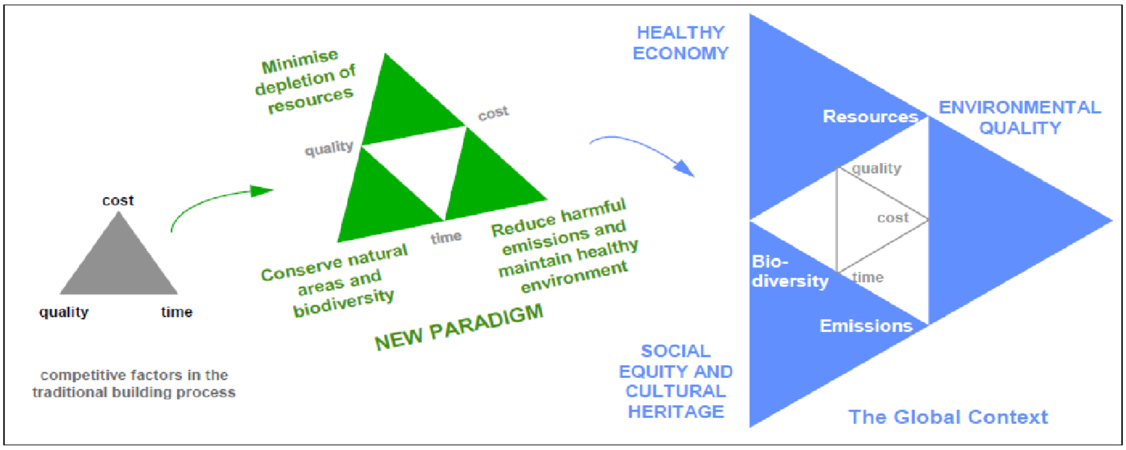


Figure 2.2: Challenges of sustainable construction globally (Huovila & Koskela, 1998)

The basic principles, policies and strategies of the construction of sustainable buildings should encompass the three following aspects: social, economic and environmental. These strategies and principles are (Halliday, 2008; Sev, 2009):

- Increasing the usage of natural, recyclable and renewable resources, and utilising them effectively in the process of material sourcing and selection and construction; Buildings should be manageable, affordable and maintainable in use.
- Minimising the use of materials, water, energy and land during construction and operations.
- Improving the natural habitat through water use and appropriate planting, and enhancing biodiversity.
- Creating a comfortable and healthy environment at work and at home, and not putting the health of the occupants, builders or any other party at risk.
- Improving community support by identifying the requirements, real needs and aspirations of the people involved, and engaging them in the key decisions.

- Delivering process management to achieve sustainable buildings to ensure building performance over time and to validate building-system functions through identifying benchmarks, tools and targets as well as managing their delivery.

These principles have been broadly adopted by governments worldwide in their strategies (Hall and Purchase, 2006). For instance, in the UK, one of the key published documents by the government on sustainable construction is entitled 'Building a better quality of life: A strategy for more sustainable construction' (DETR, 2000). This document comprises the following principles, which were widely used by the UK government strategies and reports:

- Enhancing and protecting the natural environment.
- Reducing the impact of structures and buildings on natural resources and energy consumption.
- Delivering structures and buildings that provide well-being, greater satisfaction and add value to users and customers.
- Treating and respecting the stakeholders more fairly.
- Being more competitive and more profitable.

CIB (1994) articulated seven main sustainable building construction principles for informing decision-making during different design phases and construction processes, through the whole project lifecycle (Kibert, 2005):

- Reduce resource consumption.
- Protect nature.
- Reuse resources.
- Focus on quality.
- Use recyclable resources.
- Eliminate toxins.
- Apply lifecycle costing (economics).

2.4.2 Sustainable Building Design

According to the National Aeronautics and Space Administration (NASA), the overarching concept of sustainability is to integrate appropriate sustainable design elements into the different life stages of a building or structure in order to reduce the environmental impact, and to balance and improve the whole lifecycle cost, the occupants' safety, comfort, productivity and health (NASA, 2001). NASA (2001) highlighted the following elements as essential for sustainable design:

- Water conservation.
- Energy efficiency.
- Site selection to reduce transportation and environmental impact.
- Sustainable materials.
- Efficient and durable equipment and materials.
- Healthy environment including indoor air quality.
- Features in support of and enhancing worker productivity.
- Design for personal security and safety.
- Design for decommissioning and disposal.
- Enhanced building maintenance and operating characteristics.
- Defining facility operational objectives, tests and validating building-system functions to have been properly installed and be performing to the level intended.

There are other essential elements of sustainable design, as mentioned in the literature (Zanni, 2017) (see Table 2.4).

Table 2.4: Sustainable design elements (Zanni, 2017)

Sustainable design elements	**Source**
Functionality	(Giedion, 1967)
Adaptability	(Glen, 1994),
Flexibility	(Slaughter, 2001)
Health and safety	(Doroudiani and Omidian, 2010)
Human building interaction	(Du Plessis, 2001)
Disassembling	(Macozoma, 2002)
Maintainability	(Chew et al., 2004)
Energy efficiency	(Kneifel, 2010)
Embodied energy and embodied carbon	(Hammond and Jones, 2008)
Recycling	(Thompson, 1977),
Equipment and appliances	(Wood and Newborough, 2003)
Technology use	(Emmitt and Ruikar, 2013)

Environmental design	(CIBSE, 2006)
Performance, energy, waste and emissions	(Brandon, 1999)
Reliability and usability	(Markeset and Kumar, 2003)
Durability and longevity	(Kibert et al., 2000)

Moreover, the design and construction phases have a significant impact on the operation phase. For instance, it was found that maintenance and operational costs have a ratio of 5:1 to the initial (capital) cost (Evans, Haryott, Haste & Jones, 1998). In other words, a reduction of £1 in the construction cost will increase the operation and maintenance costs by £5. Therefore, adopting the above-mentioned strategies, elements and principles in the design phase, such as whole life costs, is most likely to lead to having a building with lower maintenance and operational costs, lower air pollution, healthier and productive occupants and less material use (Yazan, 2010).

2.4.3 Sustainable Building Assessment Methods

Sustainable buildings are those that are designed to meet the above issues and are environmentally benign, socially acceptable and economically viable (Yazan, 2010). To address building sustainability issues, many rating systems to assess sustainable construction are issued by countries and international organisations (Haapio and Viitaniemi, 2008; Azhar, Carlton, Olsen & Ahmad, 2011). The following are examples of these systems:

- The UK's BREEAM (Building Research Establishment's Environmental Assessment Method).
- Australia's GREEN STAR.
- Hong Kong's BEAM Plus.
- The US's LEED (Leadership in Energy and Environmental Design).

These systems have been divided into two categories: assessment tools, which provide a quantitative performance indicator for design alternatives, and rating tools, which provide the level of performance of a building in stars (Ding, 2008). These tools cannot provide design alternatives for the design teams; however, they support the design teams to evaluate buildings in terms of their sustainability at the end of the design stage (Crawley and Aho, 1999).

Although these systems have proven benefits (Stumpf, Kim & Jenicek, 2009; Gerber, Lin, Pan & Solmaz, 2012; Parasonis, Keizikas & Kalibatiene, 2012), careful consideration of the informational requirements is necessary when implementing these systems. Moreover, these systems encourage designers to focus on obtaining the relevant certification with the lowest possible cost by focusing on “points-chasing” (Cole, 2005). Therefore, these systems lead to a lack of interest in the long-term assessment of the social and ecological aspects of buildings, such as lifecycle costing (LCC), which is claimed to be an essential element to achieve sustainability (Pandey and Shahbodaghlou, 2015).

2.4.4 Sustainable Building through Project Management Approaches

The preconstruction stage has been the focus of previous research in the field of delivering sustainable buildings, such as building design regulations (Hamza and Greenwood, 2009), sustainable building design (SBD) (Zanni, 2017; Bossink, 2007; Labuschagne and Brent, 2005) and the tools for sustainable building assessments (Wang et al., 2010). However, recently, researchers started to investigate the delivery of sustainable buildings through project management approaches. Sustainability for a business enterprise was defined in 1992 by the International Institute for Sustainable Development (IISD) as:

> Adopting business strategies and activities that meet the needs of the enterprise and its stakeholders today while protecting, sustaining and enhancing the human and natural resources that will be needed in the future. (IISD, 1992, p. 11)

Arguably, sustainable development, in reality, is easier to implement at the strategic level of a business than the operational one (Labuschagne and Brent, 2005). Therefore, project management methodologies should be studied to attain sustainable development in a business environment. However, traditional business management systems were criticised for their focus on financial performance. Thus, social and environmental sustainability aspects are excluded (Bieker, Dyllick, Gminder & Hockerts, 2001). Wang, Wei and Sun (2014) classified the sustainable project management criteria based on the literature and key UK governmental sustainability measures into three main sustainability criteria that is social, economic and environmental, as shown in Figure 2.3.

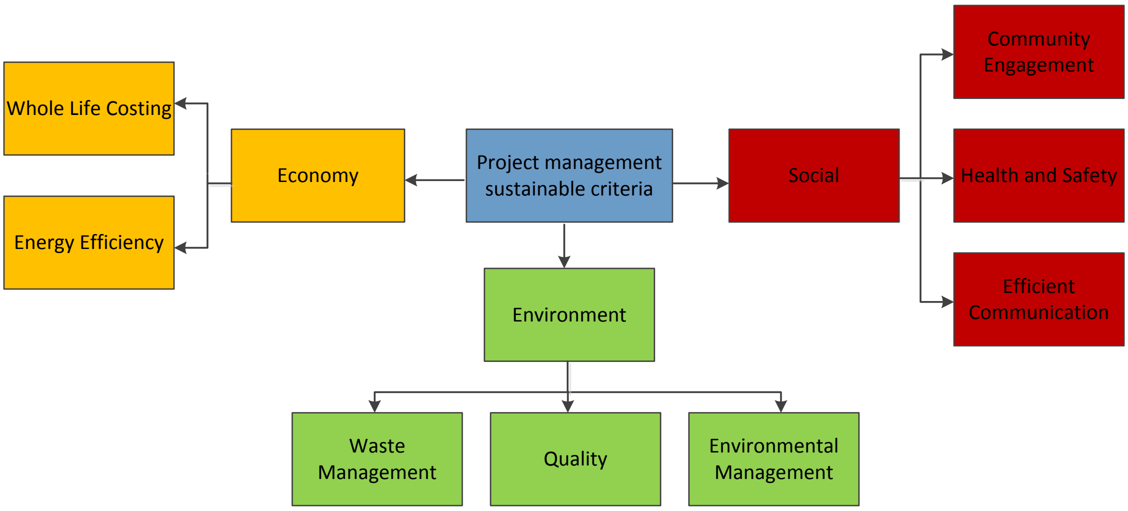


Figure 2.3: Criteria for sustainable project management (Wang et al. 2014)

In the construction context, and in the current management systems, such as the traditional procurement approach, there is segregation between the design, construction and operations phases, and a lack of continues management of the project. According to Molenaar et al. (2009), the majority of LEED accredited professionals (APs) believe that building projects delivered under alternative management systems, such as construction management at risk (CMR) and design-build (DB), will have a better chance of achieving sustainability goals when compared to traditional procurement approaches.

Recently, fairly new project management innovation technologies were adopted to overcome the issues in delivering sustainable projects, such as lack of integration and communication. BIM and integrated project delivery (IPD) were among these technologies. BIM will be discussed further in Chapters Three and Four while IPD along with other construction project management systems will be investigated in Chapter Four. BIM's main characteristics are (Kim, 2014):

- Effective collaboration and communication among project stakeholders.
- Construction project information integration and management throughout the entire project lifecycle.

American Institute of Architects (AIA) defined IPD as:

> A project delivery approach that integrates people, systems, business structure and practices into a process that collaboratively harnesses the talents and insights of all participants to optimise project results, increase value to the owner, reduce water

consumption, and maximise efficiency through all phases of design, fabrication and construction. (AIA, 2007)

The focus of Sections 2.3 and 2.4 was on sustainable development and sustainable construction worldwide, specifically in developed countries. On the other hand, developing countries have a lack of engagement with the sustainable development process, especially in sustainable construction. Therefore, these countries must invest in developing and implementing alternative, innovative and more sustainable strategies. Jordan as a typical developing country is the focus of this research. The next section will explore the Jordanian Construction Industry (JCI) with a focus on sustainable construction.

2.5 SUSTAINABLE PUBLIC BUILDINGS IN JORDAN

2.5.1 Introduction

In this section, the current state of the JCI is reviewed. This review is conducted to establish a better understanding of the state of the building projects performed in the JCI with a focus on sustainability. Following the introduction, an overview of the JCI examines: JCI development during the period from 1980 to 2011, Jordan's public clients and public sector projects. The section on sustainable development discusses: Jordanian sustainable development strategies, sustainable construction, sustainable construction stakeholders and the challenges to and drivers of sustainable construction in Jordan.

2.5.2 Review of the Jordanian Construction Industry (JCI)

The former prime minister of Jordan, Abdullah Ensour, highlighted that the construction industry in Jordan is the largest sector in the country in term of invested projects; moreover, it is environmentally and economically significant to the country, and it forms an integral part of its security systems (Al Emam, 2015). The current JCI shape is a result of the interaction of many factors, including geographical, political, economic, historical, social, technological and institutional factors. JCI operates under difficult geographical, economic and social circumstances:

- **Geography**

The country has twelve main cities: Amman, Zarqa, Irbid, Mafraq, Karak, Madaba, Balqa, Jarash, Ajloun, Maan, Aqaba and Tafileh (see Figure 2.4). According to the last national census conducted in November 2015, the total population in Jordan was 9.523 million, with 6.6 million Jordanian nationals, and 2.9 million non-Jordanians living in the country, as shown in Figure 2.4 (Ghazal, 2016). This is due to the waves of recurring forced immigration from neighbouring countries over the past 69 years because Jordan is considered one of the most stable countries in the Middle East.

The urban population in Jordan exceeds 80% of the total of which 15.7% live in slums (UN-Habitat, 2008). Increasing urbanisation is making the building sector the fastest growing in the country. Moreover, 70% of the population lives within 30km of the capital, Amman (Kisbi, 2011), which has placed a huge burden on the public buildings, services, environment and infrastructure.

- **Culture and society**

Arabic and Islamic elements are the basics of the culture in Jordan, with a western influence. Jordan has always been formed by a diversity at any given point because of its location.

- **Economy**

There are 139 middle-and-low income economies, referred to as developing countries, according to World Bank (World Bank, 2016). The Hashemite Kingdom of Jordan, as a typical developing country, is a small, resource-starved, middle-income country. It lacks sources of water, oil and other natural resources, and it has a significantly growing population (MWI, 2016). Moreover, as Jordan is a non-oil based country, it imports nearly all its needs from neighbouring countries, which has added pressure to the national economy of the country.

As shown in Figure 2.4, Jordan is largely landlocked with one port, Aqaba, and the rainfall is low and highly variable; much of the groundwater in Jordan is not renewable (Bani Ismail, 2012) which has led to a diminishing water supply in the country. This also affects the importing and exporting activities. In addition to this, 95% of Jordan's land mass is desert, and the rest is at risk of desertification (Kisbi, 2011). These problems have led Jordan to rely on external aid, exporting potash and phosphates, its service sector, tourism and external funding for investment into the country. For external funding, it was found that $50 billion were invested into developing construction projects in Jordan between 2005 and 2011 (Haddadin, 2014).

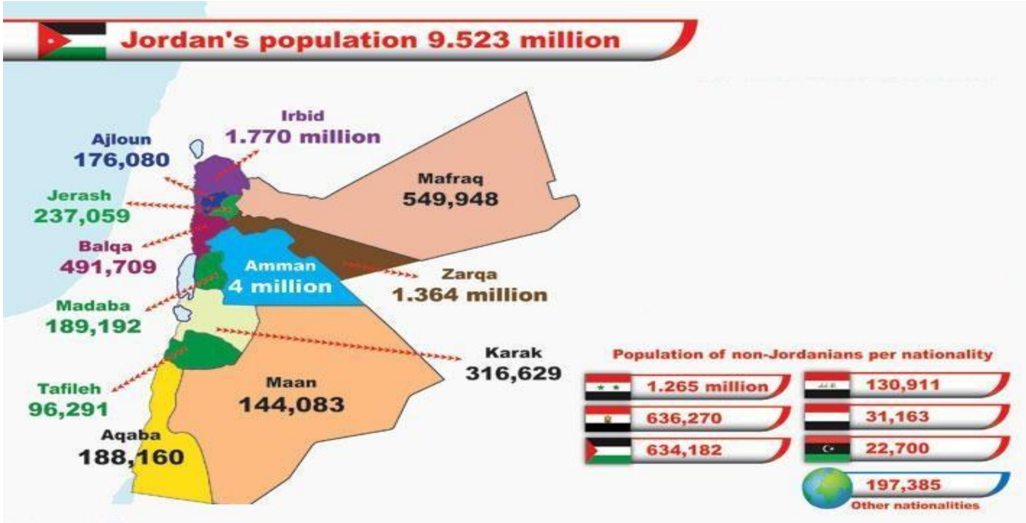


Figure 2.4: Jordan population (Ghazal, 2016)

2.5.2.1 Development of the JCI

Between 1980 and 1999, Jordan faced many issues, such as (Bani Ismail, 2012):

- Complicated government procedures.
- Bureaucratic culture.
- Slow economic growth due to the Gulf wars.
- Increased government taxes on raw materials.
- Unemployment.
- Monopolies of the government (including the Jordan refinery company in which steel and cement imports were limited).
- According to MPWH (2007), JCI has also suffered from many financial and managerial problems.

In 1999, King Abdullah ascended the throne to make real changes and to enhance living standards; a comprehensive reform plan was adopted. This reform started with better education methodologies, enhancing the democratisation process and regular meetings with international and local investors and business leaders. This led to external support in: the signing of new trade agreements on an international level, in 1999; new joint free trade agreements (FTA) being signed in 2001, with the US; access being obtained to the World Trade Organization (WTO) in 2000; and signing an association agreement with the

EU in 2001. These efforts by both the royal family and the government have had a dramatic and positive effect on the construction industry by improving the integration of the Jordanian economy with the international economy, enhancing the living standards of the local citizens, and expanding the suppliers' markets for construction, health and other sectors. For instance, in Jordan, the real GDP growth between 1990 and 2014 was 4.9%, associated with a per capita GDP growth of 2.2%, in which the construction sector in Jordan became one of the leading contributing sectors to the real GDP growth at 12.2% (Toukan, 2018). However, in terms of the employment of Jordanians, around 6% of the total workforce in 2011 was employed in the construction sector, with a decrease from its 7.1% value in 2004; this is mainly because of the increased number of foreign workers in the construction sector (RSSJ and FES, 2013).

2.5.2.2 The Jordanian Public Client

The party that has the funds and the powers to authorise constructing a project is either the client or the owner. Consultants undertaking the design and contractors performing the construction are key stakeholders who provide expert advice and executive tools that the client uses to exercise his rights most effectively.

The government as a client plays a significant part in the construction industry; its level of involvement varies in different countries, and it could play a direct or indirect role. In most of the Middle Eastern projects, the major construction client is the government (Gerges et al., 2017). The government in Jordan has always been "the major client for the most important construction works that represent the major part of the expenditure in the construction work" (Awni, 1983), and is one of the JCI key movers (Haddadin, 2014). Also, Jordan is primarily a service economy with a significant dependence on the public sector. It is, therefore, the intention to focus this research on the public sector context.

MPWH and its 18 departments are the most important public construction bodies that are responsible for the procurement and implementation of the central governmental construction projects in Jordan (Al Assaf, 2017). Another important department which is responsible for all the central government tenders is called the Government Tenders Department (GTD), established for and connected to the MPWH, according to 'Government Works By-Law No. (71) of 1987'. Therefore, this research considers the MPWH and GTD as being representative of the public clients in Jordan.

2.5.2.3 Public Sector Projects

Buildings and civil engineering projects represent the Jordanian public projects. Public building projects are frequent (see Table 2.5) and consist of residential and non-residential projects. Residential buildings represent public housing and single unit dwellings. This type is the simplest of construction projects and familiar to both contractors and clients (PPA, 2010). On the other hand, non-residential projects cover a great variety of projects, such as hospitals, schools, universities and governmental buildings. According to Grifa (2006), this type of project requires skilled staff, qualified designers, workers and operatives. This type of building is less familiar to contractors and clients compared to the residential ones. Table 2.5 represents the Jordanian public projects by construction type.

Table 2.5: Public construction projects by construction type (Al Assaf, 2017)

Type of Construction	**Project Sponsor (PS)**	**Client**	**Frequency**	**Budget+**
Buildings	MoE – Schools MoH – Hospitals MPWH – Housing and Governmental Buildings	MPWH	High	Small to High
Water, Wastewater Infrastructure, Irrigation and Dams	MoWI	Ordering Body	Medium	High
Roads and Transportation	MPWH or MoT	MPWH	Medium	High
Electromechanical and Communication	JREEEF MoICT	Ordering Body	Low	Small to Medium
Mining	Governmental Companies	Ordering Body	Low	High

In Jordan, many large governmental residential and non-residential projects were established in the last five years. According to Halaseh (the Minister of Public Work and Housing), 188 million Jordanian dinars (JD) worth of construction projects were executed recently, with JD1.5 billion worth of construction projects on-going. These include the new Amman Customs' buildings estimated at a value of JD96 million, the justice department buildings valued at JD16 million and a housing project containing 400 housing units in the first phase worth JD16 million (Jordan Times, 2017a). In addition to these, there are projects that include education and health centres. These projects increase the importance of enhancing the performance of the public buildings in Jordan.

2.5.2.4 Public Buildings Issues in the JCI

The basic and most used metrics are time, cost and quality when delivering building projects. In Jordan, public buildings are facing costs that are overrunning their budget. Sweis (2013) analysed different public building types in Jordan, and he found that 65% of the buildings were not completed within their budget. Cost overruns can be defined as not achieving the project objectives within the estimated budget (Dlakwa and Culpin, 1990). Al-Hazim (2017) added that there is a substantial gap between the final and the estimated cost of public buildings, which can range between 101% and 600%, with an average of 214%. He added that public buildings in Jordan also reported a time delay, with a range between 125% to 455%, and an average of 226%. Twenty main factors were found to cause such delays such as terrain condition, design mistakes, variation orders and planned cost for project construction.

Adding to the aforementioned issues of the time delay and the cost overruns, public buildings in Jordan suffer from sustainability performance issues in terms of the environmental, economic and social issues. According to Tewfik and Ali (2014), most of the public and commercial buildings in the highest populated cities in Jordan (Amman, Zarqa and Irbid) have currently installed various types of systems, including ventilation, heating and air-conditioning, which have the poorest energy performance compared to the available options. This is because the focus is on reducing the capital cost by applying cheaper systems over the more environmentally efficient ones that focus on the whole life costs of such systems (Tewfik and Ali, 2014). The following sections will analyse sustainability development and sustainable construction in the context of Jordan.

2.5.3 Sustainability Development in Jordan

As mentioned earlier in this chapter, the government around the world and specifically in developed countries began in the late 1960s and early 1970s to consider and adopt approaches that link decision-making with the environment (Hanf and Jansen, 1998; Janicke and Weidner, 1997). The issue of protecting the environment should be of great interest to developing countries (Ofori, 2008) since these countries face severe environment-related problems (UNCHS, 1996), as seen in their uncertain economic environments, environmental degradation, rapid rates of urbanisation, weak governance, social inequity, institutional incapacity, deep poverty and low skill levels (Alsubeh, 2013). Therefore, Jordan as a typical developing county, should start paying more attention to the sustainability issues it is facing, especially due to the instability of the security in the region.

2.5.3.1 Sustainable Development Strategies

In the early 1970s, Jordan began to show an interest in the environment and issues related to the environment, such as atmosphere, air quality and environmental health. This was achieved by establishing institutions and initiating activities related to protecting the environment (MMRAE, 1991, 1999). This was followed in 1980 by the establishment of a department for the environment; this department was affiliated to the Ministry of Municipal and Rural Affairs and Environment (MMRAE). One year later, five one-year (between 1981 and 1985) successive development plans were formulated (MP, 1993). Several problems were identified in these plans that related to soil erosion, contamination and land use, including untreated wastewater and water pollution, which were affecting the quality of the groundwater basins (MMRAE, 1991). More development plans were produced between 1986 and 1990, 1993 and 1997 and 1998 and 2000 where the environment was one of the main foci (MP, 1993, 1998). In this emerging sector, a description of the issues, goals, characteristics and organisational measures as they relate to the environment in Jordan were established (AL-ZOABI, 2001). Due to the increased interest in the environment through different plans and strategies, in 2003, the Ministry of Environment was established due to the '2003: Environmental protection law NO 1' (Ciriaci, 2000; Petra, 2000). The ministry's vision is to protect and sustain Jordan's environmental resources and contribute to a better quality of life.

The first national environment strategy in Jordan was adopted in 1992; long-range plans of action were taken into consideration (MMRAE, 1995). Most parts of these plans aim to protect the environment, address legal and management issues and, most importantly, to revise the existing laws for more ecologically oriented ones.

The first 'Act of the Environment' in 1995 comprised 36 articles, which provided the needed legislation to protect the environment (MMRAE, 1995). This act calls for the establishment of a ‘General Corporation for Environmental Protection’ (GCEP), an ‘Environment Protection Council’ and an ‘Environment Protection Fund’. It also calls for the issuing of standards, codes and regulations in the fields of natural reserves, fauna, noise, waste, hazards, soil, air and water (MMRAE, 1999; Al-zoabi, 2001).

Following the first act and since the development of the first ‘National Environment Strategy’ in 1992, many sustainability strategies were established, as can be seen below:

- National Environmental Action Plan (NEAP), 1996.
- National Strategy for Sustainability Development Agenda 21, 2001.
- National Strategy for Environmental Education and Communication, 2001.
- National Strategy for Environmental Information, 2001.
- National Strategy for Biodiversity, 2001.
- National Strategy to Combat Desertification, 2005.
- National Action Plan for Persistent Organic Pollutants, 2005.
- Review of Environmental and Sectorial Strategies, 2005.
- Environmental Strategy Implementation Plan, 2007-2010.
- Environmental Strategy Implementation Plan, 2011-2013.

In addition, the first national ‘Millennium Development Goals’ report (MDGs) was released by the government in 2004 (Al-Kilani, 2015). This report had a significant impact on policy-making in which the indicators, goals and targets were aligned and adapted to the national plans and strategies. This report was followed by publishing two documents in 2006, namely ‘We Are all Jordan’ and ‘National Agenda’, which articulated the vision of the country. This vision was subsequently operationalised into a three-year ‘National Executive Programme’ (NEP), specifying projects, policies and programmes for government institutions (Awad, 2016).

The second MDGs report, ‘Keeping the Promise and Achieving Aspirations’, was released in 2010. This report shows the progress and challenges of achieving the MDGs in the country. By reviewing the indicators for a MDG, it can be said that there have been accomplishments for all the goals, as in building partnerships for development, ensuring environmental sustainability, eradicating hunger and poverty, improving child and maternal health, promoting gender equality and achieving a basic education. However, there were many factors that hindered the full achievement of the MDGs by 2015, as a consequence of the global economic crisis (Al-Kilani, 2015).

Another national strategy called 'Jordan 2025' was released in 2015 as a result of the previous strategies, policies and recommendations. Several sustainable development goals (SDGs) are embedded in this strategy as:

- The development of the sustainable communities and cities.
- The improvement of the educational system.
- The eradication of poverty.
- The guarantee of decent work and economic growth.
- The provision of clean water and sanitation.

However, there is still a need for further efforts to make this strategy effective and enable Jordan's development to be inclusive and sustainable (Awad, 2016).

Globally, the implementation of consultations in Jordan had a significant impact on the first preliminary report of the 'United Nations Development Group' (UNDG), which was issued in 2013 and called 'The Global Conversation Begins: Emerging Views for a New Development Agenda'. Post 2015, Jordan was one of the eighty-eight countries worldwide that carried out national consultations. One of the main messages 'areas for change' out of this national dialogue is to enhance awareness of the environment, address water scarcity and promote renewable energy (Al-Kilani, 2015). The guiding principles were set in the latest vision for Jordan (Jordan 2025) to deliver a better quality of life and achieve sustainable development, such as by: (i) enhancing the business environment; (ii) improving policies that promote sectorial development and innovation; (iii) enhancing competitiveness; (iv) supporting small-and-medium enterprises through preventing monopolies and encouraging competition; (v) improving the governmental service quality provided to citizens in various fields in a manner that builds on public sector reform programmes; and (vi) training programmes that meet market requirements.

In 2015, Jordan also adopted 'Transforming our World: the 2030 Agenda for Sustainable Development', which was driven by the United Nations (UN). This agenda acts as an action plan for the planet, people and prosperity, which aims to support universal peace and freedom (United Nations, 2015). The Ministry of Planning and International Cooperation (MoPIC) is responsible for mobilising the implementation of the 2030 Agenda for Sustainable Development Goals (SDGs) and for evaluating and monitoring its progress. Producing the 'Voluntary National Review' (VNR) report is also one of its tasks. The VNR is a voluntary report that countries can choose to produce at their convenience. In 2015, 22 countries produced their VNR reports, and Jordan was one of over 40 countries that did so in 2017. The report details the country's way forward towards sustainable development (Nassar, 2017). However, one of the main challenges, as expressed by the Minister of Planning and International Cooperation, Imad Fakhoury, is that:

> Jordan is unable to achieve comprehensive and sustainable economic, social and environmental development on its own due to the enormous pressure it is facing on its' infrastructure due to conflicts in the region and the influx of large numbers of refugees, which poses a real challenge to achieving the sustainable development goals by 2030. (Jordan Times, 2017b)

Therefore, national efforts in Jordan need to continue to improve energy efficiency in the infrastructure, specifically public, industrial and commercial buildings by promoting green buildings and energy-oriented building codes of practice (United Nation, 2017). The next section discusses further sustainable buildings in Jordan.

2.5.3.2 Sustainable Buildings

Buildings are of the utmost importance to the sustainability development in Jordan due to its significant impacts on the consumption of natural resources in a country that it imports 96.5% of its energy needs from neighbouring countries (MEMR, 2012), and considered as one of the world's most water stressed countries (Kisbi, 2011). Therefore, delivering sustainable buildings becomes a key target (RSSJ and FES, 2013).

In Jordan, the focus when delivering buildings is on incorporating insulating material, shadowing effects, wind direction and natural lighting (RSSJ and FES, 2013). However, a shift in building patterns including technology, zoning and land use was due to the population growth and rapid urbanisation. Moreover, in recognition of the side effects of the economic growth in Jordan, a shift towards sustainable building concepts, design, construction and operations has taken place (ibid). This shift is critical in minimising the negative impact on the natural environment. Furthermore, a building's energy performance improvement is among the most cost effective ways of combating climate change (Enkvist, Naucler & Rosander, 2007).

Despite the continuous national efforts to improve the public buildings' energy efficiency (United Nations, 2017), as in issuing the solar energy code, the energy efficient buildings' code and the Jordan Green Building Manual, a high percentage of the building sector in Jordan, especially the public projects, suffers from sustainability performance issues (FFEM and ANME, 2010). This is because the building codes are not fully enforced, and there are no rigid governmental actions that have yet been taken towards delivering sustainable buildings, such as policies, strategies and plans. Therefore, the sustainable building sector in Jordan remains at an embryonic stage (Tewfik, 2014). According to Alsubeh (2013), finding a holistic approach to deliver sustainable buildings in Jordan that contribute to the economic, human and physical development and meet sustainable development requirements is the biggest challenge.

2.5.3.3 Sustainable Building Projects' Stakeholders

Sustainability is a diffuse subject. Various sectors, disciplines, organisations and ministries are involved directly or indirectly in environment-related issues. In Jordan, the major player in green building development is MPWH and specifically the National Building Development Department. This department was formed by the 'Temporary Law No. (31) of 1989' within the 'National Building Law'. This law was mandated in 1993 by 'Law No. (7)'. Then, the national building codes were developed by the National Building Council and regulated throughout all the buildings' phases (RSSJ and FES, 2013). Other major stakeholders in the process of green building development in Jordan are shown below in Figure 2.5.

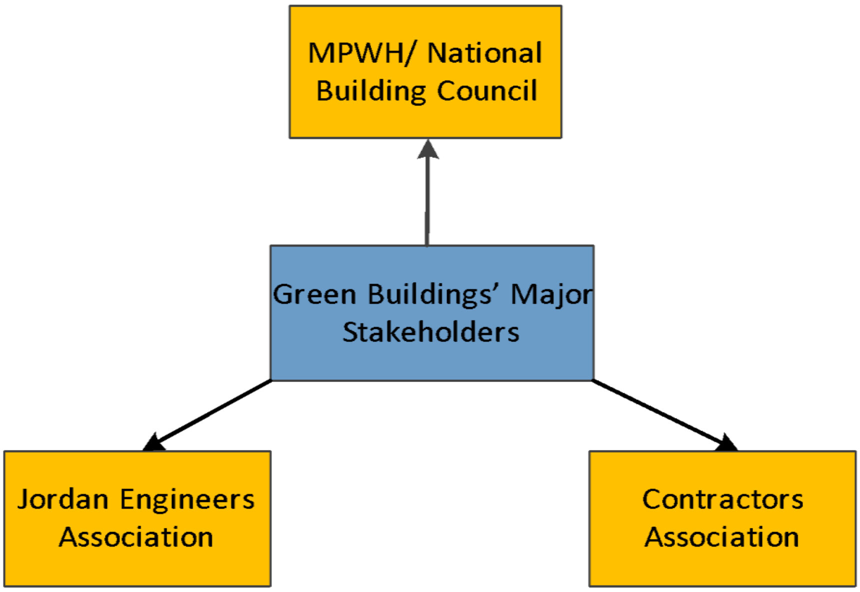


Figure 2.5: Green building development major stakeholders (RSSJ and FES, 2013)

Each of these stakeholders has a major role in green building development in Jordan. Table 2.6 shows these roles. In the process of green building development, the government established new research centres, as in the Royal Scientific Society to explore renewable and activist energy sources. Moreover, according to Alsubeh (2013), the government organisations supported energy effectiveness for achieving an efficient building architecture. However, despite the involvement of many major stakeholders in the process of green building development, there still lacks an enforcement body (see Table 2.6), which outlines a gap in the process (RSSJ and FES, 2013). This has led to an absence of rigid governmental actions towards delivering sustainable buildings, such as through policies, strategies and plans. Therefore, in order to deliver sustainable public buildings in Jordan, the public client needs to step up and start enforcing and requesting sustainable buildings. Moreover, the public client should start considering the adoption of sustainable construction strategies and plan to deliver sustainable buildings. Innovative technologies and sustainable management systems should be a key part of these strategies and plan.

Table 2.6: Stakeholders and their respective roles (RSSJ and FES, 2013)

Stakeholders Roles	**Ministry of Public Works and Housing and National Building Council**	**Jordan Engineering Association (JEA)**	**Jordanian Construction Contractors Association (JCCA)**
Regulatory Body	Develop building codes		
Administrative and Procedural Body	Construction building permits	Certify engineering plans	
Outreach, Awareness and Capacity Building		Access and outreach to engineering offices and training	Organise the work for the contractors and buildings
Technical Body	Hosting the technical committee that oversees the green building guidelines	Participate in the Green Building Guidelines	

2.7 CHAPTER SUMMARY

This has chapter identified the concepts, principles, strategies and plans for sustainable development and sustainable construction worldwide. The reviewed literature reveals that most of the previous research concentrated on the preconstruction phases to achieve sustainable buildings. These research focuses on building design regulations, innovative and sustainable building design and building sustainable assessment tools. However, delivering sustainable construction through a system of project management has recently started to receive attention from researchers.

Jordan is the focus of this research due to its pivotal political role in the Middle East. The construction industry in Jordan is the largest sector in the country as it is not only environmentally aware, but it is also economically significant to the country and an integral part of its security systems. Therefore, this chapter has explored the sustainable construction issues in Jordan beginning with the country's geographical location, traditions and economy. Then, the Jordanian construction industry development from 1980 until 2011 was discussed. The public sector was identified as the major client in Jordan; therefore, the research will focus on the Jordanian public construction sector.

Furthermore, this chapter has identified that there is a performance deficiency in the public buildings in Jordan, such as in the cost overruns, delays and lack of sustainability regarding the environment, economy and issues related to society. The reasons for this performance deficiency have been identified as political, cultural and economic. To tackle these issues, the Jordanian government represented by the MPWH and GTD and other major stakeholders established a green building development process and green building codes. However, there is still an absence of an enforcement body and rigid governmental actions towards delivering these sustainable buildings, as can be seen in the existing policies, strategies and plans. Moreover, there is a lack of research on delivering sustainable construction through project management approaches, which this research tries to fill. The next chapter introduces BIM as a new project management innovation system that can be adopted to achieve sustainable buildings.

CHAPTER 3: BIM-ENABLED SUSTAINABLE DESIGN AND DELIVERY

3.1 INTRODUCTION

Maximising value, lowering cost and achieving sustainability for construction clients is a key issue nowadays, especially in an industry that has been criticised for its lack of productivity and inefficiency (see Section 2.5.2.4). Moreover, the clients' requirements have become more bespoke and irregular; therefore, it becomes more difficult to present these requirements in a two-dimensional (2D) style.

Traditionally, 2D drawings and documents were relied on for design development and project information management, as Cohen (2010) has stated; this practice led to miscommunication and human error due to misinterpretations in the design and construction documents. On the other hand, one of the major considerations nowadays in the construction industry is the push for sustainability considerations for construction projects, as in having a high energy performance and low environmental impact. This adds an extra layer of specialised construction information requirements, which increases the complexity of the design and delivery process. Moreover, fragmented management practices currently used in the construction industry cause there to be a reworking and/or a redesigning of construction projects more frequently over a project's lifecycle (Smith and Tardif, 2009). Reworking and redesigning affect the project performance in terms of cost, quality and time. Reworking was estimated to cost 11% of the original contractual costs (Forcada, Gangolells, Casals & Macarulla, 2017; Love, Edwards, Smith & Walker, 2009). Additionally, quality defects and schedule delays are caused predominantly by redesign (Lopez, Love, Edwards & Davis, 2010; Goodrum, Smith, Slaughter & Kari, 2008; Sun & Meng, 2009). Therefore, managing, coordinating, integrating and updating the substantial amount of information from the construction project stakeholders over the lifecycle of a project becomes crucially important (Hooper and Ekholm, 2010; Clough, Sears & Sears, 2008; Kim, 2014).

BIM has been introduced as a response to the above issues, and it has been considered one of the most effective technological and organisational innovations in the Architecture, Engineering and Construction industry (AEC) (Succar, 2015). Technological innovation plays a key role in both short-term and long-term economic, societal and environmental sustainability. BIM has been classified as innovative (Davies and Harty, 2013; Brewer and

Gajendran, 2012) and as a disruptive piece of technology (Eastman et al., 2008). Disruptive innovation has been defined in the following:

> The extent to which it departs from industry norms […] renders existing business models obsolete, changes the basis of competition in an industry and produces sustainable competitive advantage by changing the way a whole industry works. (Loosemore, 2013)

Therefore, BIM is considered to be a major paradigm shift in the construction industry because it requires a change to the culture and the processes involved to achieve a more integrated approach (Succar, 2009; Ibrahim, Krawczyk & Schipporiet, 2004; HM Government, 2012; Hannele et al., 2012). This chapter develops a contextual background of BIM to ascertain whether it enables the design and delivery of the sustainable buildings' projects. This chapter comprises five main sections:

- An overview of BIM, which includes different BIM definitions, the levels of maturity, applications, dimensions and management.
- Identification of the BIM benefits and barriers from the literature.
- BIM adoption and implementation in the public sector in Jordan, including the global BIM status, BIM in the Middle East and Jordan. Moreover, this section emphases the importance of the BIM implementation in the public sector.
- BIM-sustainable buildings' nexus, which includes the BIM-supported lifecycle of sustainable buildings and the BIM-supported sustainable building assessment and analysis.

3.2 OVERVIEW OF BIM

3.2.1 BIM Definition

There is considerable divergence among those who attempt to define the meaning of BIM. Some ambiguity is in the phrase itself. For example, is the term modelling intended as a noun or verb? Does the model refer to an instantiated model or the underlying schema? BIM is usually written as Building Information Modelling with two distinct but complementary meanings: a particular engineering software or a managing process. The latter can be characterised as the adoption of an information-centric view of the whole lifecycle of a building (Watson, 2010). It is, therefore, challenging to find a single satisfactory definition of what BIM is. It is proposed that it should be considered and analysed as a multidimensional, evolving, complex phenomenon. The following are some of the BIM definitions found in the literature, arranged by year:

Table 3.1: BIM definitions

Author	**Year**	**Definition**
Jung and Gibson	**1999**	"Integration of corporate strategy, management, computer systems, and information technology throughout the project's entire lifecycle and across different business functions."
Graphisoft	**2003**	"A computer model database of building design information, which may also contain information about a building's construction, management, operations and maintenance."
Penttila	**2006**	"A methodology to manage the essential building design and project data in digital format throughout the building life cycle."
National Institute of Building Sciences	**2007**	"A digital representation of the geometric and non-geometric data of a facility."
AIA	**2008**	"A digital representation of the physical and functional characteristics of the single model or multiple models elements, and the process and technology used to create the model."
Autodesk	**2008**	"An innovative approach to building design, construction, and management that is characterised by the continuous and immediate availability of project design scope, schedule, and cost information that is high- quality, consistent and reliable."
London, Singh, Taylor, Gu and Brankovic	**2008**	"An information technology-enabled approach to managing design data in the AEC/FM (Architecture, Engineering and Construction/ Facilities Management) industry."
Kymmell	**2008**	"A tool helping project teams to achieve the project goals through a more transparent management process based on a three-dimensional (3D) model."
Eastman	**2008**	"A verb or adjective phrase to describe tools, process, and technologies that are facilitated by digital, mechanic-readable, documentation about building its performance, it's planning, its construction, and later its operation."

Krygiel and Nies	**2008**	"A creation and use of coordinated, internally consistent, computable information about a building project in design and construction."
Succar	**2009**	"A set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's lifecycle."
Hardin	**2009**	"A revolutionary technology and process that has transformed the way buildings are designed, analysed, constructed and managed."
Zuppa	**2009**	"A tool for visualising and coordinating AEC works to avoid errors and omissions."
Eastman, Teicholz, Sacks and Liston	**2011**	"A 'generic technology' that in principle allows many benefits, like more efficiency in construction, fewer mistakes, more accurate and up-to-date information, more illustrative and accessible exposition of the building and its characteristics to all project stakeholders."
Weygant	**2011**	"A technology that allows relevant graphical and topical information related to the built environment to be stored in a relational database for access and management."
Azhar	**2011**	"A Building Information Model characterises the geometry, spatial relationships, geographic information, quantities, and properties of building elements, cost estimates, material inventories, and project schedule."
Langdon	**2012**	"The ability to use and manipulate objects that can have extensive data on a variety of properties associated with them (geometry, connections to other objects, thermal performance, cost, delivery, life expectancy, etc.). And allows designers to produce accurate, coordinated, buildable and robust designs that can be tested in virtual 3D space before they are built."
NBIMS	**2012**	"A digital representation of the physical and functional characteristics of a facility creating a shared knowledge resource of information about it, forming a reliable basis for decisions during its life cycle from earliest conception to

		demolition."
Ilozor and Kelly	**2012**	"A myriad of computer software applications that can be utilised by design and construction professionals alike to plan, layout, estimate, detail and fabricate various components of a building."
HM Government	**2012**	"A collaborative way of working, underpinned by the digital technologies which unlock more efficient methods of designing, creating and maintaining our assets."
NHBC	**2013**	"Building Information Modelling (or 'management', more appropriately) is about identifying the important information or data that is used throughout the design, construction and operation of buildings, or any other built asset, and managing it to make it useful to all those involved."
Miettinen and Paavola	**2014**	"A digital representation of a building in the form of an object-oriented three-dimensional model, or a repository of project information to facilitate interoperability, automation of processes and exchange of information with related software applications."
BIMTG	**2014**	"Essentially a value-creating collaboration through the entire lifecycle of an asset, underpinned by the creation, collation and exchange of shared 3D models and intelligent, structured data attached to them."
Kim	**2014**	"An information management system to integrate and manage various construction information throughout the entire construction project life cycle based on a 3D parametric design to facilitate effective communication among project stakeholders to achieve a project goal(s) collaboratively."

Despite the many existing definitions for BIM in the literature, three important common characteristics of BIM can be identified (Kim, 2014):

1. Construction project information integration and management throughout the project life cycle.
2. Effective collaboration and communication between project stakeholders.

3. Building a representation digitally in a 3D object form with geometric and non-geometric attributes based on parametric design. Eastman et al. (2008) state that a building information model contains precise geometry and relevant data needed to support the design, procurement, fabrication, and construction activities required to realise the building. The building model has been characterised by (Eastman, 2008):
   - Data attributes and parametric rules.
   - Consistent non-redundant data so changes are propagated to all views, and the presentation of all views of the model are coordinated.
   - Components that include data which describe how they behave.
   - Building components represented by digital objects that know what they are and can be associated with computable graphics.

Depending on the definitions mentioned above, BIM is defined in this research as:

> An innovative information management process to collect, integrate, coordinate and communicate relevant graphical and non-graphical information related to the built environment throughout the entire construction project life cycle to achieve the client requirements and project goals.

3.2.2 BIM Level of Maturity

As BIM is a developing phenomenon, not all businesses are adopting systems and technologies at the same rate. A particular organisation defines BIM as a reflection of its 'maturity level' (Azhar, Hein & Sketo, 2008). And although BIM maturity definitions continue to be evolving (Kassem, Iqbal, Kelly, Lockley & Dawood, 2014; Succar, Sher & Williams, 2012), the main subject is still delivering co-ordinated graphical and non-graphical project information.

A BIM 'maturity level' is defined as "the quality, repeatability and degree of excellence within a BIM Capability" (Succar et al., 2012). A 'BIM Capability' is defined as "an organisation's level of performance or ability within a particular stage, which is measured to determine BIM Maturity according to the five maturity levels; ad-hoc, defined, managed, integrated, and optimise" (ibid) (see Figure 3.1). According to Barlish and Sullivan (2012), BIM capabilities are categorised into three main groups: object-based modelling, model-based collaboration and network-based integration. In each of these groups, there are five BIM maturity levels.

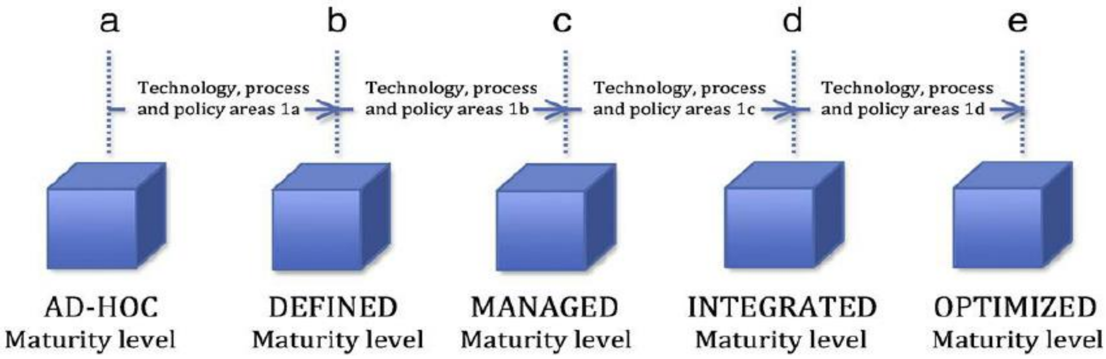


Figure 3.1: BIM maturity levels (Barlish and Sullivan, 2012)

Many others have attempted to benchmark the maturity of BIM implementation (Succar, 2009; NBIMS, 2007; Succar et al., 2012). The diagram in Figure 3.2 shows the most commonly adopted definitions of BIM maturity levels in the UK; it includes:

- Level 0: CAD files and paper-based documents are exchanged in an unstructured process.
- Level 1: Modelling: the use of object-oriented 3D modelling software within one organisation by a single disciplinary (Gu and London, 2010).
- Level 2: Collaboration: object-oriented models shared between two or more parties.
- Level 3: Full Integration: the integration of several multidisciplinary models using BIM servers where the ultimate goal is to move from local servers to a web-based environment (Gu and London, 2010).

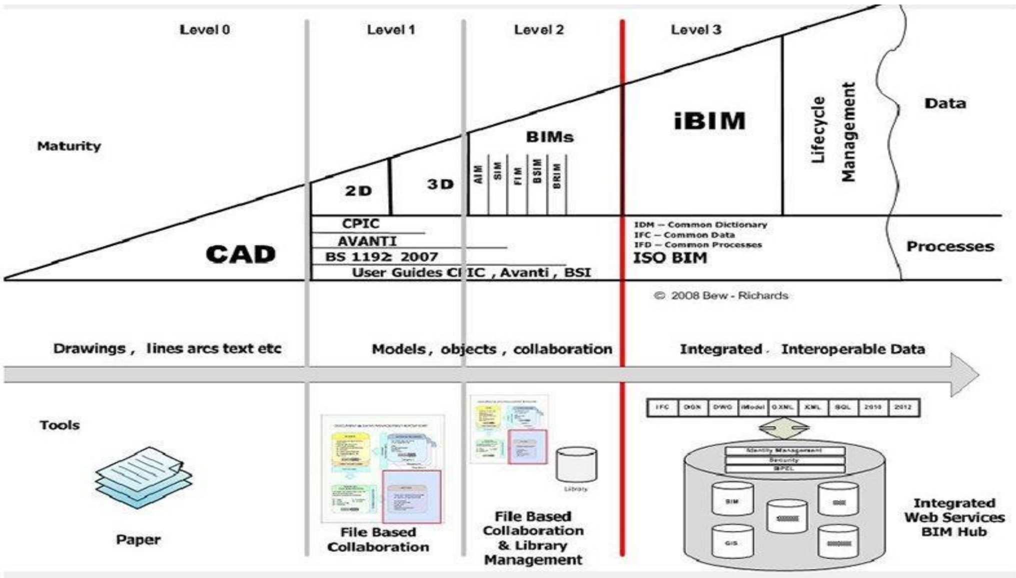


Figure 3.2: BIM maturity diagram (BIMTG, 2014)

3.2.3 BIM Application

BIM can be used over the entire lifecycle of a facility. BIM usage will change the ways building projects are designed, constructed, communicated and conceived; however, the core responsibilities of the building projects' stakeholders will not change (Simonian and Korman, 2010). Different stakeholders adopt BIM for different reasons. Identifying BIM potential applications is the first and most important step for developing strategies to fully implement BIM for building projects (Ahn, Kwak & Suk, 2016). BIM application by the major project stakeholders: clients, designers, constructors and facility managers are presented in Table 3.2 below.

Table 3.2: BIM application by project stakeholders (Azhar et al., 2012)

BIM application	Owners	Designers	Constructors	Facilities Managers
Visualisation	X	X	X	X
Options analysis	X	X	X	
Sustainability analysis	X	X		
Quantity survey		X	X	
Cost estimation	X	X	X	
Site logistic	X		X	
Phasing and 4D scheduling		X	X	
Constructability analysis		X	X	
Building performance analysis	X	X	X	X
Building management	X			X

In the context of Jordan, identifying how BIM is currently used for public buildings and also determining how construction stakeholders can implement BIM will have an impact on maximising the potential BIM benefits at each stage of the buildings' lifecycle. The BIM benefits are discussed in Section 3.3.1.

3.2.4 BIM Dimensions

BIM dimensions (nD) reflect the extent to which BIM applications are used to manage and deliver different aspects of the construction process. For example, "the extended use of 3D intelligent design (models) has led to references to terms such as 4D (adding time to model) and 5D (adding quantities and cost of material) and on and on" (AGC, 2006, p. 3). BIM dimensions (2D, 3D, 4D and 5D) are the only universally accepted BIM dimensions (Ahmed, 2014). However, there are more extended dimensions which are named and understood differently by different individuals and organisations. Table 3.3 shows different uses of BIM in a construction building project under each dimension.

Table 3.3: BIM dimensions and description

BIM (nD)	Capability	Description	References
2D	Drafting		(Autodesk, 2003, p. 1; Hardin, 2009, p. 253)
3D	3D Model	Project visualisation, clash detection model walkthroughs and prefabrication	(Autodesk, 2003, p.1; Hardin, 2009, p. 253; Eastman et al., 2011)
4D	3D + Time	Schedule, visualisation, construction planning and management	(Chartered Institute of Building 2010, p. 30; Eastman et al., 2011; Hardin, 2009, p. 253)
5D	4D (3D + Time) + Cost	Quantity take-offs and real time cost estimating	(Hardin, 2009, p. 253; Eastman et al., 2011)
6D	5D (3D + Time + Cost) + Facility Management	Data capturing and monitoring (the actual data on energy efficiency and building lifecycle costs) and lifecycle management	(Hardin, 2009, p. 253; Eastman et al., 2011)
7D	6D (3D + Time + Cost + Facility Management) + Sustainability	Embodied carbon, manufacturers and recycled content	(Hardin, 2009, p. 253)

BIM, via these 7 dimensions, can be implemented as a sustainable tool to design and manage construction projects. It has also been argued that the sustainability dimension (7D) could impact the rest of the BIM dimensions (Kapogiannis, Gaterell & Oulasoglou, 2015). For example, BIM can make the required information for sustainable design, certification and analysis consistently available, leading to cost (5D) reduction associated with sustainability analyses (Autodesk, 2003).

3.2.5 BIM Management

Building Information Modelling can be rephrased as 'Building Information Management' or 'Better Information Management'. However BIM is defined, at the 'heart' of BIM is information. There are three key documents to manage the information in BIM, and thus achieve a successful BIM project; these documents are BIM protocol, the employer's information requirement (EIR) and the BIM execution plan (Barnes and Davies, 2015).

3.2.5.1 The BIM Protocol

The BIM protocol aims at enhancing the production efficiency through adopting a consistent and coordinated approach to working within BIM (Barnes and Davies, 2015). BIM protocol is also used to define best practices and standards that ensure the delivery of high-quality data and uniform drawings' output over the entire project cycle (Ibid).

In the UK, the Construction Industry Council (CIC) BIM Protocol was issued to meet the requirements of BIM level 2. This protocol can be used as a supplementary legal agreement that can be incorporated into a construction contract and professional service appointments by way of a simple amendment. Moreover, this protocol puts in place specific obligations, liabilities and associated limitations on BIM model usage. In the US, the AIA released its 'Building Information Modelling Protocol Exhibit', which is intended to be attached to owner–architect and owner-contractor agreements (Lowe and Muncey, 2010).

A typical BIM protocol document could include (Barnes and Davies, 2015):

- An introduction to the project.
- BIM usage extent for the project.
- How the protocol is placed in the contractual document.
- BIM manager's details and who should appoint him/her.
- Employer information requirements.
- An organogram that shows how different stakeholders contributed to the BIM process.

- BIM execution plans.
- Level of model development (LOD).
- Details of the BIM models' 'data drop'.
- The common data environment (CDE).
- Details of the software to be used.

3.2.5.2 Employer Information Requirements (EIR)

EIR is considered to be one of the key documents to successfully deliver BIM-based construction projects (Dwairi, 2016). EIR could be developed alongside the project brief, which defines the nature of the built asset that the client/developer wishes to procure. By contrast, the EIR defines the information that complies with the project/asset that the client wishes to procure, in which the design is guaranteed to be developed according to their needs (Barnes and Davies, 2015).

EIR usually forms part of the tender document on a BIM project (Barnes and Davies, 2015). It includes requirements in three main areas regarding commercial, management and technical information. Table 3.4 shows the possible information with regard to these areas that can be embedded in the EIR.

Table 3.4: EIR items (Dwairi, 2016)

Commercial	Management	Technical
Project deliverables and data drops	Standards	Software platforms
Client strategic purpose	Roles and responsibilities	Data exchange formats
Define BIM/ project deliverables	Planning work and data segregation	Coordinates
BIM-specific competence assessment	Security	Level of detail
	Coordination and clash detection	
	process	
	Collaboration process	

3.2.5.3 BIM Execution Plan (BEP)

BEP can sometimes be abbreviated as BxP. The purpose of BEP is to manage the delivery of the project and to ensure that responsibilities and opportunities are clearly understood by all the stakeholders in a BIM-based project. The four main steps within a typical BIM execution plan procedure are as follows (see Figure 3.3) (Computer Integrated Construction Research Program, 2010):

- Identifying BIM goals and uses during the project lifecycle.
- Designing the BIM project execution process by creating process maps.
- Developing an information exchange by defining BIM deliverable and responsible parties.
- Defining the project infrastructure to support the developed BIM process.

BEP comprises two parts: a pre-contract BEP and post-contract BEP. Prospective suppliers prepare a pre-contract BEP in which the required capacities, proposed approaches and competences are set out to meet the EIR. Subsequently, the supplier with the awarded contract prepares the post-contract BEP to confirm the supply chain's capabilities and provides a master information delivery plan (MIDP) alongside individual task information delivery plans (TIDPs). Individual TIPDs include responsibilities for specific information tasks. A series of individual TIPDs build up the MIDP, which is a primary plan that explains when the information for the project is to be prepared, the responsible parties and the procedures and protocols to be used (Barnes and Davies, 2015). Figure 3.3 represents the relationship between the BIM protocol, EIR, pre-contract BEP and post-contract BEP as mapped by the British standard (PAS1192-2:2013).

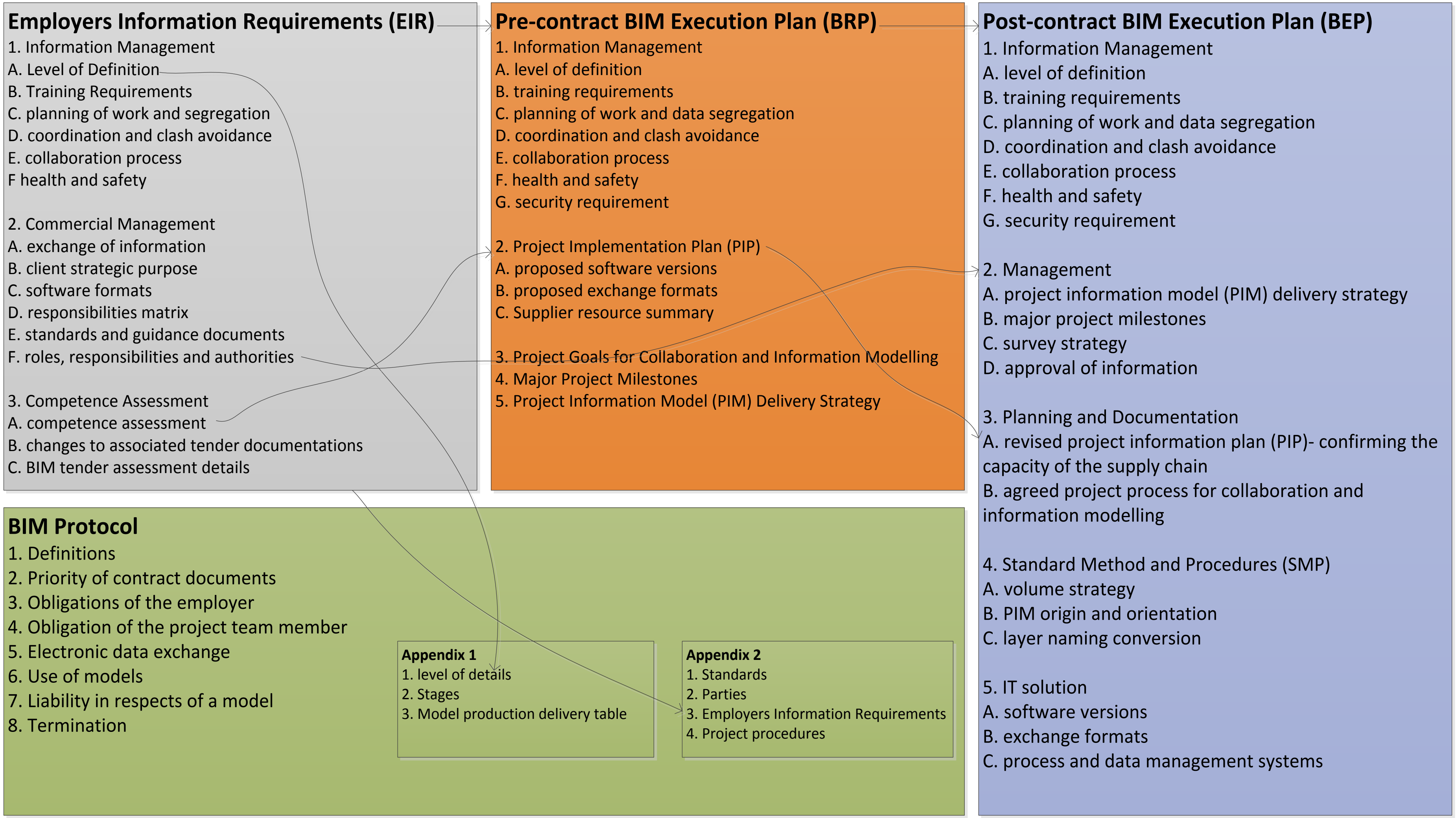


Figure 3.3: A map of the PAS1192-2:2013 delivery process from EIR up to post-contract BIM execution plan, adapted from (Earley, 2015)

3.2.5.4 Level of Development (LOD)

LOD consists of two principal pieces of information: 'level of details' and 'level of information' (LOI). Level of details refers to the graphical content of a BIM model whereas LOI refers to the non-graphical content of a BIM model. These two concepts are usually aligned as both are developed alongside each other (Barnes and Davies, 2015). LODs are identified as an important and critical issue since they represent the model information at specific stages, and they are associated with the BIM implementation's practical side (Wu and Issa, 2014). Table 3.5 represents the suggested level of development by CIC (2013) and AIA (2013).

Table 3.5: Level of development (AIA, 2013; CIC, 2013; BIMForum, 2013, P.10)

LOD (AIA, 2013)	**LOD (CIC, 2013)**	**Description (BIMForum, 2013)**
LOD100	1 (Preparation and brief)	"The Model Element may be graphically represented in the Model with a symbol or other generic representation but does not satisfy the requirements for LOD 200. Information related to the Model Element (i.e. cost per square foot, the tonnage of HVAC, etc.) can be derived from other Model Elements."
LOD200	2 (Concept design)	"The Model Element is graphically represented within the Model as a generic system, object, or assembly with approximate quantities, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element."
LOD300	3 (Developed design)	"The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of quantity, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element."
LOD350	4 (Technical design)	"The Model Element is graphically represented within the Model as a specific system, object, or assembly in terms of quantity, size, shape, orientation, and interfaces with other building systems. Non-graphic information may also be attached to the Model Element."
LOD400	4 (Construction)	"The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of size, shape, location, quantity, and orientation with detailing fabrication, assembly, and installation information. Non-graphic information may also be attached to the Model Element."
LOD500	5 (Handover and close out)	"The Model Element is a field verified representation in terms of size, shape, location, quantity, and orientation. Non-graphic information may also be attached to the Model Elements."

3.2.5.5 Common Data Environment (CDE)

Many BIM protocols such the one in the UK (CIC BIM Protocol) propose the existence of a common data environment (CDE) in order to exchange the project information in BIM-based construction projects (McPartland, 2016). The CDE is the single source of information for the project and acts as the central repository of the project information. It is used to collect, manage and disseminate documentation for project stakeholders; it includes graphical and non-graphical information (that is information created in a BIM environment and in a conventional data format) (Barnes and Davies, 2015).

As can be seen in Figure 3.4, the CDE consists of four main areas of information: a work in progress area in which unapproved information is held for each organisation; a shared area in which information is held that has been checked, reviewed and approved for sharing with other organisations; a published area with information that the client or their representative has 'signed off'; and an archive area where progress at each milestone, changed orders and transactions are recorded.

The BIM information exchange within the CDE should be managed by an information manager (BIM manager). BIM protocols normally require the appointment of a BIM information manager by the client (CIC, 2013). The main role of a BIM information manager is to set and manage the CDE by policing it to make sure that the data are secure, and that it follows the agreed protocol. The following are a summary of other BIM information manager's principle responsibilities (CIC, 2013):

- Managing the processes and procedures for information exchange on projects.
- Initiating and implementing the Project Information Plan (PIP) and Asset Information Plan (AIP).
- Assisting in the preparation of project outputs, such as data drops.
- Implementation of the BIM protocol, including the updating of the MPDT.

The BIM information manager's role could be performed by different entities over the project lifecycle. For example, the lead consultant or lead designer may be the information manager during the early stages, with the contractor acting as the information manager in the construction phase (Barnes and Davies, 2015).

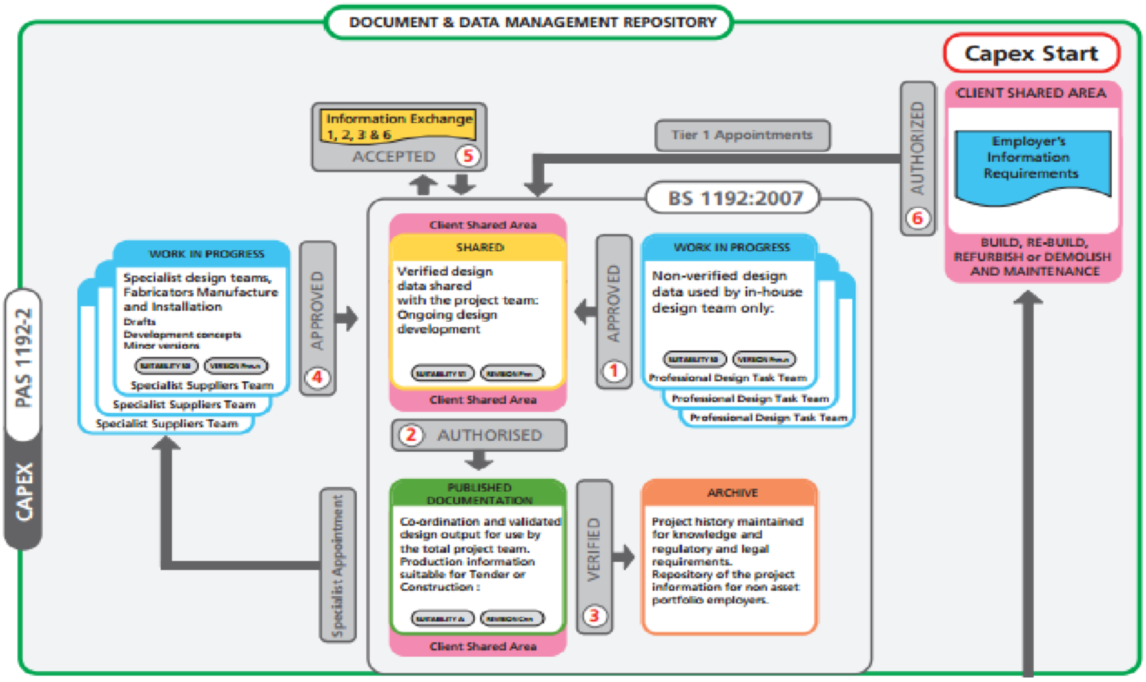


Figure 3.4: Common data exchange (BSI, 2013b)

3.3 BIM BENEFITS AND BARRIERS

3.3.1 BIM Benefits

The benefits associated with BIM implementation are vital (Ahn et al., 2016). There is a belief that the adoption of BIM can improve the performance of the construction industry (Crotty, 2012) since BIM implementation is a means for providing accurate scheduling timetables, diminishing total project costs, yielding quantity take-offs and enhancing project quality (Eastman et al., 2008). The National Research Council (NRC) (2009) conducted one of the first studies on developing a strategy for improving the efficiency, productivity and competitiveness in the US construction industry. The findings from this study identified BIM as a promising solution in terms of enhancing sustainability, timeliness, quality and cost-effectiveness, which the JCI suffers from (see Section 2.5.2.4). According to the Cooperative Research Centre (CRC) for construction innovation (2007), the key benefits of BIM implementation are having an accurate representation of the building parts in an integrated data environment. In 2007 and based on 32 major projects that used BIM, the Stanford University Centre for Integrated Facilities Engineering (CIFE) indicated that the following were achieved:

- Cost estimation accuracy within 3%.
- Up to 40% elimination of unbudgeted change.
- Up to 80% reduction in the time taken to generate a cost estimate.
- A saving of up to 10% of the contract value through clash detections.
- Up to 7% reduction in project time.

Table 3.6 includes the BIM benefits that have been identified by scholars and construction practitioners in a typical construction project.

Table 3.6: Benefits of BIM implementation

Benefits	References
Improved decision-making process (better visualisation and 'what if' scenarios)	Construction Users Roundtable (CURT) (2010); Eastman et al. (2008); Fox and Hietanen (2007); Lu et al. (2015); Manning and Messner (2008); Sacks et al. (2010); Yan and Damian (2008)
Better design and multi design alternatives	Aranda-Mena et al. (2009); CRC Construction Innovation (2007); CURT (2010); Eastman et al. (2008); Fox and Hietanen (2007); Sacks et al. (2010); Saxon (2013)
Predictive analysis of performance (finite-element, energy analysis and code analysis)	Eastman et al. (2008); Fox and Hietanen (2007); Lee et al. (2015); Sacks et al. (2010); Taylor and Bernstein (2009)
Improve collaboration in design and construction	Bolpagni (2013); Lee et al. (2015); Lu et al. (2015); Sacks et al. (2010); Saxon (2013); Taylor and Bernstein (2009); Young et al. (2008); Wu and Issa (2014)
Reduced project time and costs	Bolpagni (2013); Bynum et al. (2013); CURT (2010); Hergunsel (2011); Saxon (2013); Suermann and Issa (2009); Yan and Damian (2008); Azhar et al. (2008); Young et al. (2008)
Improved quality	Bolpagni (2013); CURT (2010); Sacks et al. (2010); Suermann and Issa (2009); Yan and Damian (2008); Young et al. (2008)
Improved construction process and efficiency (less reworking and fewer document errors and omissions)	Aranda-Mena et al. (2009); Barlish and Sullivan (2012); Boktor et al. (2014); CRC Construction Innovation (2007); CURT (2010); Dossick and Neff (2010); Eastman et al. (2008); Hergunsel (2011); Sacks et al. (2010); and Suermann and Issa (2009); Redmond et al. (2012)
Improved safety	Ku and Mills (2010); Sacks et al. (2010); Sulankivi et al. (2010); Zhang et al. (2012)

Reduced claims or litigation (risks)	Bolpagni (2013); Aranda-Mena et al. (2009); CURT (2010); Eastman et al. (2008); Saxon (2013)
Improved operations and maintenance (facility management)	Azhar (2011); CRC Construction Innovation (2007); CURT (2010)
Sustainability enhancement	Krygiel and Nies, (2008); Redmond et al. (2012)

Sustainability enhancement is the focus of this research and research suggests BIM supports sustainability in many ways, in the case of informed decisions regarding energy performance and embodied carbon dioxide (CO_2 in the early stages by assessing the buildings' energy performance and embodied CO_2) (Krygiel and Nies, 2008; Redmond et al., 2012). Section 3.5 discusses in detail the BIM support for sustainability over the buildings' project lifecycle and sustainability assessment.

3.3.2 BIM Barriers

Despite the numerous BIM benefits for project stakeholders, there are many barriers to BIM implementation. BIM barriers were classified by Bernstein and Pittman (2004) into three main categories: Human/organisational, technical and business barriers. Business barriers were investigated further by Kiviniemi et al. (2008) and expanded to become the business and legal barriers. Table 3.7 represents the BIM barriers identified in the literature under each of these categories.

Table 3.7: Barriers to BIM implementation

Barriers categories	Barriers description	References
Business and Legal Problems	**Additional resources and expenses (high economic investment software)**	Dedrick et al. (2003); Young et al. (2008); Yan and Damian (2008); Aranda-Mena et al. (2009); Bolpagni (2013); Hergunsel (2011)
	Fragmented procurement approaches	Becerik-Gerber and Kensek (2010); Bolpagni (2013); Sackey et al. (2015)
	Increased risk and liability	Young et al. (2008); Becerik-Gerber and Kensek (2010); Azhar (2011)
	Lack of a comprehensive framework or implementation plan	Azhar (2011); Jung and Joo (2011); Bolpagni (2013); Saxon (2013); Lu et al. (2015)
	Lack of a legal framework (model ownership and legal contract)	Aranda-Mena et al. (2009); Becerik-Gerber and Kensek (2010); Azhar (2011); Olatunji (2011)

Technical Problems	**Lack of standards**	Pittman (2004); London et al. (2008); Howard and Bjork, (2008); Succar (2009); Manning and Messner, (2008); Taylor and Bernstein (2009); Eastman et al. (2011)
	Lack of interoperability	Aranda-Mena et al. (2009); Prins and Owen (2010); Becerik-Gerber and Kensek (2010); Azhar (2011); Hergunsel (2011); Bolpagni (2013); Saxon (2013)
Human/ Organisational Problems	**Attitude and awareness (resistance to change from 2D drafting practices)**	Yan and Damian (2008); Young et al. (2008); Aranda-Mena et al. (2009); Becerik-Gerber and Kensek (2010); Gu and London (2010); Prins and Owen (2010); McCuen et al. (2012)
	Complexity (long hours to develop a BIM model)	Goedert and Meadati (2008); Becerik-Gerber and Kensek (2010); Prins and Owen (2010)
	Cultural change	Azhar et al. (2008); Bolpagni (2013); Saxon (2013)
	Employees lack BIM skills, education and training (design, engineers and subcontractors)	Cook (2004); Young et al. (2008); Aranda-Mena et al. (2009); Becerik-Gerber and Kensek (2010); Prins and Owen (2010); Saxon (2013); Wu and Issa (2014)
	Organisational challenges among construction professionals	Taylor and Bernstein (2009); Won et al. (2009); Dossick and Neff (2010); Saxon (2013); Boktor et al. (2014); Lee et al. (2015)

- **Business and Legal Problems:**

The absence of a universal BIM standard resulted in having customised BIM standards by different construction project stakeholders, which are unclear on the type of information within LODs that needed to be exchanged with the other stakeholders (Langdon, 2012). As a result, the roles and responsibilities, which have been clearly defined in conventional construction projects, are not well defined in BIM-based construction projects (Ilozor and Kelly, 2012). Therefore, the legal and contract issues related to certain risks have arisen. Legal and contractual risks in BIM-based construction projects include (Azhar, 2012):

1. Un-defined intellectual property of a BIM model, which includes ownership and copyright (Holzer, 2007). Rosenberg (2007) suggested that setting ownership rights and responsibilities in the contractual documents is the best solution to prevent copyright disagreement issues.
2. Controlling the data entry and inaccuracies responsibilities: this is a BIM contractual issue where being responsible for updating the project information

model data and keeping the data accuracy about a project lifecycle entails a high risk.

3. The BIM integrated concept blurs responsibility levels to the limit that risk and liability might be increased.

Azhar (2012) suggested that one of the most effective ways to deal with such risks is to have a procurement approach that is integrated and collaborative in nature.

- **Technical problems**

A lack of BIM standards for model integration and managing multidisciplinary teams is amongst the significant technology-related barriers. Multidisciplinary information integration into a single BIM model needs to have access available to multiple users, which in turn gives the need to have BIM protocols to ensure consistency in information and formatting styles (Azhar, 2012). In the absence of a standard protocol, each stakeholder uses his/her standard which could lead to inconsistencies and inaccuracy of the BIM models.

Other technological-related risks, as expressed by Azhar (2012), are interoperability issues and licensing issues. Interoperability issues can be defined as problems relating to the data exchange between different applications to avoid data re-entry and to facilitate automation. Common languages such as Industry Foundation Classes (IFC) and XML Schemas have considerably helped to overcome interoperability issues (Smith and Tardif, 2009).

- **Human/Organisational Problems**

It has been argued in the literature that human/organisational problems are derived from the other two types of BIM problems. According to Hardin (2009) and Eastman et al. (2011), the current fragmented practice of the construction industry is the main cause of human/organisational problems that effect BIM implementation. Therefore, increased collaborative and integrated construction practices and cultural changes are required to implement BIM effectively (Hannele et al., 2012; Succar, 2009).

Cultural change is one of the main requirements for effective BIM implementation, which can be achieved by changing the mind-set of the stakeholders towards embracing new technologies, changing the working environment to being cooperative instead of adversarial, increasing the awareness of the BIM benefits and adopting a ‘no blame’ culture (Porwal and Hewage 2013; Smith 2014).

3.4 BIM STATUS

3.4.1 BIM Global Status

The perceived benefits of BIM implementation have resulted in an increase of BIM adoption worldwide in the last few years. In the US, BIM adoption by the contractors has increased significantly from 2007 to 2012 (McGraw Hill, 2014). Between 2007 and 2012, there was a surge of 54% of BIM adoption in the construction value in the US construction industry (Lee et al., 2014). Moreover, BIM adoption by the construction industry practitioners has increased in European countries to 36% in 2010 (McGraw-Hill, 2010b).

National Building Specification (NBS) conducted an international BIM survey in 2015 to investigate the BIM adoption within the international design community. The respondents were from design firms, consultants, general contractors, subcontractors or suppliers and research institutes. This report shows the implementation percentage of BIM in 2015 in the UK, Canada, Denmark, the Czech Republic and Japan. In the UK, BIM usage in the construction projects has increased by 9% between 2013 and 2015. Canada moved from 64% in 2013 to 67% in 2015. Table 3.8 shows the BIM implementation percentages in construction projects in these countries. Another report (McGrawHill, 2014) confirmed that BIM usage was projected to increase sharply in the construction industry, especially in the contractors’ firms in many countries, as shown in Table 3.9; this is due to the realisation of the potential of this technological and procedural evolution within the construction industry (Gerges et al., 2017).

Table 3.8: BIM implementation percentages in construction projects (NBS, 2016)

Country	**2015**
The UK	48%
The Czech Republic	25%
Denmark	78%
Canada	67%
Japan	46%

Table 3.9: BIM implementation percentage in contractors' firms in 2013 and 2015 (McGraw, 2014)

Country	2013	2015
Germany	37%	72%
The United States	55%	79%
Brazil	24%	73%
France	39%	71%
Australia	33%	71%
Japan	27%	43%
New Zealand	23%	50%
South Korea	23%	52%

3.4.2 BIM in the Public Sector in Jordan

One of the main drivers that has influenced BIM implementation is the political pressure applied to the construction industry, as has occurred in many countries; BIM has been pushed and mandated by certain public bodies such as UK government (Won, 2013). Many researchers have investigated BIM adoption and implementation worldwide, and where some focused on the public sector, others did so on the private sector or on the whole construction industry including both private and public sectors. At the same time, the main focus of these researchers was on standards, guidelines, reports, visions and roadmaps of BIM implementation or the roles and responsibilities of the stakeholders when implementing BIM.

Succar (2009) listed all the reports, visions and guides that related to BIM and which are publicly available in the US, Denmark, Australia, Finland, Norway, Netherlands and a consortium of organisations in Europe. Other researchers discussed the roles of both sectors that are the public and private sectors in Norway, Singapore, Finland and Denmark in promoting and providing support for BIM implementation. Jauhianian (2011) presented examples of BIM adoption in the public sector in three countries: the General Services Administration (GSA) in the US, the Senate Properties in Finland and the Statsbygg in Norway. Wong (2011) compared the governmental guidelines, standards, policies and implementation status in the US and Hong Kong.

Martin (2012) conducted a comparative review of the BIM national guidelines in the UK, the US, Norway, Finland, Australia, Sweden and Denmark. Cheng (2015) compared the different kinds of roles and efforts made by the public sector for BIM adoption in four main regions: Europe, the US, Asia and Australia. By highlighting the successful BIM implementation strategies and identifying the gaps, it was surmised that the public client has six roles to play for BIM adoption. These include driver and initiator, educator, regulator, researcher, demonstrator and funding agency. Cheng (2015) and Wong et al. (2009) concluded that the public sector has a primary role in BIM adoption. Many countries around the globe have realised the vital role of the public authorities in promoting BIM, such as in the UK and the US (Won, 2013). Therefore, many governments including the US (Wong et al., 2009), Australia (BuildingSMART, 2012) and the UK (HM Government, 2012) have set implementations strategies for the use of BIM on construction projects.

In the US, the General Services Administration (GSA) "an independent agency of the United States government, was established in 1949 to help manage and support the basic functioning of federal agencies", committed to adopting 3D, 4D and BIM technologies on a strategic and incremental levels to bridge the adoption gap since 2003 (Cefrion, 2011).

In Australia, the Cooperative Research Centre (CRC) for Construction Innovation and the Australian Institute of Architects have collaborated in the development of a conceptual framework for BIM implementation; this framework provided the key elements of a BIM evolutionary process as well as a roadmap for the higher levels of BIM (CRC for Construction Innovation, 2007). Moreover, a range of actions was also suggested for the government and the industry in Australia (Porwal and Hewage, 2013):

- National strategies for BIM implementation to be developed and include national priorities and stimulation of the involvement of the government and private clients.
- New procurement approaches to be developed and implemented for BIM.

In the UK, BIM adoption and implementation were among the main principle objectives of the 'Government Construction Strategy (GCS) 2016' to improve the national infrastructure. The following are the main principle objectives of this strategy:

- Embedding and increasing the use of digital technology, such as BIM Level 2.
- Deploying collaborative procurement approaches.

The UK government has also mandated BIM since 2016 for all the public projects that exceeded £5 million as per the 'Smart Market Report' to reduce project delays and cost overruns (Lee et al., 2014). This has led to an increase in BIM adoption in the UK from 19% to 39% between 2010 and 2012 (NBS, 2013). Francis Maude (2012), the Minister for the Cabinet Office, stated the following:

> The government's four-year strategy for BIM implementation will change the dynamics and behaviours of the construction supply chain, unlocking new, more efficient and collaborative ways of working. This whole sector adoption of BIM will put us at the vanguard of a new digital construction era and position the UK to become the world leaders in BIM. (McGough, Ahmed & Austin, 2013, p. 396)

The UK governmental construction strategies have increased the importance of BIM adoption and implementation in the UK. Thus, various construction professional organisations have released standards, protocols and guidelines for effective management and integration of construction information. Table 3.10 shows these standards, protocols and guidelines (NBS, 2015; NBS, 2016).

Table 3.10: UK BIM Standards, protocols and guidelines (NBS, 2015; NBS, 2016; Kim, 2014)

Organisations	BIM Standards and Protocols
BSI	"PAS 1192-2:2013, specification for information management for the capital/delivery phase of construction projects using building information modelling"
	"PAS 1192-3:2014, specification for information management for the operational phase of assets using building information modelling BIM"
	"BS 11924-4:2014 - Collaborative production of information. Part 4: Fulfilling employer's information exchange requirements using COBie (Construction Operations Building Information Exchange) – Code of practice"
	"PAS 1192-5:2015; Specification for security-minded building information management, digital built environments and smart asset management. Provides guidance on how to secure the intellectual property, the physical asset, the processes, the technology, the people, and the information associated with the asset"
	"BS 8536:2015; Facilities Management (FM) briefing for design and construction. For the building's infrastructure, guidance upon the definition of required social, environmental, and economic outcomes as well as the process of achieving those required outcomes"
	BS 8541; Range of standards for "library objects (architectural, engineering, and construction)"
CIC	BIM Protocol, Standard Protocol for use in projects using Building Information Models
RIBA	BIM Overlay to the RIBA Plan of Work

	RIBA Plan of Work 2013 Construction
RIBA and NBS	"Uniclass2015. A classification system that can be used to organise information throughout all aspects of the design and construction process"
BIM Task Group	GSL (Government Soft Landings) – Developed to champion better outcomes for the UK's built assets during the design and construction stages, powered by BIM, so as to ensure that value is achieved in the operational lifecycle of an asset
	Construction Operations Building Information Exchange (COBie) UK 2012

Mandating BIM adoption and implementation by the UK government had a positive impact on BIM adoption in the Middle East due to the significant economic relationship between the Middle East and the UK, which has led to the dominance of British architects, consultants, contractors and project managers in the Middle East (Gerges, 2016). Therefore, BIM adoption and implementation in the Middle-East region is expected to rise. Other significant factors for increasing the BIM adoption rates in the Middle East are:

- The existence of multi-national firms with multiple offices across the Middle East region, which in turn have imposed the adoption and implementation of BIM in the Middle East (Gerges et al., 2017).
- The rapid growth of mega and complex projects in many of the Middle Eastern countries was one of the main motivators for increasing BIM adoption and implementation (Gerges et al., 2017).
- The widespread use of some of the UK BIM Standards, protocols and guidelines mentioned in Table 3.10 in the Middle East. For example, the RIBA Plan of Work established an international chapter called 'RIBA Gulf Chapter' for members in Jordan, UAE, Bahrain, Saudi Arabia, Kuwait and the Sultanate of Oman. This chapter is one of eleven international RIBA chapters. The RIBA Gulf Chapter is actively engaged with a diverse and very significant number of RIBA and non-RIBA practitioners to support and communicate with RIBA overseas members and arrange activities, such as networking events (RIBA Gulf Chapter, n.d).

Despite these influences, most of the Asian countries are still lagging behind the US and Europe in general in BIM adoption (Cheng et al., 2015). In the Middle East, Jordan and the Gulf Cooperation Council (GCC) countries were surveyed in (2011) by BuildingSMART to report on the adoption of BIM in the Middle-East region. This survey showed that 25% of the participants were 'familiar' with BIM processes, but only 5% were using it (BuildingSMART, 2011). It was also stated that the use of BIM had improved productivity and quality control and reduced design errors (ibid). Another study was conducted by Gerges (2016) on BIM implementation in the Middle East, particularly in Kuwait. He reported that many of the BIM benefits in the region included improving communication, encouraging collaboration, thus mitigating project risks, and monitoring the status of the project throughout the project phases, facilitating stakeholders in a transparent way.

In 2014, another survey took place and reported that 10% of the construction professionals in the Middle East are using BIM with an increase of only 5% from the previous survey in 2011 (CW Staff, 2014). This could be because the use of BIM is not mandatory in the region (BuildingSMART, 2011). On the other hand, BIM has been implemented mainly for basic tasks, such as drawing extraction, 3D visualisation and rarely for planning (Awwad, 2013).

Recently, a survey was conducted by Gerges et al. (2017) to investigate BIM implementation in the Middle East, including Jordan, the GCC, Egypt and Lebanon. 297 questionnaires were sent out with a 67.34% response rate. The findings revealed that 20% of the AEC organisations in the Middle East were using BIM, but Jordan was one of the countries with the least BIM projects (Gerges et al., 2017). Comparing the findings from Gerges et al.'s (2017) research with BuildingSMART's (2011) studies, it seems clear that BIM adoption in the Middle East is rising. However, the surveyed respondents from Jordan totalled only 3% of the overall response to the questionnaire distributed by Gerges et al (2017).

As stated above, BIM adoption in the Middle East has slowly increased, but it is lagging behind the rate of BIM adoption in the aforementioned developed countries. Awwad (2013) explained that the main reason is that no steps have been taken by the public sector to implement BIM. The Jordanian government, on the other hand, was the first in the Middle East to take the BIM oath. MPWH and the JEA have signed an agreement with BuildingSMART and the BIM Journal to establish the BuildingSMART Forum in Jordan and to promote BIM adoption and implementation (Middle East Construction News, 2011). However, since signing the agreement, there have been no steps taken toward achieving its targets.

Recently, the Jordanian government showed an increased interest in BIM implementation on its building projects by starting to request the use of BIM to deliver significant public buildings. For example, the Al Tafaileh Governmental Hospital (Matarneh and Hamed,

2017) and the new airport terminal were requested to be designed and delivered using BIM. Therefore, it can be said that the Jordanian government is in the process of requesting BIM for its public building projects.

However, the literature revealed a lack of studies on BIM adoption and implementation in Jordan in both the private and public construction sectors. Adding to the aforementioned BIM survey conducted in 2011 by BuildingSMART on the GCC and Jordan, Al Awad (2015) conducted research to provide insight into the context of IT and BIM adoption by small and medium-sized enterprises (SMEs) in construction in Jordan; his research was the first academic work to investigate BIM in Jordan, and it was concluded that "BIM adoption among construction SMEs in Jordan is virtually non-existent" (Al Awad, 2015, p. 207). Moreover, AutoCAD was found to be the main design tool. Al Awad (2015) also found that one of the main barriers to implementing BIM is the 'culture and tradition of work', which he suggested needs to be overcome along with other barriers; there is a need for management change, communication, training and streamlined processes. There are limitations in his work in that there were a small number of surveyed participants and the focus was not the public construction sector in Jordan.

At the time of writing up the thesis, the most recent research was conducted by Matarneh (2017) to identify BIM experiences and the perceived benefits, values and challenges of BIM adoption and implementation in Jordan. The findings from the research revealed that BIM adoption and implementation in Jordan is still in a primitive phase.

Despite the crucial role of the public client in Jordan (see Section 2.5.2.2), the public construction sector was not investigated in any of the above studies. Therefore, this demonstrates a gap in the research on the BIM status, benefits, barriers and feasibility in the Jordanian public construction sector. This research will try to fill this gap by investigating the current status of BIM in the public sector in Jordan.

3.5 BIM-SUSTAINABLE BUILDINGS NEXUS

Sustainability enhancement is among the main benefits of BIM implementation. The main objective of this chapter is to investigate the impact of adopting BIM approaches for the design and delivery of sustainable building projects. Therefore, this section will discuss the BIM support for delivering sustainable buildings.

Delivering sustainable buildings bears not only building performance-related considerations, but also addresses the economic, social and environmental impacts of the building industry; this adds extra layers of necessary information, and so it is desirable to have efficient information-technological solutions. BIM was identified as the most promising solution in terms of improving sustainability and meeting the global need for sustainable buildings (Kumanayake and Bandara, 2012) since BIM supports the supply, management and integration of such requisite information throughout the lifecycle of a building (Häkkinen and Kiviniemi 2008). Moreover, although BIM is not a new technology within the construction industry, recently, the potential for BIM and its relationship to sustainability is beginning to be realised as the demand is increasing annually (Bynum et al., 2013). As such, practitioners believe that BIM can achieve sustainable construction outcomes more efficiently than non-BIM approaches (McGraw-Hill, 2010a), and that such benefits accrue in projects across the globe (Mihindu and Arayici, 2008).

Love and Smith (2003) sent 100 questionnaires to AEC practitioners and academics in the UK and the US to ask about BIM benefits. It was found that BIM can improve sustainability and increase creativity in addition to reducing cost and time and improving quality. Khosrowshahi and Arayici (2012) surveyed respondents from the UK construction industry to find the issues that BIM can address; they found that BIM implementation can improve sustainable design, construction, risk management, the reliability of the facilities, asset management, coordination of client changes to the design, and reduce errors, reworking and waste.

In order to provide a holistic understanding and critical reflection on the nexus between BIM and sustainable buildings, Figure 3.5 presents the 'Sustainable BIM Triangle'. As can be seen, two central themes reflect the nexus between BIM and sustainable buildings: BIM, if managed, can supports the lifecycle of sustainable buildings. And BIM supports the sustainable building analysis and assessment.

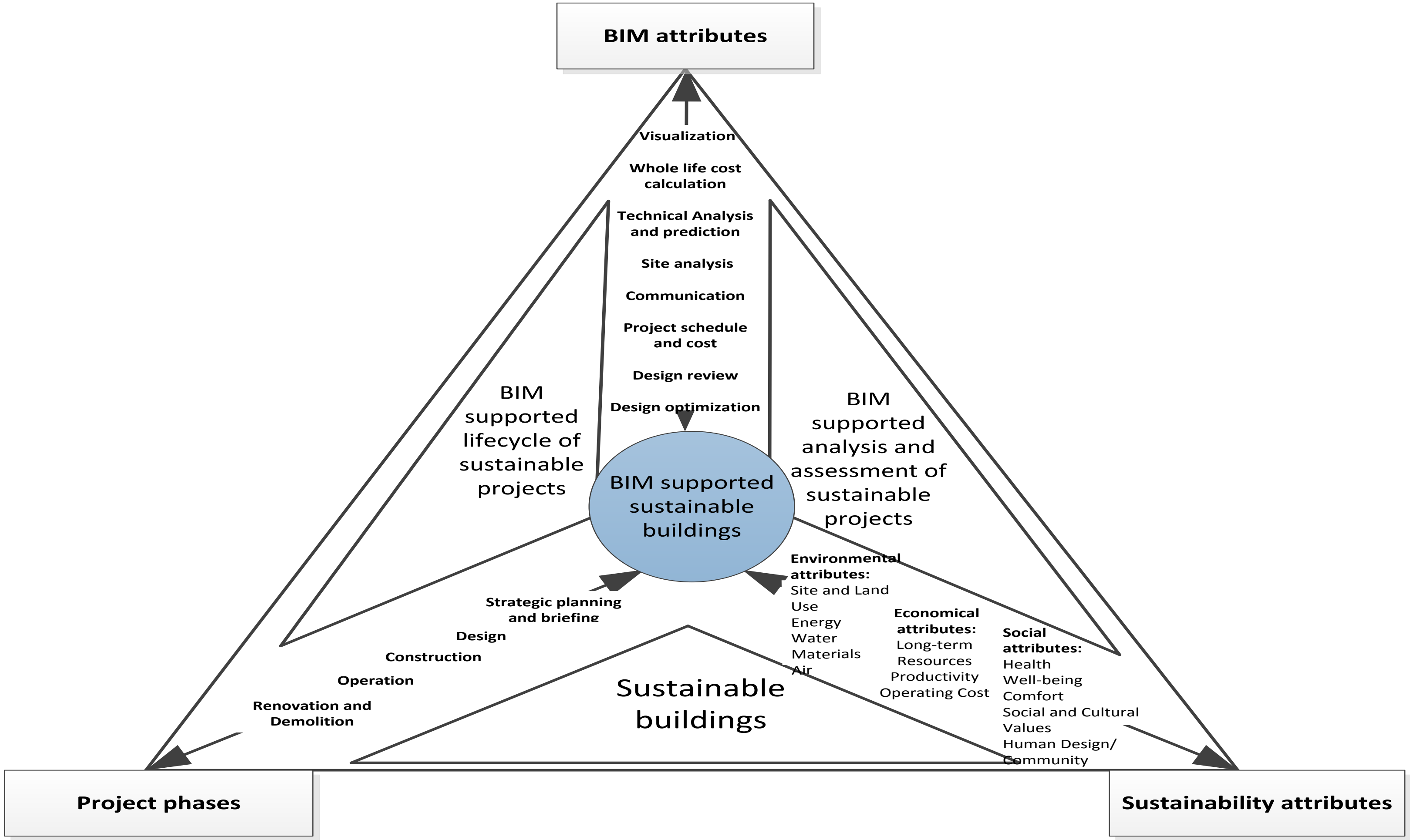


Figure 3.5: Sustainable BIM Triangle taxonomy adapted from Lu, Wu, Chang and Li (2017)

3.5.1 BIM Supports the Lifecycle of Sustainable Buildings

BIM can contribute to sustainable construction over the facility lifecycle from the early stages to demolition, and through facilitating important decisions (Azhar and Brown, 2009). BIM can also support sustainability in the construction supply chain by making construction and procurement processes more effective and efficient, and reducing construction waste materials throughout a project lifecycle (Crosbie et al., 2011; HM Government, 2012; McGraw-Hill, 2010). The following sections represent the contribution of BIM to sustainability over the various building stages.

3.5.1.1 BIM Supports Sustainable Strategic Planning and Briefing

Well defined, in-place strategies enable organisations to adapt to on-going changes in the external world. Therefore, a strategy that takes the organisation's abilities and the opportunities presented by the environment is essential in order to be viable (Jennings and Wattam, 1998).

In terms of project sustainability, the planning stage is significant as it creates the highest impact on the environmental, economic and social aspects (Chong et al., 2017). It has been argued in the literature that sustainability considerations and assessments should firstly take place in the strategic planning and briefing phases. This is because it is essential to develop a plan for sustainability within the project scope that identifies the sustainability goals of a project (Hardin, 2009). Table 3.11 shows the sustainability considerations, as reported by Zanni (2017) and Mulvihill and Jacobs (1998).

Table 3.11: Plan for Sustainability

(Zanni, 2017)	**(Mulvihill and Jacobs, 1998)**
Project summary	Establishing and refining the project vision and objectives based on sustainable development principles and stakeholders' needs
Accreditation goal summary	Establishing common values
Local recycling resources	Identification of contextual issues that influence the problem definition
Local municipal sustainability initiatives	Identification of significant assessment issues based on social values and professional judgment
Project limits	Development of terms of reference for the stages of the assessment process
Project initiatives	Scheduling all critical decision-points in the project's lifecycle along with the identification of the information needed
Evaluation	N/A

Effective BIM implementation in the planning and procurement stages will reduce cost variation and make the project more accommodating, thus more socially sustainable (Holzer, 2009). According to Zuo and Zhao (2014), social sustainability affords a healthy and safe environment for all the involved stakeholders. Moreover, BIM implementation can enhance the efficiency and effectiveness of the project development processes mainly by eliminating unnecessary waste from the re-planning and re-working (Gibbs et al., 2015).

To solve planning issues around climate conditions, site information, site location, transport infrastructure and ecological value, the civil 3D, Auto-CAD and BIM software were used alongside other environmental software packages to deliver the Tent Hotel in Hengshan NaShan village (Bonenberg and Xia, 2015). Moreover, a Development Strategy Simulator (DSS) and Development Strategy Formulation and Evaluation Methodology (DSFEM) are automated BIM systems, which were created to support the stakeholders' decision-making in the planning phase by evaluating alternative plans based on a visualisation of the actual design and construction retrieved from the integrated system (Kim, Kim, Fischer & Orr, 2015). These studies were conducted to improve the environmental, economic and social aspects of sustainability through optimising decisions using BIM in the planning phase.

Chong et al. (2017) conducted a review of publications between 2011 and 2016 to determine "the current state-of-the-art of BIM development for sustainability". Ninety-one studies and thirty-six standards and guidelines were found. He concluded that despite the importance of the planning phase, there is still a lack of innovative research about BIM implementation in the project planning and procurement systems for sustainability.

3.5.1.2 BIM Supports Sustainable Design

The design is the core of both BIM standards and guidelines where sustainability depends on the matter of design (Chong et al., 2017). A study by Lim (2015) showed that sustainability simulation through BIM during the pre-design stage or early in the design phase is crucial for evolving a sustainable building design. BIM can virtually construct buildings before the construction phase, which effectively assesses their constructability and resolves any uncertainties during the process that could affect building sustainability performance. Moreover, BIM facilitates the use of 'reduce and optimise' approaches by the design team, which helps achieve sustainability goals (Kumanayake and Bandara, 2012). Sustainability goals for a project can be categorised into three overlapping dimensions corresponding to the triple bottom line of sustainability, namely the environment, economy and society (see Figure 3.6).

In the environmental dimension, most of the BIM applications were developed to tackle environmental sustainability issues in the design phase with the focus on building performance analysis, such as integrated building performance optimisation (Asl et al., 2015), lighting simulation (welle et al., 2012), CO_2 emission analysis (knight, 2011; Basbagill et al., 2013) and energy performance analysis (Wong and Fan, 2013; Schlueter and Thesselling, 2009; Shrivastava and Chini, 2012; Kim and Anderson, 2012). These applications can lead to better and more efficient designs that optimise energy usage, promote passive design strategies and limit wasted resources (Eastman et al., 2008) by providing, in the early design stage, increased visualisation and integration in the views of building performance.

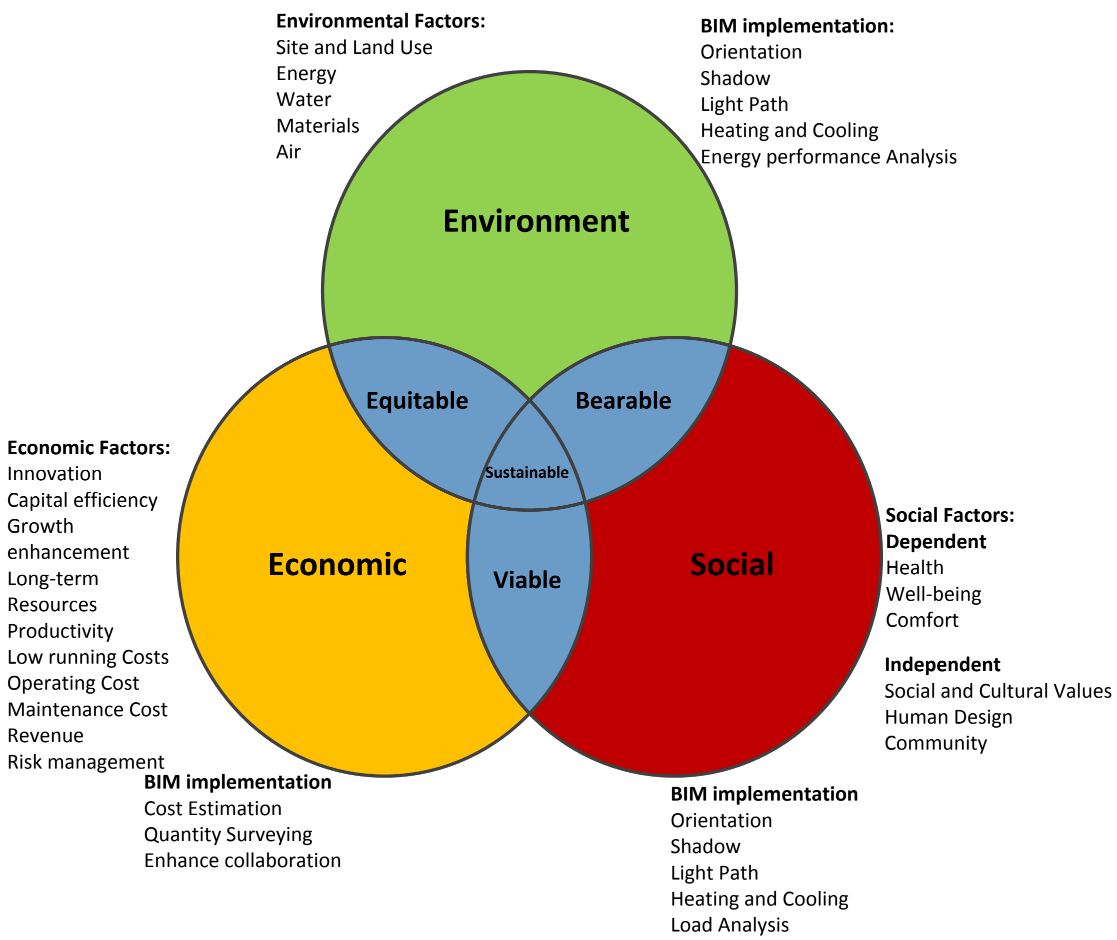


Figure 3.6: Triple sustainable factors and BIM implementation, adapted from Pearce, Han Ahn and Global (2012)

Hartmann et al. (2012) stated that BIM has a direct, significant impact on the economic dimension of sustainable construction through the process of risk management and cost estimation during the design phase. For risk management, project managers can incorporate the fourth dimension of BIM (time) in their analysis to estimate the projects' risks more effectively and make them more cost-effective and progressive, which will have an impact on reducing project costs (Zhang and Hu, 2011). Despite the benefits associated with this process, it cannot be considered as a sustainable approach until it includes the environmental benefits and promotes the quality of life concepts in its calculations; social-oriented values and human well-being should be included in their priorities (Sassi, 2006).

Moreover, other aspects of BIM implementation can influence the economic efficiency by enhancing stakeholders' communication and collaboration, which leads to promoting building management, saving time and reducing wastage, and thus reducing project cost (Hartmann et al., 2012; Eastman et al., 2011).

The occurrence of social sustainability has been defined by the Western Australia Council of Social Services (WACOSS) as:

> When the formal and informal processes; systems; structures; and relationships actively support the capacity of current and future generations to create healthy and liveable communities. Socially sustainable communities are equitable, diverse, connected and democratic and provide a good quality of life. (WACOSS, 2000)

The improvement of social sustainability is considered within the improvement of the economic and environmental aspects of sustainability, which results in comfort and health as well as promoting human well-being (Sassi, 2006; Eere, n.d). Soltani (2016) classified the interaction between social sustainability and BIM into two categories: dependent and independent features. Dependent features can be quantified and measured through environmental assessments, which BIM can support, such as lighting and energy performance. Therefore, improving some environmental features in the process of sustainable design can promote health and enhance performance while negative environmental conditions can lead to health disorders, such as discomfort, stress and absenteeism. Independent features from other variables which are mainly qualitative in nature, such as community, social and cultural values and human design-related features, also have a role to play (Sassi, 2006). Improved environmental quality, knowledge transfer, minimised risks from pollutants associated with building energy use and neighbourhood restoration are other ways to improve quality of life on the social scale through the design stage (Eere, n.d).

3.5.1.3 BIM Supports Sustainable Construction

Many standards especially in the US have encouraged and stipulated the use of BIM in the construction phase. The Los Angeles Community College District (LACCD) (2016) has encouraged the contractors to issue a schedule based on a 3D BIM model that is linked to the sequence of construction. The Port Authority (TPA) (2016) stipulated that BIM 4D (time) and 5D (cost) should be used for logistic planning, interface management and project forecasting.

The construction phase has a significant effect on the environment in terms of many aspects, such as carbon emissions (Mah et al., 2011), resource consumption, noise pollution and waste generation (Liu et al., 2011; Chang et al., 2017). BIM provides various effective solutions for mitigating such environmental impacts as BIM can facilitate project information. Zhang et al. (2016) found that the information embodied in BIM is suitable for fabricating modular units, which will reduce site disturbance, wastage from the costly construction materials, air pollution and enhance design change flexibility and re-use (Zhang et al., 2016).

For construction planning support, a BIM-based automated framework has been created to generate dynamic site layout models (Kumar and Cheng, 2015). The aim was to optimise the travel distance of construction personnel and equipment for this framework by using an algorithm with genetic algorithms. It was found that the use of information embedded in the BIM models have helped achieve a 13.5% reduction in the total travel distance compared to conventional methods.

The performance gap is that which exists between design intent and the actual building which could reduce the chances of delivering a sustainable building design. The reasons for this gap have been widely studied (Menezes et al., 2012; Zero Carbon Hub, 2014; Bordass et al., 2001). The substitution of products on-site is one of the major reasons for such a gap, which could lead to improvising certain modifications that are detrimental to the fabric performance and also creating less thermal efficient materials (Carbon Hub, 2014). BIM contributes by monitoring the construction progress. The ‘Scan-vs-BIM’ technique was created by Bosche et al. (2015) to track the mechanical, electrical, and plumbing (MEP) elements between as-planned and as-built. Matthews et al. (2015) also created a cloud-based BIM to provide real-time information on the reinforced concrete structure on-site. As having access to information of the performance of a building project will help improve the decision-making of both the contractors and designers, thus ensuring project deliverability are met and the performance gap is minimised (ibid).

3.5.1.4 BIM Supports Sustainable Operations and Maintenance

The operation phase has a significant role in maintaining the sustainability of the built environment. In the operation phase, it is essential to monitor the buildings' sustainable performance to verify the actual performance compared to the design phase set targets (Lu et al., 2017). This task is complicated due to the need for collecting the building's information from different stakeholders over various phases (Chong et al., 2017). Bernstein (2010) found that in the operation phase, BIM is an invaluable tool for monitoring the buildings' sustainability performance. This is because BIM can contribute the ability to support the integration, supply and management of information over the building lifecycle (Häkkinen, 2008).

BIM is also an adequate tool for supporting the data for maintenance (Akbarnezhad, 2012; Eastman et al., 2011; Cheng and Ma, 2013) due to its ability to manage the building information accurately (Liu and Issa, 2012), thus reducing the building maintenance costs. A strategy framework was proposed by Adeyemi et al. (2014) that incorporated zero emissions, lean thinking and green building into the BIM to minimise the maintenance costs.

3.5.1.5 BIM Supports Sustainable Renovation and Demolition

Globally, buildings consume 45% of the world energy (see Table 2.2). Moreover, it has been estimated that more than half of the existing building stock will still be in use in 2050. Also, despite the focus on reducing emissions from new buildings, the existing stock remains mostly untouched, missing opportunities to reduce emissions and deliver zero or near-zero carbon buildings (Carbon Trust, 2008). Renovating the existing building stock is one of the most effective ways to minimise the carbon emissions by reducing the energy consumption in these buildings. This, in turn, will improve the indoor climate by mitigating the air pollution, which will lead to healthier living (Kyilili et al., 2015).

BIM applications were found to be beneficial in addressing these sustainability issues on the project renovation phase by providing feasible solutions (Bernstein, 2010). A number of researchers have demonstrated BIM usage on retrofit/renovation projects. For example, a research framework was proposed to improve BIM roles in energy-driven retrofits (Khaddaj and Srour, 2016). A sustainable deconstruction strategy was proposed by Akbarnezhad (2014) which uses BIM-sourced information to retrieve the capital and energy invested in building components. Cheng and Ma (2013) created an integrated BIM-based system to estimate the amount of waste generated from construction, renovation and demolition; therefore, it contributes to improving the sustainability of renovation and demolition projects to support project control.

3.5.1.6 Summary: BIM Supports Sustainable Project Lifecycle

As a summary, BIM can support sustainable buildings over the project lifecycle, including strategic definitions and briefing, design, construction, operation and maintenance and renovation and demolition (see Figure 3.7). Based on the current research, BIM can contribute to the sustainable building lifecycle in three ways:

- Visualisation is one of the primary applications of BIM, as mentioned in Section 3.3.3. Therefore, the first BIM contribution is the ability to provide visual information that relates to building and process performance. This includes 3D models and walkthrough features. This will make stakeholders' decisions more sustainably oriented.
- Secondly, the ability to exchange data embedded in BIM among multi-disciplinary users with different sustainability analysis tools and the automation of the design evaluation processes (Lu et al., 2017).
- Finally, BIM contributes by improving the collaboration and communication between various stakeholders during sustainable design, construction and operations (Grilo and Jardim-Goncalves, 2010). A new paradigm of a shared vision for all stakeholders working on the same project is offered by this integrated platform (Azhar et al., 2012).

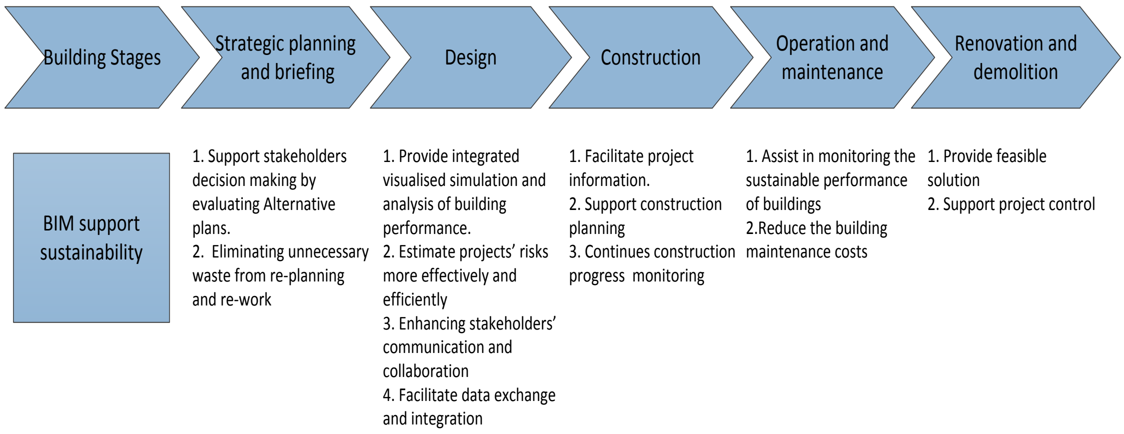


Figure 3.7: BIM-supported sustainable projects lifecycles

Despite these benefits of BIM over the different phases, there is still a lack of research about BIM implementation in some of these phases, such as project planning and procurement approaches for sustainability (Chong et al., 2017) and BIM for facility management (Dong et al., 2014). This research will investigate different procurement approaches adopted in the public sector in Jordan for better BIM implementation to achieve sustainability.

3.5.2 BIM Supports Sustainable Building Assessment and Evaluation

'Sustainability analyses or building performance analyses' refer to various types of evaluation and assessment methods for determining the environmental performance of a building; these analyses include internal ones, such as the HVAC system optimisation and contextual analyses, as in site orientation, building massing and day lighting (Azhar and Brown, 2009). Fragmented information in the traditional delivery approaches causes the discontinuity of these sustainability analyses systems (Eastman et al., 2011). BIM contributes through the use of such technology as a database for data exchange and integration (Steel, 2012). Specifically, throughout the design process, BIM creates the opportunity to incorporate the sustainability measures by allowing multi-disciplinary information to be superimposed on one model (Autodesk, 2012), thus BIM can be used to analyse the buildings as fully integrated dynamic systems and adjust their construction process to enhance their sustainability (Holness, 2008).

In BIM, much of the necessary data for sustainability are in the coordinated data sets of information that are naturally captured over the project lifecycle in the building information models. Furthermore, BIM integration with other performance analysis software significantly simplifies these rigorous analyses (Azhar and Brown, 2009). Such integration could take the form of combining an energy-simulation tool with Revit Architecture. For instance, the lifecycle impact tool ATHENA impact estimator and Green Building Studio can be employed to study the use of different building materials and their impact on energy performance (Ajayi et al., 2015). Grafosoft, EcoDesigner and Archicad 14 BIM were used by Tahmasebi et al. (2011) to calculate the energy consumption and carbon footprint of glazed windows, as a result to any changes made to the building.

To integrate the sustainability software with BIM to perform a lifecycle analysis (LCA), direct access to BIM information is needed (Anton and Diaz, 2014). The typical flow of information in BIM-based sustainability analyses and BIM functions for such analyses are presented in Figure 3.8. Building BIM-based sustainable analysis can be performed based on the basic information embodied in BIM, such as building systems, building materiality, building geometry and internal load as well as the additionally entered information in the performance analyses software (Azhar and Brown, 2009). Based on previous research, the impact of BIM on these analyses can be categorised into eight main types: carbon emission, thermal comfort, acoustics analyses, water usage analyses, solar radiation and lighting analyses, natural ventilation system analyses, energy performance analyses and whole life cost analysis (Lu et al., 2017).

As mentioned in Section 2.4.3, sustainable building assessment methods, such as BREEAM, GREEN, BEAM Plus and LEED, were issued by different countries to address building sustainability. Most of these assessment standard methods were criticised as they are based on the predicted performance, rather than the actual one (Tuohy and Murphy, 2015). For example, it was found that 28% to 35% of the LEED buildings consume more energy than their “conventional counterparts”, as per floor area (Newsham et al., 2009). BIM can enhance the efficiency of such assessment methods through estimating and interpreting different methods’ credits, which could enhance the stakeholders’ understanding of these credits, thus ensuring the achievement of certification requirements. Moreover, stakeholders can choose more effective strategies through BIM to achieve the required building certification (Wu and Issa, 2014). BIM can also assist in applying and maintaining the certificates associated with different sustainable building assessment methods through facilitating the required documentation management (Lu et al., 2017).

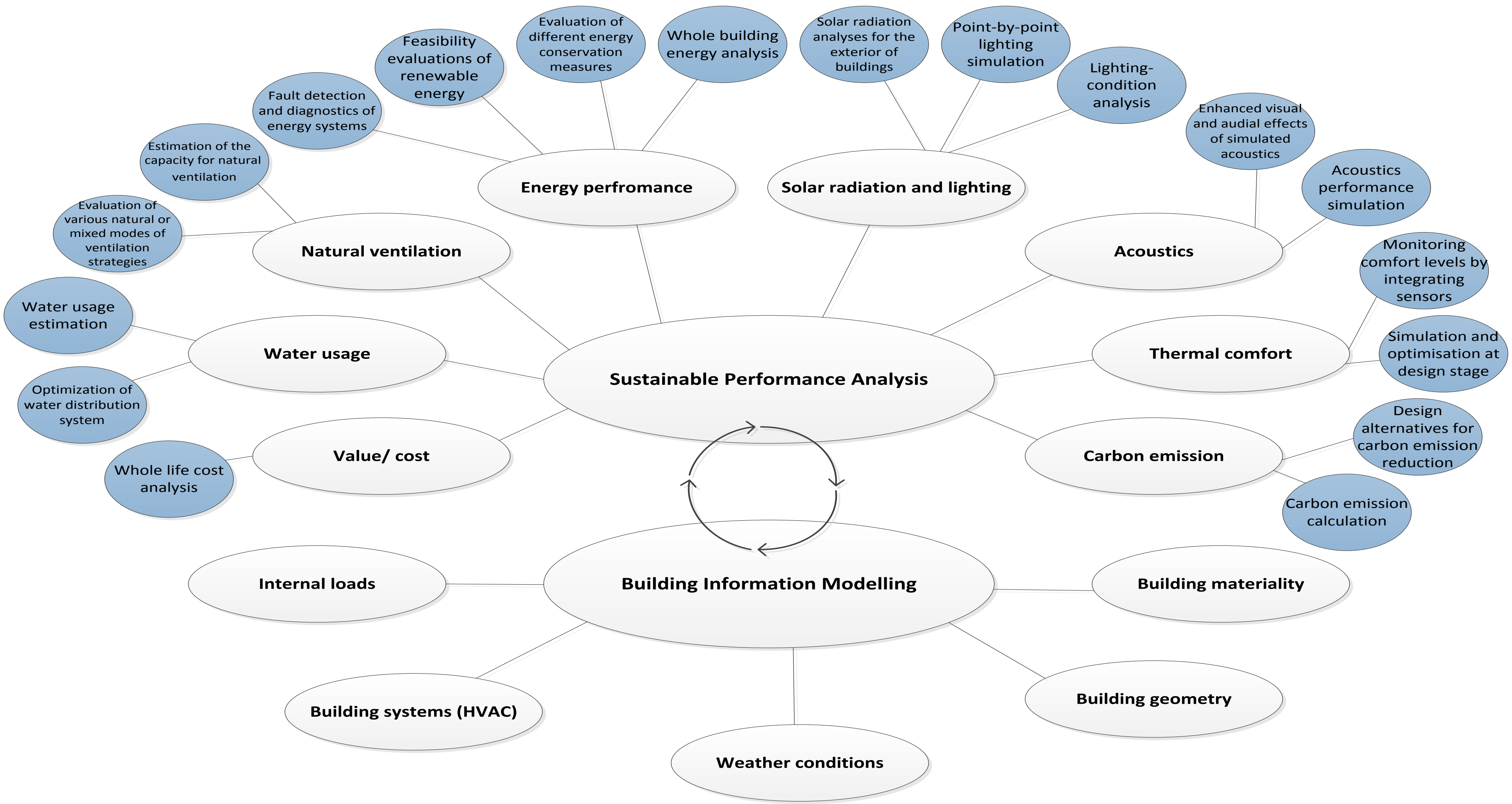


Figure 3.8: BIM-based building sustainability analyses; typical information flow and BIM functions, adapted from Azhar and Brown (2009) and Lu et al. (2017)

3.6 CHAPTER SUMMARY

Through the literature review, it was revealed that public sectors worldwide play a primary and significant role in implementing BIM through various national implementation strategies and plans. However, a lack of full commitment to BIM by public sector clients in Jordan was reported. This affects its status in both the private and public sector in Jordan as recent studies stated that BIM is still in a very primitive phase in Jordan. It could be said that the main reason is the paucity of studies on BIM adoption and implementation in the public sector in Jordan. Therefore, it is anticipated that this research will provide a unique insight into the current state of BIM usage in the public sector in Jordan. This would be achieved by exploring the extent of the adoption of BIM among the government, public contractors and consultants. In addition, this study attempts to measure the relative significance of BIM benefits and barriers to the public construction sector in Jordan.

Research suggests BIM can help overcome many of the issues reported in the public buildings in Jordan, such as time delays, cost overruns and a lack of sustainability performance. Indeed, sustainability enhancement is among the main BIM benefits. Therefore, this chapter introduced the Sustainable BIM Triangle, which provides evidence that BIM adoption and implementation supports sustainability on different project phases from planning to demolition in addition to sustainability assessment.

However, there are barriers to utilising BIM. These barriers are categorised under three main headings: business and legal, human/organisational and technical barriers. Current procurement strategies, which fall under the business and legal barriers, are considered among the most significant challenges to BIM implementation in the public sector. Thus, when many public clients around the world propose a range of actions to implement BIM, deploying collaborative procurement approaches seems to be the optimal solution. The next chapter discusses BIM implementation under various procurement approaches.

CHAPTER 4: THE IMPLICATION OF CONSTRUCTION PROCUREMENT ON BIM IMPLEMENTATION AND SUSTAINABILITY CONSIDERATIONS

4.1 INTRODUCTION

Public buildings in Jordan have been criticised due to their lack of design performance, especially in sustainability. This is because of political, cultural and economic reasons (see Chapter 2). BIM as an innovative technology can contribute and enhance buildings performance, especially in sustainability (see Chapter 3). However, construction procurement has been considered to be one of the principal business and legal BIM implementation challenges to the public sector. The key objective of this chapter is to review the literature that is pertinent to construction procurement and to analyse the implications of this on BIM implementation and sustainability.

This chapter is comprised of six main sections:

- An overview of construction procurement.
- The implications of construction procurement on BIM implementation.
- The need for innovative procurement approaches to implement BIM.
- The implications of construction procurement on sustainability considerations.
- Construction procurement in Jordan.
- The justification for carrying out this research.

4.2 AN OVERVIEW OF CONSTRUCTION PROCUREMENT

Construction procurement is termed by several researchers and practitioners in the construction industry under different terms, such as the procurement approach, procurement systems, procurement methods, procurement delivery methods or project delivery methods. In recent years, these terms have become common and fashionable phrases in the construction industry (Rwelamila and Edries, 2007; Jin Lin et al., 2015). It is considered as a fundamental parameter that contributes to the success of the construction project and client satisfaction (Love et al., 2008; 2012). In principle, the procurement approach determines the overall framework for allocating the authorities and responsibilities of project stakeholders in the construction project (Rwelamila and Edries, 2007).

4.2.1 CONSTRUCTION PROCUREMENT DEFINITIONS

Many definitions have been given for procurement in construction in the literature (Francom, Asmar & Ariaratnam, 2014). This is due to the misconception about the clear nature of procurement, and whether it is purchasing or a contract. Grilo and Goncalves (2011) have clearly stated that it includes both purchasing and contract providing services and merchandise. Table 4.1 represents the different definitions found in the literature.

Table 4.1: Definitions of procurement in construction

Construction procurement definition	**Source**
The strategy that the clients adopt to buy resources and activities from specialists in the building industry to deliver a new building.	(Root and Hancock, 1996)
"A process in which the clients' requirements and objectives are elicited throughout the project life cycle, moreover, forming the power structure".	(Dalgliesh et al., 1997)
"a procurement system is an organizational system that assigns specific responsibilities and authorities to people and organizations, and defines the relationships of the various elements in the construction of a project."	(Love, Skitmore & Earl, 1998, p. 221)
"A collective process for the achievement of mutual benefit, where it adds value to the clients and profits for the participants through the contractual structure".	(Koolwijk & Vrijhoef, 2005)
"A system that represents the organizational structure adopted by clients for the implementation of project processes and eventual operation of the project".	(Chan, 2007)
"A comprehensive process by which designers, constructors, and various consultants provide services for design and construction to deliver a complete project to the owner".	(Molenaar et al., 2009)
"The set of relationship, roles, and responsibilities of project team members and the sequence of activities required for the development of a capital project".	(Park et al., 2009)

"A mechanism for linking and coordinating members of the building team throughout the building process in a unique systematic structure, both functionally and contractually. Functionally via roles, authority and power, contractually via responsibilities and risks. The main aim is to deliver a project that meets its objectives and fulfil the client criteria and expectations".	(Naoum, 2011)
"An organisational structure that arranges specific relationships and authorities to the participants, defines the relationship of key elements in the construction project and acts as a management framework to the client for the management of design, construction and eventually operation of the project".	(Gamage, 2011)
"A strategy to satisfy client's development and/or operational needs with respect to the provision of constructed facilities for a discrete lifecycle".	(Poplic et al., 2014)
"A comprehensive process by which a facility is designed and constructed"	(Francom et al., 2014)
"the process by which products and services are acquired from an external provider for incorporation into the project, programme or portfolio"	(APM, online)
'the strategic process of how contracts for construction work are created, managed and fulfilled'	(Hughes et al., 2015, p. 11)

It can be concluded from the various definitions in Table 4.1, that there is no single commonly accepted construction procurement definition. These definitions suggest that construction procurement consists of a wide range of processes which are interrelated and sequential in nature. Depending on the various definitions and descriptions in Table 4.1, this research defines construction procurement as a set of tasks that govern the activities undertaken by clients, consultants and contractors to plan, design, assess, purchase and construct projects in order to deliver the required end-product to the client. This definition is adopted to ensure that this research tackles any aspect of construction procurement that could influence BIM implementation.

4.2.2 Construction Procurement Approaches

Many construction procurement approaches have been developed over the last few decades (Jin Lin et al., 2015). Construction procurement approaches (see Figure 4.1) can be classified into four main categories: cooperative and separated, management-oriented, integrated procurement and innovative approaches (Mante et al., 2012; Love et al., 2008; Bolpagni, 2013).

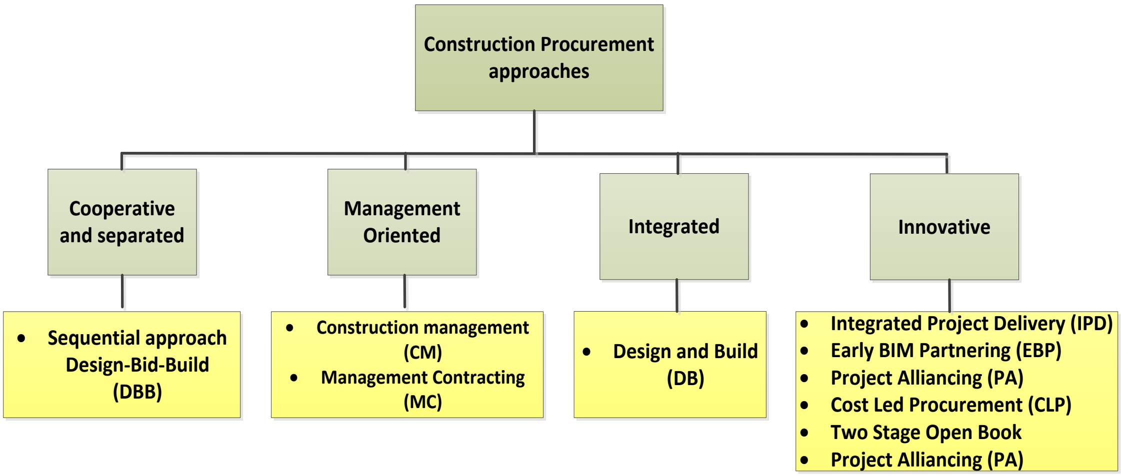


Figure 4.1: Procurement approaches classification Bolpagni (2013), Love et al. (2008) and Rwelamila and Edries (2007)

4.2.2.1 Cooperative and Separated Procurement Approaches

In these types of procurement approaches, consultants and contractors carry out the project development activities in a sequential order, one after another (Nikou et al., 2014). Project activities start from feasibility studies, design and construction activities to handing over the project (Rwelamile and Edries, 2007). The main characteristics of such approaches are the separation between the design and construction phases in which little or no interaction between consultants and contractor organisations occurs (Mante et al., 2012). In these approaches, the client signs two separate contracts with the consultants and contractors in which the majority of the design and drawings preparation are completed prior to the site works' commencement (Rwelamila and Edries, 2007).

4.2.2.2 Management Oriented Approaches

In these approaches, an organisation is appointed to manage and coordinate the design and construction phases of a project. It has been stated that:

> Under a management-oriented procurement system, the management of the project is carried out by an organisation working with the designer and other consultants to produce the designs and to manage the construction work which is carried out by contractors. (Thwala and Mathonsi, 2012, p. 16)

The most common approaches are construction management and management contracting. The main difference between the two is that the former is based on managing the trade contracts in which the client is responsible for placing the contracts. The latter is where management contractors are contracting works contractors directly.

4.2.2.3 Integrated Approaches

In these approaches, the main feature is that both the design and construction work are carried out in parallel (Migliaccio et al., 2009). The responsibility for the design and construction are integrated or combined into a single contracting organisation. According to Konchar and Sanvido (1998), having a single contracting organisation that is responsible for both the design and construction is the main benefit of these approaches for the client.

4.2.2.4 Innovative Procurement Approaches

Innovative procurement approaches are new approaches that have become popular in the AEC/FM industry in order to enhance collaboration between the different parties involved in the process. There are six main approaches identified in the literature: integrated project insurance (IPI), project alliancing (PA), integrated project delivery (IPD), two-stage open book, cost led procurement (CLP) and early BIM partnering (EBP) (Bolpagni, 2013). IPD and PA have been established to create a cooperative environment and to form collaboration environment between the construction project stakeholders that reaches a new level. CLP, IPI and two-stage open book were established and trialled by the UK government to enhance collaboration and integration aimed at reducing the public projects' cost and enhancing sustainability. EBP was established according to the existing procurement in the public sector in Canada, and it aims to smoothly introduce BIM to the current working processes.

4.2.3 Tendering Procedures

The terms procurement and tendering are usually used interchangeably without looking at the actual meaning of both. According to Garner (2014), this led to confusion about the differences between the meanings of these terms. Different procurement approaches are defined in Section 4.2.1. Tendering, on the other hand, is a stage in the construction procurement. It can be defined as a process of purchasing or the bidding process in order to obtain a price and appoint a contractor (Garner, 2014). Appointing a qualified contractor is amongst the critical issues for delivering a successful project (Mohemad et al., 2011). The general tender process includes the tender specification preparation, invitation to the tender, submission of the tender documents by the bidders, evaluation of the proposals and tender awarding (see Figure 4.2). The mediator could be the consultant, project manager or construction manager. The provider could be the main contractor or trade contractors. This depends on the procurement approach adopted.

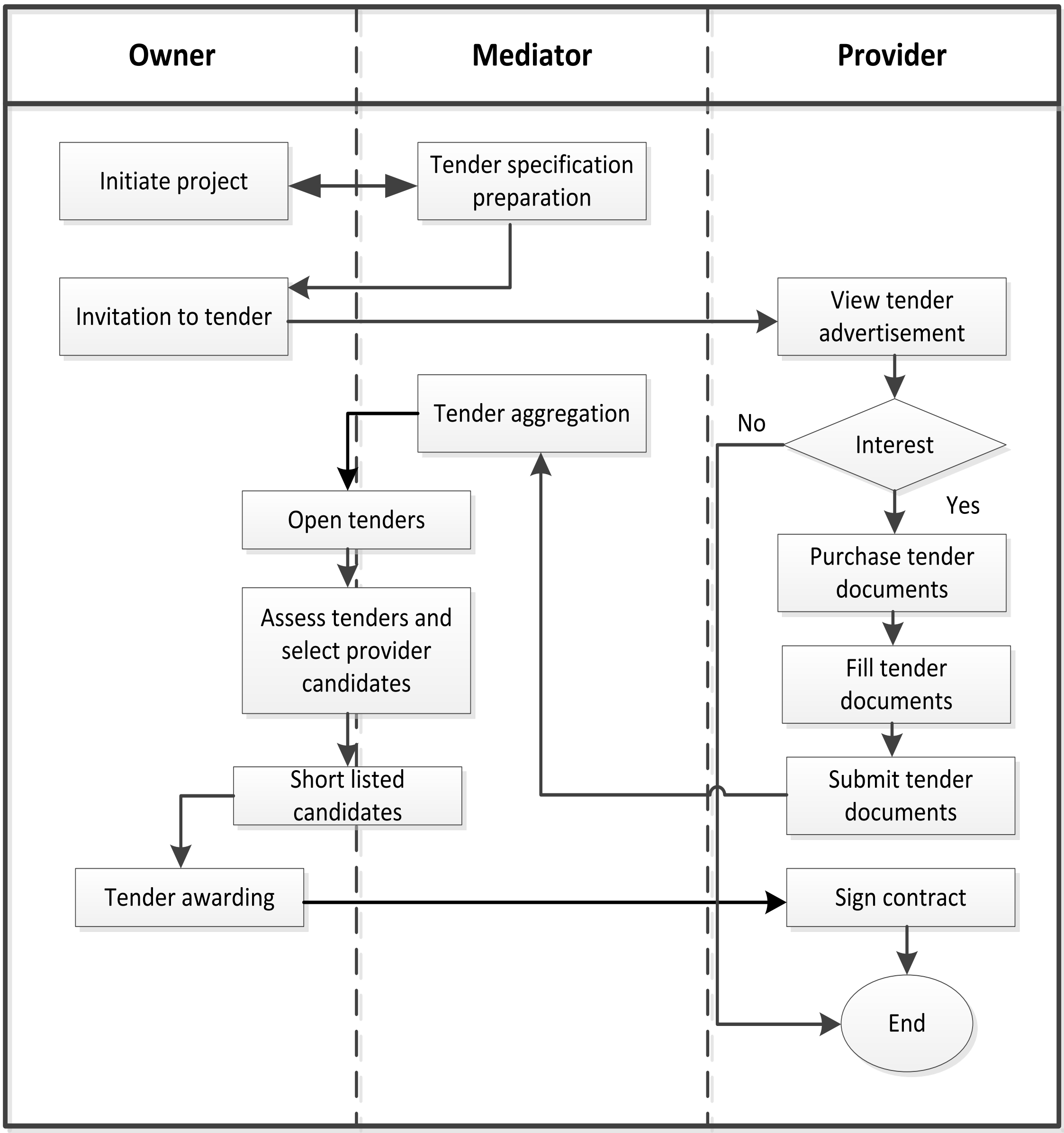


Figure 4.2: Usual tendering process adapted from Mohemad at al., (2011)

There are three common types of tender strategy in the construction industry: single-stage, two-stage and negotiated tendering (Garner, 2014). These strategies can be used within most of the procurement approaches; therefore, the chosen procurement approach should not affect the tendering strategy.

4.2.3.1 Single-Stage Tendering

The single-stage tendering strategy is frequently chosen; in this approach, the clients conduct a single-stage competitive tender to obtain a price for the construction work (Garner, 2014). A number of contractors compete by bidding for a project based on the same tender documentation. This occurs at the end of the design phase where the bidding contractors have a predetermined time for preparing and submitting their bids. The bids are then analysed in terms of their cost and quality, and a single contractor is assigned to deliver the tenderer's works (ibid).

4.2.3.2 Two-Stage Tendering

The two-stage tendering strategy has become more common in recent years. This strategy is used if the design process benefits from the contractor's technical inputs. The basis of choosing the preferred contractor is based on the quality of the contractor's bid, their team, preliminary prices, profits and overhead allowances (Garner, 2014). Then, the preferred contractor is involved in the design stage on a consultancy basis using a pre-construction services agreement (PCSA) to complete the design together before presenting a bid.

For instance, the use of two-stage tendering under a traditional procurement approach is called the accelerated traditional procurement approach. The ultimate goal of this approach is to appoint the contractor earlier in the design phase on the basis of an agreement to undertake the pre-construction services (stage 1) with the intention that the parties will enter into a contract with a target cost, following a period of negotiation (stage 2) (Donovan, 2017).

In stage 1, the client tenders the project during the design stage on a competitive basis, but based on an incomplete design, outline price and programme of the works, prepared by the client design team. The contractors then submit a proposed method statement, construction programme, price of the preliminaries and overheads and the percentage of the profits (Donovan, 2017). This stage includes a competitive tendering of the already designed work packages in addition to a lump sum for the pre-construction services and design fees. The client then appoints a 'preferred contractor' on the basis of a separate PCSA or the provision of an identified contract (ibid).

In the second stage, the client is in a form of contract negotiation with the 'preferred contractor'. The second stage is typically concluded by an agreement on a lump-sum contract (Rawlinson, 2006). Figure 4.3 represents the process of the two-stage tender.

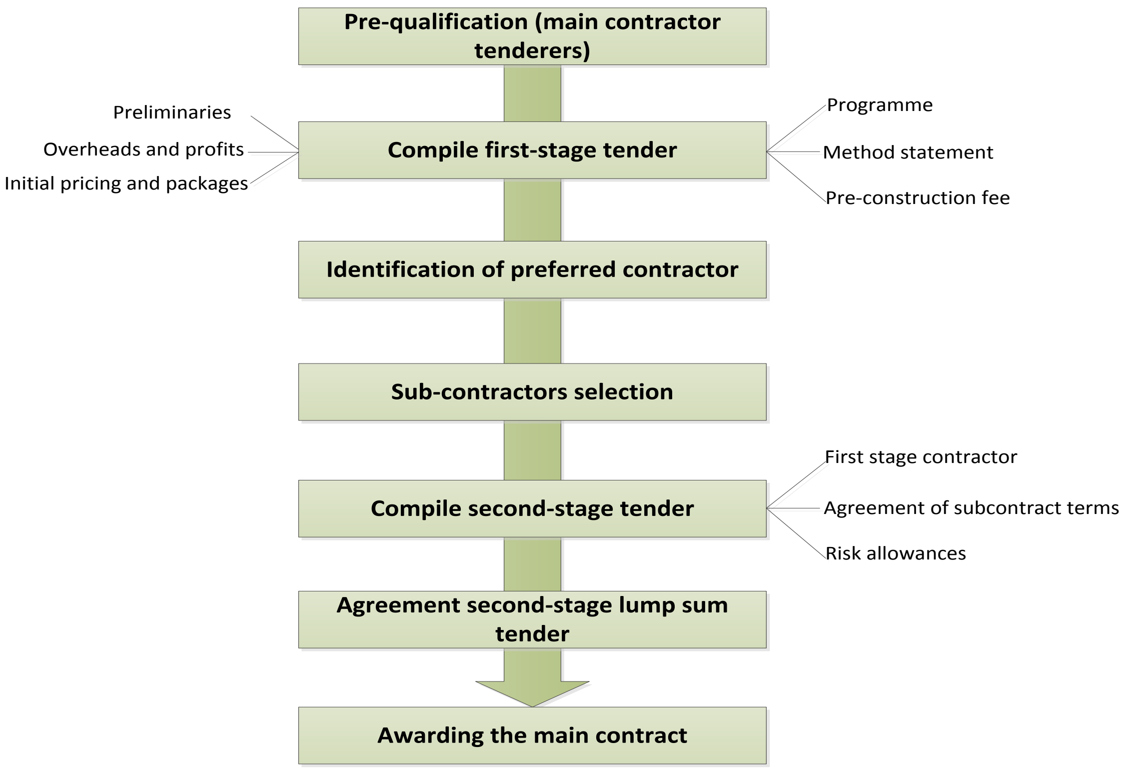


Figure 4.3: Two-stage tender process, adapted from Rawlinson (2006)

4.2.3.3 Negotiation Tendering

A negotiation tender is a single-stage tender with one contractor. In this tender strategy, the contractor proposes an initial tender price, and then a negotiation between the client and the contractor is carried out in order to reach a final price for the construction works (Garner, 2014).

4.3 THE IMPLICATION OF CONSTRUCTION PROCUREMENT APPROCHES ON BIM IMPLEMENTATION

The construction industry is behind in the necessary transformation to improve technological development, sustainability, productivity and sufficient returns on investment (ROI) for the clients (Mostafa, 2016). The application of 2D CAD has a significant impact on improving the construction industry and the communication among projects stakeholders. However, it has been criticised for its inefficiency in dealing with issues such as sustainability, cost analysis and value engineering. These analyses are usually performed by the contractor after the completion of the design phase. Consequently, the required changes and inconsistencies are determined too late (Eastman et al. 2011). BIM has been introduced as a response to these issues, and it has been considered as one of the most effective organisational and technological innovations in the AEC (Succar, 2015). BIM is also considered as a potential solution for overcoming the current fragmentation in the construction industry (Hardin, 2009). BIM's various potential benefits are presented in Sections 3.3.1 and 3.5.

To implement BIM effectively, the current construction processes should be altered at every level: the industry, organisation and project levels (Arayici et al. 2011). It has been argued that profound process changes are needed for effective BIM implementation on a project level (Volk et al., 2014), particularly to create a collaborative environment between multiple stakeholders over the project lifecycle (Pcholakis 2010; Laishram, 2011). Early stakeholder involvement will reduce any conflict of interest and will add their inputs to the design phase, which is indeed not achievable under the traditional procurement methods, such as DBB (Azhar et al., 2012). Therefore, it is suggested that clients should change the way that they procure buildings when implementing BIM to ensure a fully integrated, collaborative BIM-enabled work processes (Foulkes, 2012).

Ghassemi and Becerik-Gerber (2011) have identified the following aspects, which differentiate a collaborative procurement approach from a traditional method: (i) early and continuous involvement of key stakeholders; (ii) clear roles, responsibilities and communication lines; (iii) integrated project team consisting of clients, designers, constructors, specialist suppliers and facilities managers; (iv) common goals and collaborative decision-making; and (v) an integrated design process where design, construction and operations are considered as a whole.

A collaborative procurement approach will unlock the usefulness of BIM for clients by treating BIM as a shared resource for the facilities over their whole lifecycle; this will be from design conception through to the construction, operation phases, adaptive re-use and any alterations until the end of their useful operating lifecycle (Laishram, 2011).

However, to date, procurement approaches were not chosen for their ability to deliver collaborative environments. For instance, in the UK (a country which is comparatively mature in BIM adoption), in a survey of construction experts from 70 organisations across the UK undertaken by the law firm Pinsent Masons in 2013, 66% of the respondents suggested that the selected procurement approaches were not fit for a BIM-enabled world (Withers, 2014). Therefore, BIM has been used in a relatively isolated way, with limited collaboration between designers and contractors within the projects. In order to reap BIM benefits in the construction industry, traditional procurement approaches need to be challenged from inception to completion and also demolition.

The following subsections will investigate the implications of BIM implementation under various procurement approaches. According to Masurier et al. (2006), Molenaar et al. (2009), Love et al. (2012) and Nikou et al. (2014), the most common and preferable procurement approaches in the public sector are traditional DBB and DB whilst the CM method is the least favoured one compared to the other two approaches. Each of the procurement approaches will be discussed and explored in order to find their advantages and disadvantages for BIM implementation. IPD is also discussed as it has been defined in the literature as the optimum procurement approach for BIM implementation.

4.3.1 Traditional (DBB)

This approach is the oldest, but it is still the most popular amongst the separated and cooperative approaches (Eastman et al., 2011, p. 4; Francom et al., 2014); therefore, it is called the 'traditional method' (Turner, 1990, p. 48; Lahdenperä, 2001). This method has been widely used all over the world for many decades for delivering public and private sector projects (Thwala and Mathonsi, 2012). The main principle of this approach is that the design and construction phases are separated, as are the stakeholders' responsibilities (Shrestha et al., 2012). Despite this separation between the client, consultants and contractors, this approach allows for cooperation between them. This is why this approach earned its other name 'separated and cooperative' (Masterman, 2002). Figure 4.4 represents the project organisational structure for the traditional procurement approach.

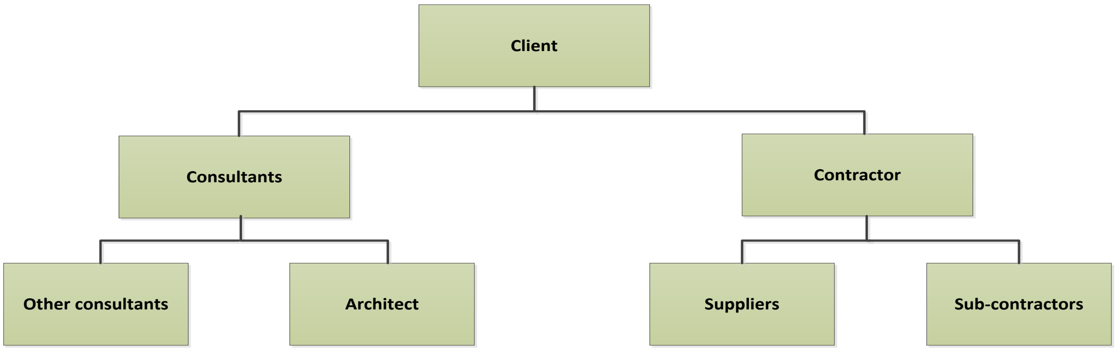


Figure 4.4: Project organisational structure for the traditional procurement approach (Maricopa, 2011)

In the DBB approach, the design should be completed, followed by an (open) competitive tendering for contractor selection, signing the contract and then proceeding with the construction phase (Eriksson and Westerberg, 2011; Pishdad-Bozorgi et al., 2012). Bids can be opened either publicly or privately depending on project type, and usually the contractor with the lowest responsible bid is selected under DBB (Eastman et al., 2011). Selective and negotiation tender procedures can also be implemented under DBB instead of the open competitive tender procedure (Rosmayati et al., 2010; Thwala and Mathonsi, 2012). The mains steps under the DBB approach are as follows (Turner, 1990, pp. 48, 50):

- Client defines the need to build and the work purpose.
- Client defines the requirements of the technical proposals.
- Design team develops design drawings and cost control.
- Client approves the design work.
- Preparing tender documentation.
- Inviting tenders to tender.
- Contractors prepare their proposals.
- Selecting a tender, thereafter signing a contract.
- Contractor proceeds with constructing the building.
- Testing the building.

The main advantages and disadvantages of adopting a DBB approach are represented in Table 4.2.

Table 4.2: Advantages and disadvantages of the DBB approach (Morledge et al., 2006; Turner, 1990; Hardin 2009; Eastman et al., 2011)

Advantages	Disadvantages
All the tendering contractors are bidding on the same basis, thus there is a competitive fairness	The processes are sequential, which affects the project duration to be longer than other delivery approaches
The client can facilitate a high level of functionality and bespoke quality in the design as this approach is design led where the client is able to have a direct influence	The design is developed away from the technology and build ability as the contractor is involved late in the process after the design is 100% completed
The client's financial commitment is known at the tender stage before commencing the construction	Contractors often bid a low price to win the project with the intention of compensating the difference through raising variation claims at a later stage, which will cause disputes between the client and the contractor
DBB procedures are well known, thus instilling confidence in the stakeholders	Although the designer should include sufficient information and details in the tender documents, they tend to include minimal details, which cause errors and disputes on fabrication
Client changes in the design phase are reasonably easy	Collecting information for facility management after completing the construction phase is not an easy task
Reasonable price certainty at contract award	

The integration between the different stakeholders is limited due to the fact that the responsibility of the design and construction are separated; the architects and engineers are responsible for the building design, and the construction phase is the contractors' responsibility. These stakeholders do not work together efficiently as they usually have competing interests and because of a lack of information interoperability, which influences the communication, integration and coordination (Lu et al., 2014). Love et al. (2012) described the cause of the issues under DBB as follows:

> DBB procurement has contributed to the so-called (procurement gap) whereby design and construction processes are separated from one another. This procurement gap is considered to inhibit communication, coordination, and integration among project team members and can adversely affect project performance. (Love et al., 2012)

BIM Implementation Issues under DBB

In 2009, 32.7% of the BIM-based projects in the US were delivered through the DBB approach, and according to Cao et al. (2015), 88.7% of the BIM-based construction projects in China were delivered through DBB. However, the full benefits of BIM cannot be achieved under DBB because of the structures of this approach (Salmon, 2012). The late contractor involvement under the DBB approach is not ideal for implementing BIM processes as their input in the design phase is not taken into consideration (Eastman et al., 2011). As a result, a disconnect will occur between the consultants' and the contractors' BIM models. The consultants may make assumptions about the contractors' BIM requirements, which means that the contractor might not receive the necessary information (Holzer, 2015). Therefore, problems can arise from the design defects and materials' selections in the construction phase, which could lead to time delays, overhead costs and increased tension between the project stakeholders (Talebi, 2014).

Another problem with this approach is that BIM adoption in the tender stage is limited, and the BIM model is not treated as an official tender document. Therefore, the tenderers cannot rely on it, which could lead to a compromise in its application (Bolpagni, 2013). Designers under the DBB approach should describe the content of the BIM model and should limit the restriction of the model in order to allow the tenderers to use it, add specifications and check the compliance between the 2D drawing and the model (COBIM, 2012). Moreover, so that the contractor can use the design of the BIM model, common languages such as IFC should be used in developing it. Porwal and Hewage (2013) stated that IFC is the most common format that supports BIM software; however, in places where BIM is still in its infancy, 2D drawings should be used alongside the BIM model in the tender document.

Despite these issues, adopting BIM with a DBB approach can benefit the clients as they receive more reliable and accurate bids, thus reducing the risk of later claims because inscrutability and conflict in the tender documents will be minimised through the BIM process (Saxon, 2013). In addition, the BIM process assures conformity between the 2D drawings and the BIM model because of the link between all the documents where a change in one element in the project will update and change the other elements accordingly; thus, they are coordinated (Bolpagni, 2013). Moreover, BIM implementation under a DBB approach can improve the overall process through (COBIM, 2012):

- visualisation and its impact on planning, collaboration and communication;
- 3D coordination and its influence on productivity and workflow; and
- the use of BIM as a digital data storage and its impact on recapturing the data through mitigating the data loss in the traditional paper-based process (Talebi, 2014).

As a summary, BIM can be implemented under a DBB approach. Despite the many BIM benefits under this approach, there are limitations for unlocking the full BIM benefits. These limitations can be summarised in two main points. The late contractor involvement after the design stage, which reduces the effectiveness of the BIM process, particularly in the collaboration and integration between the project participants (Eastman et al., 2011). The second point refers to the learning necessary for the BIM process to maximise the stakeholders' abilities for working with BIM. In places where BIM is in its infancy, finding BIM expert clients, consultants and contractors is challenging. Therefore, sufficient data might not be embedded in the BIM model, which could affect aspects such as the reliability of price (Roginski, 2011).

4.3.2 Design and Build (DB)

This approach has been widely implemented throughout the world for many years (Seng and Yusof, 2006; Turina et al., 2008). It was established to overcome the problems in the DBB approach in terms of improving the cost, schedule and quality of the construction projects (Roginski, 2011; Kent and Becerik-Gerber, 2010). Minchin et al. (2013) claimed that this approach is among the most favoured project delivery approaches due to its reputation for cost and time saving, reducing conflict and enhancing communication between the project stakeholders.

The basic concept of DB is that a single organisation is responsible for both the design and construction of a project under a single design-build contract (Turina et al., 2008; Koppinen and Lahdenperä, 2004, p. 32). This approach consists of three main elements: single responsibilities by one organisation, reimbursement using a fixed-price lump sum and the project being specifically delivered to meet the client needs (Seng and Yusof, 2006). In this approach, the client can appoint the contractor to carry out the design based on an outline brief and set of criteria. Figure 4.5 represents the project organisational structure under the DB approach.

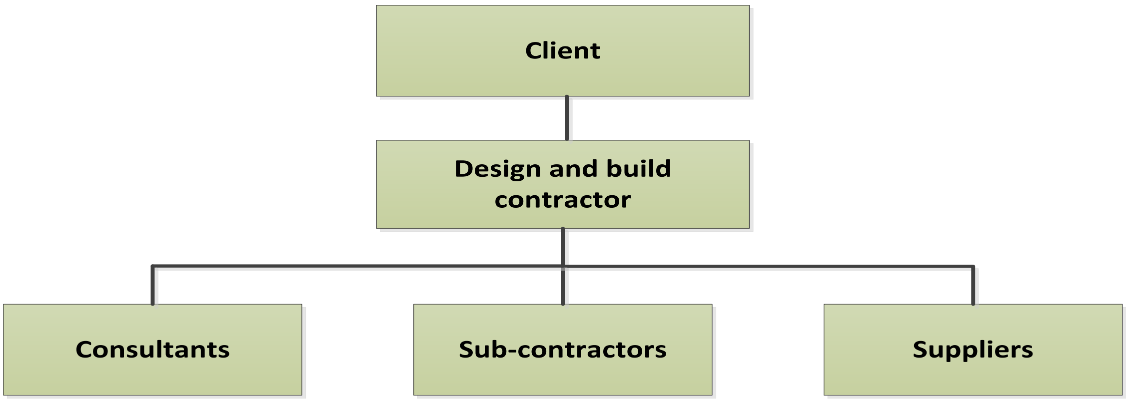


Figure 4.5: Project organisational structure under the DB approach (Turina et al., 2010; Seng and Yusof, 2006)

According to Rowlinson (1987) and Turina et al. (2008), this approach can be employed in three different forms:

- Pure design and build: in this form, the contractor strives for a self-contained approach where design and construction expertise are within one organisation, and they are able to complete any task that arises. Thus, it is more likely that a higher integration occurs in such an approach.
- Integrated design and build: the contractor organisation has a core of designers and project managers. However, the contractor is prepared to hire external design expertise when it is needed. Therefore, in-house project managers will coordinate the integration between the internal and external members of the design and construction team.
- Fragmented design and build: in this form, the contractor operates a fragmented approach by appointing external consultants who are coordinated by the in-house

project managers, whose other tasks include refining the client brief. In this form, many of the coordination and integration problems of the DBB approach are likely to stand in addition to the ambiguity of some roles among the professions. Moore and Dainty (2000) and Muriro (2015) argued that the roles and responsibilities in this form are the same as under the DBB approach.

The main steps for the DB approach are (Turner, 1990, p. 45):

- defining the client needs and requirements and the scope of the work;
- selecting a bidder to tender;
- contractors preparing their price proposal in addition to the technical and scheduled proposals;
- selecting a contractor based on price and/or qualification; and
- proceeding with designing and constructing the building.

The main advantages and disadvantages of adopting the DB approach are represented in Table 4.3.

Table 4.3: Advantages and disadvantages of the DB approach (Turina et al., 2008; Eastman et al., 2011; Morledge et al., 2006; Al Khalil, 2002)

Advantages	Disadvantages
Less risk on the client side	Few construction companies provide design and construction services, thus less competition
Single point of responsibility from the contractor	The difficulty of making changes at a later stage as it will be expensive
The flexibility of the design	The client might lose control over the design phase as he/she committed to the conceptual design before the completion of the detailed drawings
Integrated DB enables an overlap between the design and construction phases, which will enhance the communication between the contractor and the client	It might require the client side to hire additional designers to develop the design brief and tender document

Communication enhancement leads to better construction solutions	Under this approach, the lack of checks and balances will lead to less quality control
Minimising the changes in the construction phase	Comparing bids under this approach is difficult due to different designs adopted, and thus prices
The certainty of the final project cost can be achieved	
The contractor can contribute to the project planning and the design	

BIM Implementation Issues under DB

The DB approach is more integrated than DBB because the contractor team is involved early in the design phase. Therefore, the framework of this approach is structured towards better BIM implementation. Hardin (2009) argues that implementing BIM under DB is the first solid step towards implementing the full BIM process. In 2009, 67.3% of the BIM-based construction projects in the US were delivered under DB approaches (Cao et al., 2015). Moreover, BIM is considered by many authors to be beneficial for DB procurement approaches due to the single line of responsibility for the design and construction phases (Foulkes, 2012; Eastman et al., 2011). Moreover, facility management will be improved by implementing BIM with the DB approach due to the level of detail in the BIM model and digital operation and maintenance manuals that are attached to the BIM model components (Hardin, 2009).

DB faces many challenges which BIM implementation can help eliminate. For instance, the contractor under DB develops the building design based on the client's requirements and documents, arrives at a price and submits a tender. According to Foulkes (2012), in reality, this process often fails due to the inadequacy of the documents provided, the requirements not being clear, the scope being insufficiently defined, elements missing, and/or the client's requirements not having been effectively communicated to their design team. As a result, this could lead to delivering a building that does not comply with the client needs and user expectations. BIM implementation can change the process by submitting the design proposal in the form of a BIM model, which in turn allows the client to see the design in 3D and walk through its features, such that any misinterpretation in the client's requirements can be noticed easily (ibid).

Under DB, the contractor is usually selected in a negotiation process based on price, duration, quality of the design solution, pre-qualification and past performance in similar projects (Hardin 2009; Turner, 1990; Molenaar et al., 1999). To implement BIM under DB, it is important for the client to enquire about the bidder's previous experience in BIM (Eastman et al., 2011; BSI, 2013). BSI (PAS 1192-2:2013) (see Table 3.7) is a British standard, and Chapter 6 in the standard is dedicated to the procurement phase. Paragraph 6.3 in this chapter describes the Project Information Plan (PIP) as a document that can "assess the capabilities, competence and experience of potential suppliers bidding for a project" (BSI, 2013). On the contractors' side, adopting BIM under DB will be of great help to enhance the bid's accuracy regarding construction capability and price.

Despite the various benefits of implementing BIM under DB, there are issues associated with such an approach which can be summarised as follows: the risk lies with the contractor to maximise BIM knowledge transfer; a skilled contractor who understands BIM workflows is required to utilise BIM under DB; and the client's input to define operational requirements is not inevitably guaranteed (Holzer, 2015).

4.3.3 Construction Management (CM)

Construction management (CM) is a relatively new procurement approach (Thwala and Mathonsi, 2012). It is classified under management-oriented delivery approaches (see Figure 4.1). In this approach, a professional construction manager is employed by the client as a construction consultant to manage the process of building a development on behalf of the client (Al-Khalil, 2002). The main role of the construction manager is to work with the design team to ensure that the design can be built at a reasonable cost, and the drawings and specification can be understood by the builders (Thwala and Mathonsi, 2012).

In CM, the design and construction phases overlap to speed up the process. There are two forms under the CM approach (Eastman et al., 2011; Morledge et al., 2006; Koppinen and Lahdenperä, 2004):

- CM at fee (see Figure 4.6a): in this form, the construction manager is responsible for site and project management, but no involvement occurs in the construction work. Direct contracts are formed between the client and the trade contractors. The client appoints a construction manager to monitor the time, cost and quality of the project. However, no responsibility is taken by them. The client pays the construction manager a fixed fee or a time-based fee for his/her services.

- CM at risk (see Figure 4.6b): the difference from the above is that the construction manager has more responsibility, and thus risk. A construction manager's responsibility includes the construction methods, means and delivery of the project. This includes the quality and performance of the building. The contract lines are between the construction manager and subcontractors, but the client still has the final decision on the delivery process. The client pays the construction manager for services provided on a fixed or time-based fee. In addition, since the construction manager carries some construction work, the client pays for the construction based on cost and fee or a maximum guaranteed price.

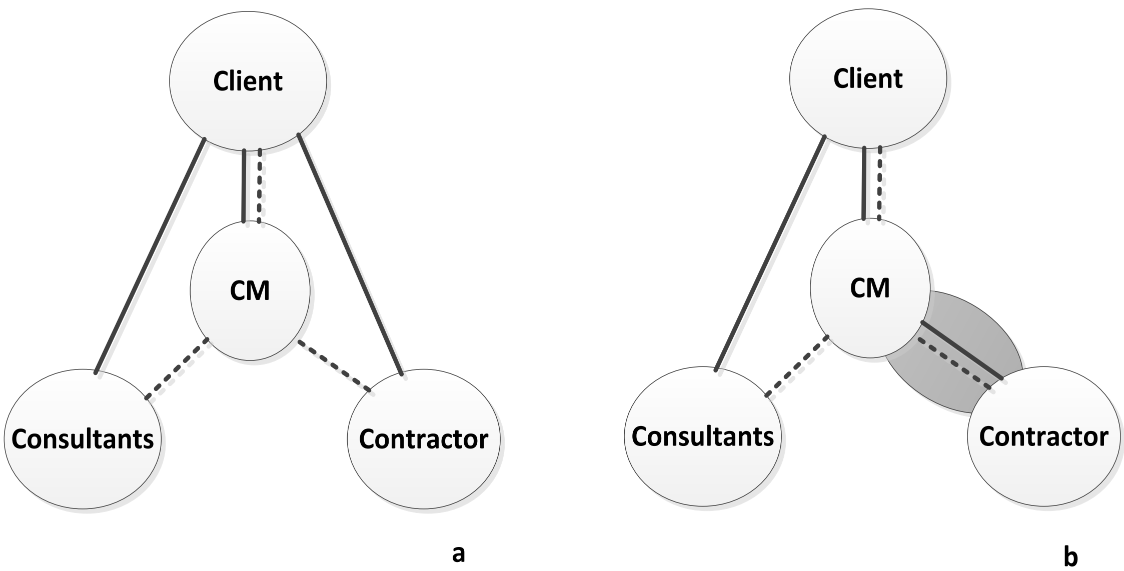


Figure 4.6: a) CM at-fee (Lahdenperä, 2001), and b) CM at-risk (Lahdenperä, 2001)

Regardless of the CM form adopted, the main steps are (Turner, 1990):

- defining the client's needs and requirements and scope of the work;
- assigning the design team;
- assigning a construction management organisation;
- developing the project programme and design requirements;
- selecting work contractors based on tendering; and
- proceeding with constructing the building.

The advantages and disadvantages of the CM approach are represented in Table 4.4.

Table 4.4: Advantages and disadvantages of the CM approach (Eastman et al., 2011; Koppinen and Lahdenperä, 2004; Turner, 1990; Lahdenperä, 2001)

Advantages	**Disadvantages**
The constructor is brought into the design stage. The value of the delivery approach stems from the early constructor involvement	Although the construction manager carries minimal financial risks under CM, the risk of the potential damage to their reputation is high
It is more cost effective to the client than DBB, especially in complex projects because the construction aspects are considered in the design phase, and the competition is extremely price oriented	Although variations can be introduced more easily due to the flexibility of the design and construction phases, it costs more than the DBB approach
Unlike DBB, CM allows the contractor to start the construction works before the design is fully completed, thus requiring a shorter time to complete the project	More risks are carried by the client due to the additional risks related to the coordination and the interfaces between the multiple contracts
Owner liability for cost overruns under the CM approach is reduced	Different entities are developing the design and construction, thus full cooperation might not be achieved
	Cost control and quality have lower priorities than the programme

BIM Implementation Issues under CM

According to Hardin (2009), the flow of information under CM supports the integration among the project stakeholders; this is because of the construction manager and the design team who report directly to the client (Hergunsel, 2011). Moreover, the involvement of the contractor and subcontractors in the design phase will allow for an integration of their inputs in the project's design and documentation (Hardin, 2009).

There are many benefits to implementing BIM under CM. BIM models hold quantitative information which can be used to prepare cost estimates in addition to improving the coordination between the project stakeholders (Mustafa, 2016). This coordination will limit requests for clarification by providing answers in a process in which ample information is exchanged due to the CM structure. Moreover, Hergunsel (2011) argued that implementing BIM under a CM approach allows space for innovation in the process by allowing different stakeholders to sit at the same table and share the responsibility of the project.

However, there are issues in the CM approach that could hinder the implementation of BIM (Hardin, 2015):

- Firstly, the consultants (the architects and engineers) are unwilling to model and/or share their model content. The main feature and benefit of CM is the early contractor involvement, but early contractor involvement does not contractually oblige the consultants to model or share their models. Appropriate contracts with the owner should handle this issue.
- The second issue that could limit BIM's potential under CM is the timely involvement of the contractor in the design phase. For example, if the contractor is required to use BIM for reviewing the design constructability, but the consultants are not required to model the design, then the contractor will be accountable for creating a model, which can be in-house or outsourced to a third party; this will lead to potential delays and additional cost for the constructability review.
- Finally, if the contractor is brought on board later, such as when 50% of the technical design is complete, this could leave the contractor with insufficient time for aggregating the models and applying a constructability analysis before completing the technical design by the consultants. According to Miller, Strombom, Iammarino and Black (2009), "if a contractor is capable of providing full project simulation but is only brought in at the end of the traditional design development phase, most of the decisions have been made" (Miller et al., 2009). Therefore, the contractor providing BIM should be involved in the design development (Hardin, 2009).

4.3.4 Integrated Project Delivery (IPD)

IPD is an emerging innovative procurement approach based on a multi-party agreement between construction project stakeholders to create a cooperative environment (Mills Oakley, 2015). Indeed, IPD aims to take the integration among different project stakeholders to a new level (Hardin, 2009). IPD is defined by the AIA as:

> A project delivery approach that integrates people, systems, business structure and practices into a process that collaboratively harnesses the talents and insights of all participants to optimise project results, increase value to the owner, reduce water consumption and maximise efficiency through all phases of design, fabrication and construction. (AIA, 2007)

IPD provides efficient collaboration among the project stakeholders, which takes place in all the delivery process stages from the pre-design, design and delivery of the project (AIA, 2007). In IPD, project stakeholders enter into a single collaborative contract where a multi-party agreement is signed to share risk and rewards (Ilozor and Kelly, 2012; Eastman et al., 2011). Furthermore, project stakeholders work collaboratively with the intention of meeting the client's requirements and achieving significant time and cost reduction by adopting collaborative tools (Eastman et al., 2011). Cost and time saving under IPD can be achieved by developing cost estimates early in the design stage; moreover, the contractor's early involvement can make a significant contribution by informing the constructability in the design process and reducing inefficiencies (ibid).

Table 4.5 presents the differences between IPD and DBB. Ashcraft (2010) added that the main difference is that the traditional approach is based on a tender process whereas IPD is based on a negotiation process.

Table 4.5: Summary of the differences between IPD and the traditional project delivery approach (AIA, 2007)

DBB	Criteria	IPD
Fragmented and assembled on a "just-as-needed" or "minimum necessary" basis; strongly hierarchical and controlled	**Teams**	An integrated team entity composed of key project stakeholders, assembled early in the process; open and collaborative
Linear, distinct, segregated; knowledge gathered "just-as-needed"; information hoarded; silos of knowledge and expertise	**Process**	Concurrent and multi-level; early contribution of knowledge and expertise; information openly shared; stakeholder trust and respect

Individually managed and transferred to the greatest extent possible	**Risk**	Collectively managed, appropriately shared
Individually pursued; minimum effort for maximum return; (usually) first-cost based	**Compensation/ reward**	Team success tied to project success; value based
Paper-based; two dimensional	**Communication/ technology**	Digitally based and virtual; Building Information Modelling (3, 4 and 5 dimensional)
Encourage unilateral effort; allocate and transfer risk; no sharing	**Agreement**	Encourage, foster, promote and support multilateral open sharing and collaboration; risk sharing

Mutual benefits, mutual respect, enhanced communication, early goal definition, appropriate technology adoption, clearly defined open standards, leadership taken by the party most capable of managing and high performance are the essential IPD principles (AIA, 2007). These principles can be applied to procurement approaches that promote (AIA, 2007):

- early involvement of key stakeholders;
- clear definition of responsibility;
- compensation structure such as incentives related to achieving project goals;
- management and control structures adopted based on the decision-making team; and
- fair balance of risk and reward.

Several studies determined the benefits and risks associated with the IPD delivery approach as presented in Table 4.6.

Table 4.6: Benefits and risks associated with the IPD approach (Ashcraft, 2010; Eastman et al., 2011; Duke et al., 2010; AIA, 2007)

Advantages	**Disadvantages (Risks)**
Shared risk and rewards	A major cultural shift is needed in the participants' behaviour and attitude

Project stakeholders acting as one firm	It could be complicated to manage and control the stakeholders as one firm
Project cost reduction through early discovery of the conflict areas as stakeholder inputs are added early in the design stage	New legal frameworks are needed by the organisation who decided to implement IPD
Significant reduction in operation and maintenance costs	Inexperienced participants can cause problems
Facility management improvement	It can only be implemented in certain project types
Enhancing the opportunity to meet the client expectations in terms of time, cost and quality	Open communication can raise issues
Moving from an adversarial to a collaborative relationship between stakeholders	A lack of projects delivered using IPD to obtain feedback and learn lessons
Reduction of time and cost due to shared costs and efficient planning	Clarity of roles and responsibility is diminished under IPD

One of the main risks associated with IPD is a culture change in which key stakeholders need to change their attitude and behaviour about the new paradigm to be able to successfully deliver the project (Ilozor and Kelly 2012). Therefore, according to Kent and Becerik-Gerber (2010), the culture of key stakeholders needs to be altered to present interpersonal dynamics such as trust, respect and good working relationships.

BIM Implementation Issues under IPD

BIM and IPD are two independent concepts. However, there are existent synergies between the two concepts. On the one hand, BIM has a positive impact on implementing IPD. In an AIA document, it was stated that “although it is possible to achieve IPD without BIM, it is the opinion and recommendations of this study that BIM is essential to efficiently achieve the collaboration required for IPD” (Eckblad et al., 2007). On the other hand, IPD was hailed as the ideal procurement approach that allows project stakeholders to achieve ‘full BIM collaboration’, but the idea of ‘full BIM’ is viewed more cautiously by the industry (Cleves and Dal Gallo, 2012). According to Holzer (2015), IPD is the closest fit approach in the context of BIM. This is due to the stakeholders' involvement and integration from the beginning of the process, which creates an effective environment for BIM implementation, and thus the full realisation of BIM benefits (Porwal and Hewage, 2013; AIA, 2007; Ashcraft, 2010; Kent and Becerik-Gerber, 2010; Succar, 2009). Lancaster and Tobin (2010) added that IPD is required to allow the efficient BIM-based process.

However, IPD in its pure form is too idealistic for common adoption on construction projects globally (Holzer, 2015). This is because of the barriers associated with implementing such an approach (see Table 4.10). These barriers can be summarised as four main issues (Wickersham, 2009):

- Financial issues with risk sharing and compensation.
- Legal issues with appropriate contracts.
- Cultural Issues with trust building and cohesive teamwork.
- Technological issues with interoperability among project stakeholders.

These barriers are echoed with the barriers in BIM implementation; therefore, there is a need to resolve these issues to fully utilise BIM, improve productivity and enhance sustainability in the construction industry. However, transforming the construction industry profoundly to a BIM-enabled collaborative project environment is a challenging task (Howard and Bjork, 2008). Therefore, a common misconception is identified by many researchers on the need to change the entire construction practice at once to adopt BIM practices (Kim, 2014).

4.4 THE NEED FOR INNOVATIVE PROCUREMENT APPROACHES TO IMPLEMENT BIM

Despite the need to employ collaborative procurement approaches such as IPD to implement BIM, Hardin (2009) argued that changing the existing procurement approaches to fully collaborative approaches to implement BIM will be faced with many challenges such as the need to reform the organisational structure and improve market maturity. Resistance to change will also hinder the process where firms are accustomed to the traditional process and structure (Porwal and Hewage 2013). Restructuring the organisation will need significant changes and efforts such as a new distribution of liabilities, redesigning the workflow and hiring experts with special skills, which could be a hindrance for the top management when adopting and implementing BIM. In addition, these concerns will increase due to the unclear definition of responsibilities when implementing BIM (Arayici et al., 2009; Eastman et al., 2008).

As a result, more and more construction projects are procured based on some elements related to collaborative procurement approaches, thereby adopting approaches such as impure IPD or "IPD-lite" as a closer fit between aspiration and current market dynamics (Sive and Hays, 2009). Despite this, little research has been conducted on developing innovative procurement approaches to facilitate BIM implementation. Porwal and Hewage (2013) and London et al. (2008) developed alternative innovative approaches to facilitate effective BIM implementation. These are presented in the following subsections.

4.4.1 Design Process Management for BIM Implementation

A contractor-led BIM project framework has been developed by London et al. (2008) (see Figure 4.7). Procurement represents a major part of the framework. In this framework, the current capability of BIM adoption in an organisation is emphasised through a systematic assessment. London et al. (2008) recommended the need to identify the internal work processes and their relationships with different external stakeholders for a framework development that is synchronised with the current work processes. This framework provides an essential point in that BIM cannot be adopted by introducing a whole new work environment with new processes designed for BIM; however, it could be adopted based on the existing work processes. Therefore, it is essential to develop a framework that is designed for a certain work environment to be able to adopt BIM efficiently.

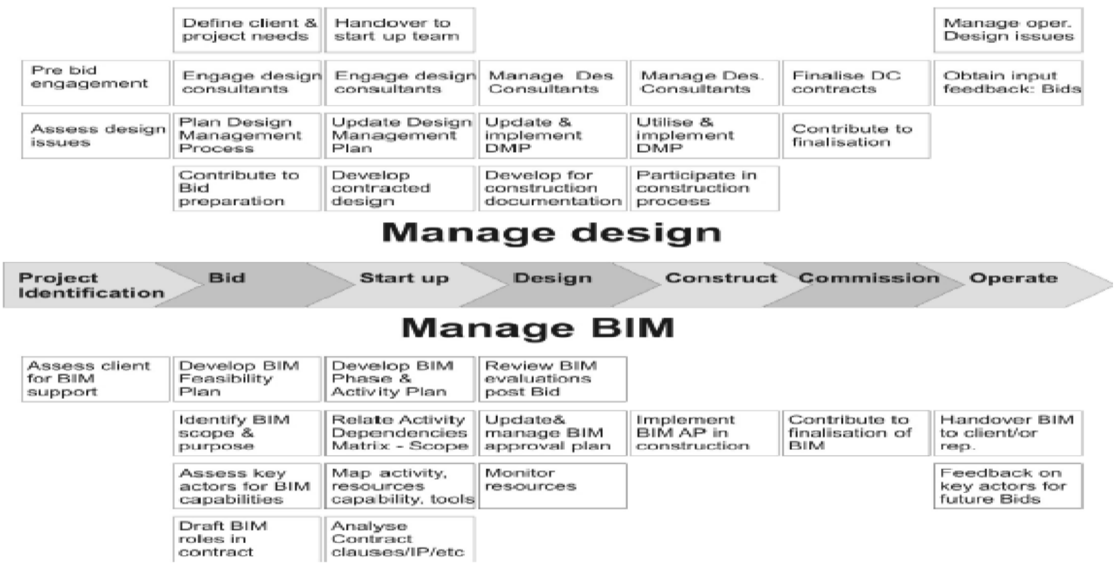


Figure 4.7: Design process management for BIM implementation (London et al., 2008)

4.4.2 Early BIM Partnering Project Delivery Approach

Porwal and Hewage (2013) conducted some research on the public sector. They criticised the adopted procurement approaches in the public construction sector in Canada due to their fragmented nature, and that the design and construction phases were carried out separately as the contractor is only involved after finalising the design. This has limited the capability of BIM; therefore, Porwal and Hewage (2013) proposed an 'Early BIM Partnering' approach to introduce BIM smoothly to the current procurement approaches in the public sector in Canada. Succar (2009) expressed the same and added that the public sector is not ready in terms of the processes, people and products to adapt and position BIM to the level of IPD.

The main features of this approach are the early commitment to BIM in the project planning phase and the early involvement of the contractor. The researchers proposed five main management processes to administer publicly funded capital projects in Canada: planning, modelling, partnering awards, early partnering and construction phases (see Figure 4.8).

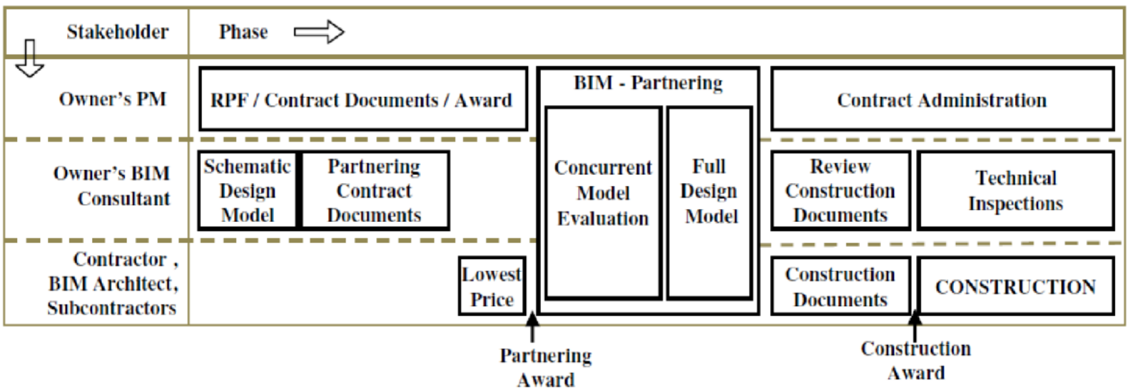


Figure 4.8: Early BIM partnering project delivery approach (Porwal and Hewage, 2013)

The above section discussed the importance of adopting innovative procurement approaches for the effective implementation of BIM. Therefore, one of the principle objectives of this research is to investigate whether the adopted procurement approaches in the Jordanian public sector are fit for the purpose of effective BIM implementation by exploring the current procurement approaches in public sector construction in Jordan and to identify the procurement challenges faced by the public stakeholders when implementing BIM. Chapter 5 will discuss how this will be achieved.

4.5 THE IMPLICATIONS OF CONSTRUCTION PROCUREMENT ON SUSTAINABILITY CONSIDERATIONS

BIM can support delivering sustainable buildings as discussed in Section 3.5. The literature suggests that construction procurement can support or hinder BIM implementation as discussed earlier in this chapter. Construction procurement is also found to be significant for delivering sustainable buildings. Some experts in the industry agree that the procurement methods are considered to be a solution to address the performance gap, which in turn helps to achieve a final sustainable product for its whole lifecycle. As Roderic Bunn (a principal consultant at the Building Services Research and Information Association BSRIA) claimed, “procurement methods and construction standards are to blame for the lack of building energy performance.” (Mark, 2013). Another expert in the same field, Tom Dollard (head of sustainability at Pollard Thomas Edwards Architects), agreed that “the performance gap will be addressed through re-structuring the procurement of buildings” (Ibid).

Despite the importance of selecting a procurement approach that facilitates sustainability and embedding sustainability into the procurement process, the academic literature is lacking (Preuss, 2009), especially in the public sector (Brammer and Walker, 2011). The following identify the construction procurement desired factors and attributes for achieving sustainability.

4.5.1 Procurement Factors and Attributes for Delivering Sustainable Buildings

In the context of a building, the shift towards and demand for sustainable buildings continues to expand due to projects having a long-term environmental, social and economic impact on society (Wang et al., 2014). Moreover, the required performance from such buildings has increased in recent years to include occupant wellbeing and user issues of satisfaction (Korkmaz, 2013). These buildings are complex, have more delivery constraints (Riley et al., 2004; Kibert, 2007; Horman et al., 2006) and are characterised by high levels of interdependence and interaction in the technical systems. Therefore, it becomes crucial for optimising building design solutions, electrical, lighting and mechanical systems and the material selections (Magent et al., 2009). According to Enache-Pommer and Horman (2009), Lapinski et al. (2006), 7 Group and Reed (2009), Robichaud and Anantatmula (2011), Riley et al. (2004) and Horman et al. (2006), this interdisciplinary interaction suggests that better sustainability outcomes will be achieved from the early involvement of participants, compatibility with the project groups 'team characteristics', team experience and the level and methods of communication. Furthermore, the clients' commitment to sustainability and an early introduction to sustainability will enable the achievement of sustainable buildings at a lower cost (Nofera and Korkmaz, 2010; Horman et al., 2006).

Korkmaz (2013) conducted interviews with owners, designers and constructors for 12 completed projects that obtained an LEED certificate; the aim of his research was to investigate the effect of construction procurement approaches on the integration level achieved in these projects, and whether project outcomes were affected with the emphasis on sustainability goals. In summary, he found that procurement approaches do affect final project sustainable outcomes in terms of the 'timing of the participants' entry' and 'team characteristics' attributes.

Swarup (2011) also found that the level of integration is an important factor for achieving sustainability outcomes, and it is one of the main attributes for procurement approaches to achieve sustainable buildings. Integration between project' stakeholders was represented by the time of the constructor involvement early in the design phase, documents and bidding. As a result, he suggested that "the constructor should be on board by the design development phase (contractually or informally)" for successful sustainability outcomes (Swarup, 2011). Furthermore, the integration level, particularly in the design phase, can be achieved from an iterative process of modelling and reappraisal to achieve an optimal and integrated design (Masterman, 2002; Bower, 2003; Hamza and Greenwood 2007; HEEPI, SUST & Thirdwave, 2008).

Moreover, Sourani (2013) conducted a pivotal study that enabled the public client to better address sustainable construction when developing procurement strategies. A set of contractual procurement factors were identified by conducting three rounds of Delphi, interviews and discussions with a highly qualified panel of experts from the UK public sector. These factors are:

- Highlighting sustainability in the project brief as a primary aim.
- Integrating sustainability requirements into contract specifications and conditions (including specifying any project-specific sustainability requirements).
- Emphasising the importance of sustainability in tender evaluation and selection procedures.

- Requirement/incentive for the supply side to demonstrate a commitment to sustainable development through policy and implementation.
- Requiring the supply side to demonstrate the capability of delivering sustainability requirements.
- Encouraging tenderers to suggest innovative solutions and approaches that support the client's overall sustainability objectives.
- Requiring the employment of a properly trained workforce within the supply side.
- Ensuring that payment mechanisms take account of whether sustainability requirements are delivered.
- Provision of incentives and rewards based on sustainability performance throughout the project lifecycle.

Therefore, it is argued in this research that in order to achieve sustainability through construction procurement, these factors and attributes need to be considered in the selected construction procurement approach to improve the sustainability performance of buildings.

4.5.2 Procurement Approaches for Sustainability

Procurement approaches such as the traditional ones have been criticised because of the segregation between design, construction, operations and a lack of continuous management of the project. According to Molenaar et al. (2009), the majority of LEED accredited professionals (APs) believe that building projects delivered under alternative procurement systems such as construction management at risk (CMR) and DB will have a better chance of achieving sustainability goals compared to traditional procurement approaches. On the other hand, Hamza and Greenwood (2007) argued that both traditional and DB delivery approaches will hinder achieving sustainable outcomes as the interactions needed are at odds with the contractor's intention to avoid extra cost and delays.

The Innovation and Growth Team within the UK government produced the 'Low Carbon Construction Report' (Morrell, 2010) to answer the question of "whether the construction industry is fit for purpose to transition to a low carbon economy". One of the main aspects included in this report is the procurement approach selection. The argument was that to afford a zero or near-zero carbon building, a degree of innovation is needed, whether in process or product, to eliminate cost; this called for an integrated team. Procurement cannot make this innovation happen, but it can prevent it from taking the design to the point that it leaves insufficient room for significant innovation. Therefore, choosing the type of procurement that assists in the integration of the design team will give sufficient room for significant innovation, which will reduce the cost for the delivery of zero/near-zero sustainable buildings, meaning it will cost the same as the buildings that were delivered according to the current building regulations (Morrell, 2010).

In response to the recommendations in the above report, the government's Construction Task Group stated that they were committed to trying three new procurement models. These models are based on the existing procurement approaches, which were established for the public sector and include: cost led procurement (CLP), a two-stage open book and an integrated project insurance (IPI). The key principles of these approaches include early supplier engagement, integrated and collaborative teamwork and transparency of cost (Cabinet Office, 2012). Table 4.7 represents the specific characteristics and common characteristics across all three procurement approaches.

Table 4.7: UK governmental new construction procurement approaches (Cabinet Office, 2012)

New Procurement Models	Model Specific Characteristics	Characteristics common across Models
Cost Led Procurement	The key characteristics of the CLP model are "integrated framework supplier teams" who "develop innovative bids against output specification" and "develop proposals to meet requirements within a cost envelope"	● Early contractor involvement ● The client specifies the output ● The client works with the integrated supply chain to create a design and construct solution ● Open book ● Independent verification Achievement of full integration
Integrated Project Insurance	The key characteristics of the IPI procurement model are an "integrated project team", "independent technical and financial validation", "genuine integration, collaboration, open-book" and a "single IPI cover".	
Two-Stage Open Book	The key characteristics of the two-stage open book procurement model are "two-stage design and build", "ECI", "open-book", "output specification" and a "team working ethos". The approach is described as drawing on the best experiences from the two-stage DB and early contractor involvement (ECI).	

4.6 CONSTRUCTION PROCUREMENT IN JORDAN

In Jordan, different laws govern the construction industry such as ‘Law No. (7) of 1993 Jordanian National Building Law’, ‘Law No. (15) of 1972, Engineers Association Law’, ‘Law No. (12) of 1987, Land Acquisition Law’, ‘Law No. (13) of 1987, Construction Contractors Law’ and ‘Law No. (24) of 1986, Law of Roads’ (MPWH, 2018a). However, the public procurement regime is governed by, ‘The Government Construction Regulation No. 71 of 1986’ issued pursuant to Article 114 and 120 of the Constitution’; which defines the tendering and procurement process of the public construction projects. A summary of the key findings in this regulation that are related to the tender stage and procurement process are in Table 4.8.

Table 4.8: Public procurement and tender processes in Jordan

The Government Construction Regulation No. 71 of 1986	Explanation
Preparation and Arrangement of	• Technical services are allocated to studies, engineering and technical design for the construction project as well as the supervision of its execution. • Works are allocated with the construction of buildings, installations, roads and various types of engineering projects.
Tender Documents	**- Technical Services:** • a general description of the project together with a table of the department's requirements; • the land plans and organisational plans concerning the building projects; • the cost limits; • the contractual conditions; • the methods for specifying the period of completion of the work, fees and amount of the required guarantees. **- Works:** • the project description; • the tender instructions; • the general and specific conditions of the contractual agreement; namely, the conditions shown in the contract agreement book, which is issued by the MPWH; • the technical specifications, bills of quantities and prices; and • the forms of contract and guarantees.

Tenders' Execution Methods	Both technical services and work tenders can be executed through: • public tenders; • tenders through special invitation; • direct awards; and • direct execution.
Tendering Procedure	The tendering procedure is based on pre-qualification procedures and follows these steps: • the tenderers shall be invited through one of the above execution methods; • an adequate period between the announcement on the tender and the time for depositing offers should be allowed; • the tender offers should be submitted as follows: 1. within one envelope containing the technical information requested in the tender invitation and the financial offer; or 2. in two separate envelopes: one containing the technical offer, and the other containing the financial offer; • the tenders' box shall be opened at the date and time set in the tender invitation, and it shall be opened in a public session; • the committee shall award the tender to the tenderer with 'the best offer'.
Consultants' Classifications	Consultants are classified by grades according to their experience, such as in buildings, roads and sewage. Under each category, the consultants were classified as: first-grade class A, first-grade class B, second grade and third grade.
Contractors' Classifications	Construction contractors are classified into grades or classes according to their financial, technical and administrative qualifications, equipment and experience in the execution of works. They are classified according to their different expertise such as in buildings, roads and sewage. Under each one, the contractors were classified into: grade 1, grade 2, grade 3, grade 4 and grade 5.

Sami Halaseh (the Minister of Public Works and Housing) expressed the importance of improving the management systems and procurement processes in the public sector in Jordan during a seminar in Amman, attended by a number of experts and executives of firms working in the field of construction:

> All participants from across the sector have agreed that our biggest challenge over the next decade is 'raising the bar' on quality and excellence [...] the quality of management systems of our companies, and the quality and integrity of our regulatory standards and procurement processes. (Jordan Times, 2015)

No specific, compulsory procurement approaches were reported in the procurement regulation (see Table 4.8) (Al Assaf, 2017). However, this regulation divided the tender documents based on the services: technical (design) and work (construction). Moreover, the technical services and works' tenders are mentioned as separate stages. Therefore, the regulation leans towards two separate agreements between the government consultants and government contractors.

For BIM, there is a paucity of research on the types of procurement approaches adopted by BIM-based projects in Jordan, especially in the public sector, and on the common construction procurement approach problems that affect the implementation of BIM in Jordan. This is because BIM is still in its primitive phase in Jordan, according to the latest studies (see Section 3.3.3).

For sustainability, Alkelani (2012) conducted some research on the sustainable procurement practices in Jordan. The findings show that despite the effort to promote sustainable procurement practices, it is still in its infancy; this is due to the ineffective procurement framework, and the government policies and regulations as an underlying cause. She recommended that to move towards more sustainable construction practices, there is a need to change the construction procurement approaches across the public sector development projects. Moreover, there is a need to alter the process of evaluation of the contractors during the tendering by ensuring that the contractors demonstrate their capacities and capabilities of working with sustainable construction methods (Alkelani, 2012).

4.7 JUSTIFICATION FOR CARRYING OUT THIS RESEARCH

The public buildings in Jordan are frequently constructed in comparison to other types of construction works (Al Assaf, 2017) (see Table 2.5). However, these public buildings are criticised for their lack of performance, especially in sustainability (Tewfik and Ali, 2014). BIM has been introduced to improve the buildings' performance regarding time, cost, quality and sustainability (see Sections 3.3.1 and 3.5). Looking at BIM's global status (see Section 3.5.1), it can be argued that BIM adoption and implementation vary from developed to developing countries. This is due to the variations in the political pressure on BIM as the public client has a significant role in pushing BIM implementation in a country (see Section 3.5.3). The public client should be acting as the driver and initiator, educator, regulator, researcher, demonstrator and funding agency for BIM implementation. In developed countries, this was demonstrated by placing BIM among the primary objectives of many governmental construction strategies, such as in the UK, the US and Australia. However, in developing countries and particularly in the Middle East including Jordan, a lack of governmental action towards BIM implementation was reported. This has resulted in a lack of clear, practical frameworks, strategies and mechanisms for its implementation (see Section 3.5.2).

Many governmental construction strategies and standards clearly stated that in order to implement BIM, the procurement approach has to be outlined in advance. Therefore, the selection of a suitable construction procurement approach represents a major concern for the implementation of BIM (see Section 3.5.2). The literature revealed two main viewpoints for dealing with these concerns:

- Profound process changes are necessary for BIM implementation (Volk et al., 2014), particularly to deliver the necessary collaborative platform that brings together multiple stakeholders over the project lifecycle (Pcholakis, 2010; Laishram, 2011). Therefore, it could be argued that clients are likely to change the way that they procure buildings when implementing BIM to ensure more integrated and collaborative working processes (Foulkes, 2012). IPD was hailed as the ideal procurement approach that allows project stakeholders to achieve 'full BIM collaboration' (Cleves and Dal Gallo, 2012) and an efficient BIM-based process.
- Others have argued that transforming the construction industry profoundly to a BIM-enabled collaborative project environment is a challenging task (Howard and Bjork, 2008). Therefore, a common misconception is identified by many researchers on the need to change the entire construction practices at once to adopt BIM practices (Kim, 2014). Instead, researchers recommend identifying work processes to develop a framework that synchronises with current work processes (Porwal and Hewage, 2013; London et al., 2008)

The existence of the two standpoints emphasise the need for investigating the current procurement practices in the public sector in Jordan, its effect on BIM implementation. There have been no previous studies conducted in Jordan on this, particularly in the public sector.

4.8 CHAPTER SUMMARY

This chapter reviewed the existing literature on the construction procurement definitions, classifications and processes of construction procurement. The effect of a procurement approach on BIM was also explored. It was found that choosing the right procurement approach can bring the necessary collaborative environment for implementing BIM effectively. The opportunities and disadvantages of the main public procurement approaches for implementing BIM and achieving sustainability were also explored and discussed. DBB is considered to be the least effective procurement approach for implementing BIM and achieving sustainability whereas IPD is seen as the ideal procurement approach for BIM and sustainability. Many procurement attributes and factors for effectively implementing BIM and achieving sustainability in buildings were revealed from reviewing the literature:

- Early key stakeholder involvement.
- Level and method of communications.
- Integrated project team consisting of client, designers and constructors.
- Compatibility with the project groups 'team characteristics'.
- Team technological- and sustainability-based competency.
- Clear roles, responsibilities and communication lines.
- Integrated design process.
- Common goals and collaborative decision-making.
- The iterative design process of modelling and reappraisal.

This research revealed a lack of BIM studies on the public sector in Jordan including procurement approaches suitable for BIM implementation. Therefore, this research aims to fill these gaps by investigating the state of BIM adoption and implementation in the Jordanian construction public sector, the construction procurement approaches used and whether these affect BIM adoption and implementation. The next chapter discusses the research methodology used to address the research aim and objectives.

CHAPTER 5: RESEARCH METHODOLOGY

5.1 INTRODUCTION

The research methodology is "far more than the methods adopted in a particular study and encompasses the rationale and the philosophical assumptions that underlie a particular study" (Knight et al., 2008, p. 3). Therefore, this chapter discusses the philosophical position supporting this research project (or the theoretical perspective and epistemology), which guides the methodology (that is the plan of action and strategies used) and justifies the used methods (the procedures and techniques) (Crotty, 1998; Creswell, 1994).

Figure 5.1 represents the methodological elements adapted from Saunders et al. (2009). This chapter unfolds the 'onion' layers from philosophy to techniques.

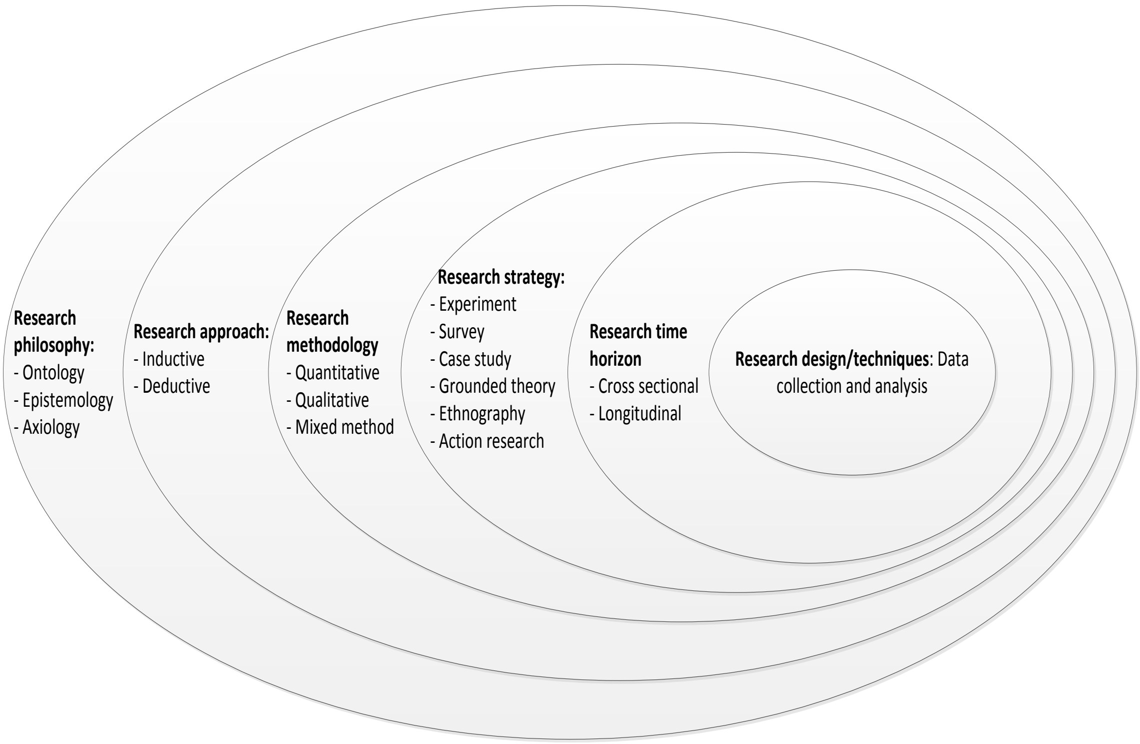


Figure 5.1: Research onion layers, adapted from Saunders et al. (2009)

To design and conduct this research, this chapter aims to provide answers to the questions stated in Table 5.1 below. Each question refers to a layer in Saunders and Lewis' (2009) model.

Table 5.1: Questions to be answered to design and conduct the research, adapted from Sexton (2003) and Hay (2002)

Question	Layer
What is knowledge?	Ontology
How do we know knowledge?	Epistemology
What is the value of knowledge?	Axiology
What is the method of reasoning?	Research approach
How can we go about acquiring knowledge?	Methodology
What are the tools used to acquire knowledge?	Research strategy
What is the timeframe of the data to be collected?	Research time horizon
What are the sources of the data to be collected?	Research design
Which precise procedures are used to collect and analyse the data?	Research design

This chapter is structured into the following sections:

- Research philosophy or theory of knowledge: ontology, epistemology and axiology (see Section 5.2).
- Research approach to reasoning: induction and deduction (see Section 5.3).
- Research methodology: quantitative, qualitative and mixed methods (see Section 5.4).
- Research strategy: experiment, survey, action research, grounded theory, case study and ethnography (see Section 5.5).
- Research time horizons: cross-sectional and longitudinal (see Section 5.6).
- Research design which includes the research data collection techniques and analysis methods (see Section 5.7).
- Research validity and reliability (see Section 5.8).
- Research ethical considerations (see Section 5.9).

The stated aim of this research is to develop a procurement framework for implementing BIM to deliver sustainable public buildings in Jordan. To realise and achieve the BIM benefits on a project level, BIM has to be implemented first. BIM implementation needs both organisational utilisation and managerial implementation. Therefore, this research is a form of 'management research'. It is defined by an organisation context and how managerial systems are conducted to solve problems (Bryman and Bell, 2007).

5.2 RESEARCH PHILOSOPHY

A research philosophy often called a research paradigm represents a philosophical worldview. It has been defined as "a basic set of beliefs that guide action" (Guba, 1990, p. 17; Creswell, 2009). A research philosophy includes the following components (Tuchman, 1994; Scotland, 2012): ontology, epistemology and axiology.

5.2.1 Ontology

Ontology is the study of being, the nature of existence and what creates reality (Crotty, 1998). An ontological position can be classified into two categories: realist and relativist (Fitzgerald and Howcroft, 1998). Realists argue that the social and natural worlds exist independent of human observation and action (Blaikie, 2007), and it can be measured objectively by bracketing and methodologically limiting personal human bias (Ramey and Grubb, 2009). Relativist argues that the external world does not exist independently of our perception (Blaikie, 2007). Moreover, it is derived from a 'point of view or evolved perspective' (Raskin, 2008; p.13), and it is created by human interpretation, perception and the consequent actions of social actors (Saunders et al., 2009).

The ontological assumptions, whether realist or relativist, are included in the adopted theory that guides the research and the methods employed (Blaikie, 2007). Ontological assumptions need to be reconciled with the epistemological ones (Gee, 2005). Next section discusses available epistemology stand for a research project.

5.2.2 Epistemology

Epistemology is the study, theory and justification of knowledge (Carter and Little, 2007). It is the examination of 'how we make knowledge' (Dillon and Wals, 2006, p. 550). According to Carter and Little (2007), epistemology influences the methods of research in three main ways:

- through the relationship between the researcher and the participants, and whether the participants are considered to be subjects of the study or as active contributors;
- by the quality of the methods being demonstrated by ensuring that the actions undertaken lead to rigorous data collection and analysis; and

- by the researchers communicating with and conceptualising their audience, and whether the varied methods can be adopted to make the participants act as active interpreters for both producing and disseminating the research findings.

Onwuegbuzie and Leech (2005) identified two main opposing camps within epistemology: positivism and interpretivism. These were described by Knight and Ruddock as being:

> Bounded by the positivist view that the methods of natural science should be applied to the study of social phenomena, and the alternative orthodoxy of interpretivism view that the method of natural science and people in that phenomena have a different subjective meaning for the actors studied. (Knight and Ruddock, 2008, p. 3)

Positivism only considers observable phenomena as being driven by natural mechanisms and laws (Riege, 2003). Theory testing is at the centre of this approach, which can be obtained by quantitative research methods, such as experiments. On the other hand, in interpretivism, which constitutes the philosophical ideas principally adopted in management and other social sciences, there is the belief that reality is socially constructed by people and their experiences, so that the context of this social reality is conceived through these human backgrounds and experiences (Creswell, 2003). Thus, this type of research is dependent on context and time. Moreover, interpreting people's perceptions is based on the researcher's own view of reality (Stiles, 1993). In short, and according to Hyde (2000), the traditional view is that qualitative researchers follow the interpretivism paradigm, and the quantitative researchers follow the positivist one.

In addition to the above two main epistemological approaches, there is also pragmatism. This epistemological stand takes a middle position between the positivists and those who favour interpretivism. It allows the researcher to use different research methods (qualitative and quantitative) to achieve the research objectives and answer the research questions. Pragmatism is based on breaking the traditional social reality viewpoints into a range that exists on a continuum between interpretivism and positivism. The focus of this epistemological position is on understanding the 'what' and the 'how' of the research questions in a real-life context (Creswell, 2003). Therefore, mixed methods are usually associated with pragmatism in which both quantitative and qualitative methods are combined (Creswell 2007; Tashakkori and Teddlie, 1998).

5.2.3 Axiology

After considering ontology (what is knowledge?) and epistemology (how do we know knowledge?), the next stage is to identify the axiology (what is the value of knowledge?). Put in a simple way, this relates to the credibility of the results. According to Saunders et al. (2009), axiology refers to a judgment about the study's value, and it stems from the Greek word αξία - axiā, "value, worth", and λόγος –logos. Axiology is classified according to whether reality is value-drive and value-laden or value-neutral and value-free (Lekka-Kowalik, 2010). The latter is followed by positivists (objectivists) researchers who claim that they are less influenced by their values as cannot change the outcome. For example, in experiments using laboratory tests, the acidity of a liquid is tested by applying the liquid on a litmus paper, which will turn red or blue. Therefore, researchers' value has no impact on the results. On the other hand, interpretivists (or subjectivists) believe reality depends on the perspective of a person or the subject. Saundres et al. (2009) claim that researchers are influenced by their values as soon as they decide to perform a piece of research. Therefore, interpretivism suggests that the research is value-drive or value-laden (Silverman, 1998). Figure 5.2 represents these considerations within ontology, epistemology and axiology.

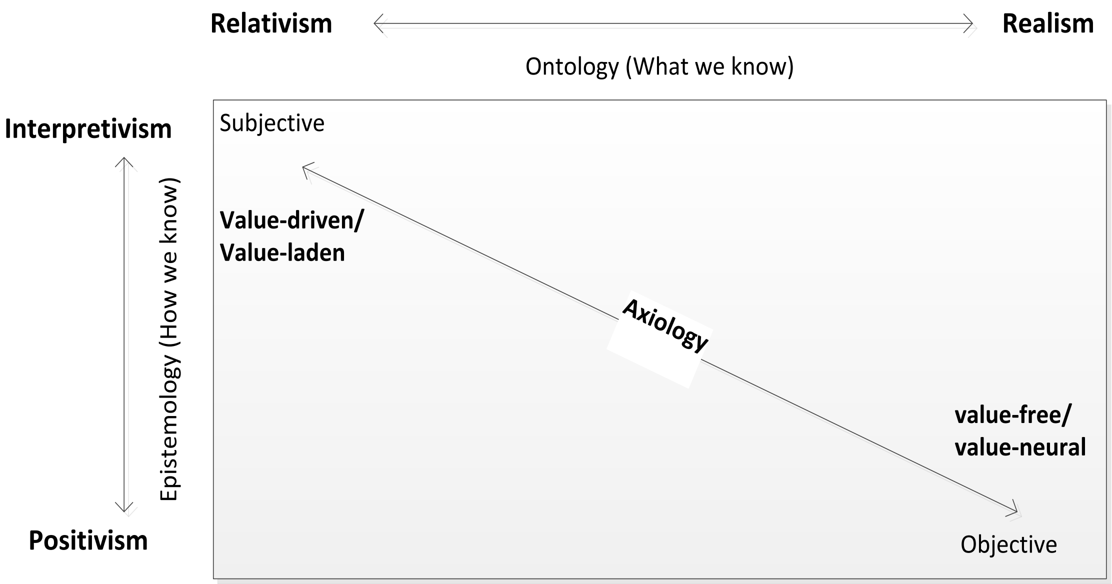


Figure 5.2: Dimensions of research philosophy, adapted from Sexton (2003), Saunders et al., (2009) and Lekka-Kowalik (2010)

5.2.4 Research Position

This research aims to develop a procurement framework to enable a more effective BIM implementation in the delivery of sustainable public buildings in Jordan. This is based on the belief that a systematic procurement approach is needed to implement BIM and to achieve sustainable buildings, which is associated with positivism. On the other hand, this research is also associated with interpretivism as it requires the contribution of the major stakeholders in the public construction sector in Jordan in which their 'subjective' perceptions, collective decisions and 'socially constructed' realities are seen as part of the BIM 'phenomena'. Therefore, this research adopts the philosophical position of pragmatism.

Moreover, this thesis is considered to be within the field of management research where the terms 'hard' and 'soft' are broadly used in the project management literature. Hard indicates a focus on the tangible aspects or the tasks involved whereas soft indicates a focus on the intangible or the people involved (Crawford and Pollack, 2004). A hard paradigm is associated with a positivist position while a soft one is connected to interpretivism (Pollack, 2007). This research will investigate the tasks and people (both hard and soft) in managing the delivery process of public buildings in Jordan; therefore, pragmatism will serve as the worldview of this research.

By adopting pragmatism, this research is better placed to highlight the challenges in the current procurement processes and provide suggestions for an improved implementation of BIM to deliver sustainable public buildings in Jordan. Moreover, a practical method for the framework development can be identified in this research.

5.3 RESEARCH APPROACH

Once the research philosophy has been determined, a research approach needs to be considered which provides the methods of reasoning about the data (Trochim and Donnelly, 2006). There are two traditional opposing approaches: deductive and inductive. These two approaches can be differentiated by hypothesis testing and theory development (Blaikie, 2010).

5.3.1 Deductive Approach

Deduction broadly means going from the general to the particular (Riege, 2003; Hyde, 2000). Therefore, a deductive approach begins by having a tentative hypothesis or a set of hypotheses in mind, which form a generalisation or theory (Hyde, 2000). The researcher tests the hypothesis through observation, thus also the theory (Bendassolli, 2013). The results either confirm or reject the hypothesis, thus the theory. Figure 5.3 represents the deductive approach.

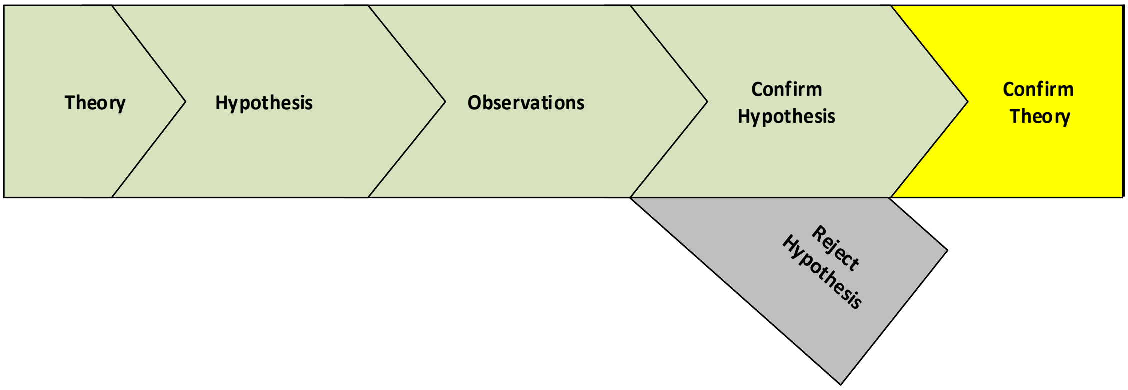


Figure 5.3: Deductive approach, adapted from Skinner (2010)

5.3.2 Inductive Approach

Induction is the process of going from the particular to the general (or universal) (Locke, 2007). Induction is in contrast to deduction as it is about building the theory from observations instead of testing a theory (Riege, 2003). Therefore, researchers adopting an inductive approach build generalisations out of observing specific events (Skinner, 2010). Their primary focus is on achieving an understanding of individuals, groups of individuals or a specific situation (Bendassolli, 2013). Thus, inductive reasoning aims to move from specific instances to a general rule, law or pattern (Hyde, 2000). Figure 5.4 represents the inductive approach.

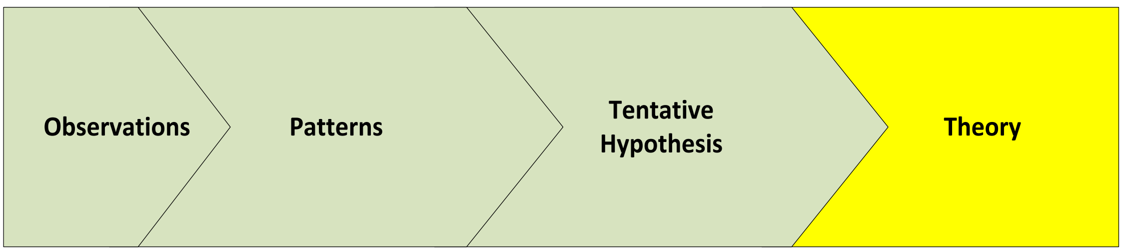


Figure 5.4: Inductive approach, adapted from Skinner (2010)

5.3.3 Research Approach Adopted

Both deductive and inductive approaches were adopted in this research. The deductive approach was adopted first by moving from generalised to more specific concepts, that is from different broad topics such as sustainability, BIM and procurement approaches were explored by analysing the literature during the early stages of the research. These components were then further narrowed down to the context of public buildings in Jordan after the data collection (see Section 5.7). Then, the inductive approach was used to develop a framework from the interviews, questionnaire analysis and the secondary data to tackle the construction procurement challenges to effectively implement BIM, and thus improve the public buildings' sustainability performance in the context of Jordan.

5.4 RESEARCH METHODOLOGY

Figure 5.5 represents the methodological choices for a research project (Saunders et al., 2012). Methodological choices are classified into: the mono-method and multiple methods. The term mono-method refers to the use of a single technique for data collection and similar analytical procedures. Multiple methods mean the use of more than one technique for data collection and corresponding analytical techniques to achieve the research objectives.

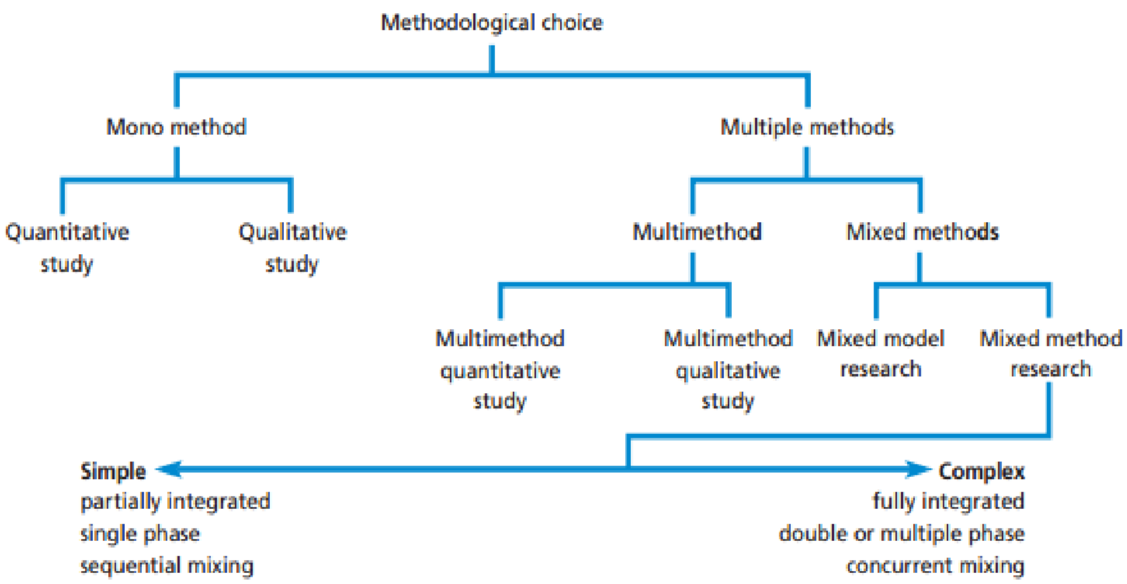


Figure 5.5: Methodological choices (Saunders et al., 2012)

5.4.1 Mono Method

There are two categories of mono methods: quantitative and qualitative (see Figure 5.6). Quantitative research is usually used to answer questions about how much or how many. This type of research is observed by positivists (objectivists) researchers as more consistent and trustworthy, thus enabling a wider acceptance and producing suitable outcomes (Baker and Foy, 2008). Quantitative research stems from the positivist philosophy and deductive approach, which begins with a general statement and/or hypothesis developed from the literature and proposing a general relationship between the variables in question (Creswell, 2003). Usually, this approach involves collecting and analysing numerical data and applying statistical tests. Therefore, to interpret this kind of data, an objective position seems to fit. As an example, a survey can be quantitative since it provides numerical data by asking narrow and precise questions (Fellows and Liu, 2015).

Qualitative research is mostly employed to answer research questions about the what, why and how (Bryman, 2004). This type of research follows interpretivism, which is usually adopted to explore and understand the meaning of groups or individual attributes in view of a human or social problem (Creswell, 2009). According to Fellows and Liu (2015), qualitative research can answer such questions as 'why things are happening' through the lens of interpretivism, which is defined by the meanings that groups of people attribute to processes or events. Moreover, qualitative research can be used to better understand a phenomenon about which little is known (Strauss and Corbin, 1990).

Table 5.2 represents the main differences between quantitative and qualitative methods, including the challenges for each method.

Table 5.2: Quantitative and qualitative research features and challenges, adapted from Easterby-Smith et al. (2012), Marshall and Rossman (2010), Bryman and Bell (2011, p. 410), Yin (2003) and Knight and Ruddock (2008)

Quantitative research	Qualitative research
Exploratory, descriptive and explanatory	Exploratory, descriptive and explanatory
Ask how much or how many?	Ask what or why?
Deductive	Inductive
Theory testing	Theory developing
Questionnaire surveys	In-depth interviews
Pre-specified	Open-ended

Large sample size	Small sample size
Generalisations	Contextual understanding
Considers statistical analysis	Studies, content and pattern analysis
Structured	Unstructured
Objective	Subjective
Outcome oriented	Process oriented
Conclusive	Impressionistic
Aims at truth	Aims at new perceptions
Artificial setting	Natural setting
Behaviour	Meaning
Macro	Micro
Hard, reliable data	Soft, deep data
Weaknesses: • It is not very effective in understanding the significance that people attach to actions. • The methods used tend to be rather inflexible and artificial. • It's hard to generate theories under quantitative research.	Weaknesses: • The results might be less credible to policy-makers than the results from a qualitative approach. • It is more difficult to control the progress and end-point of the research process. • The data analysis and interpretations might be more time consuming and difficult. • The process of data collection requires more resources and can be tedious.

5.4.2 Multi/Mixed Methods

The term 'multi-method' refers to the use of two methods that are not integrated, that is the qualitative data are gathered and analysed within a quantitative framework and vice versa (Tashakkori and Teddlie, 2003). Mixed methods research has been defined by Saunders et al. (2009) as "using both quantitative and qualitative data collection techniques and analysis procedures in one research design" where qualitative data are analysed qualitatively, and quantitative data are analysed quantitatively.

Regarding the research philosophy, both quantitative and qualitative methods can be utilised in a mixed methodology, which Patton (1990) feels is the most appropriate method. In other words, quantitative and qualitative methods of data collection and analysis or a combination of the two methods can be employed under any of the research paradigms. Their use should adhere to the overall information and requirements needed to answer the research question(s) (Balgheeth, 2016). Mingers explained the benefits of adopting a mixed methods approach:

> Adopting a particular paradigm is like viewing the world through a particular instrument such as a telescope, an X-ray machine, or an electron microscope. Each reveals certain aspects but is completely blind to others […] each instrument produces a totally different and seemingly incompatible representation. Thus adopting only one paradigm, one is inevitably gaining only a limited view of a particular intervention or research situation […] it is always wise to utilise a variety of approaches. (Knight and Ruddock, 2008, p. 9, quotes Mingers, 1997)

There are many other reasons for using a mixed methods research, such as facilitation, triangulation and complementarity. For example, the information generated by one method can inform and lead to another data collection and analysis method (Creswell, 2013). Table 5.3 represents the different reasons for using a mixed methods research.

Table 5.3: Reasons for using a mixed methods design (Saunders et al., 2009, p. 154)

Reason	Explanation
Facilitation	"Use of one data collection method or research strategy to aid research using another data collection method or research strategy within a study (e.g. qualitative/quantitative providing hypothesis, aiding measurement, quantitative/qualitative participant or case selection)"
Triangulation	"Use of two or more independent sources of data collection methods to corroborate research findings within a study"
Complementarity	"Use of two or more research strategies so that different aspects of an investigation can be dovetailed (e.g. qualitative plus quantitative questionnaire to fill in the gaps, quantitative plus qualitative questionnaire for issues, interview for meaning)"

Generality	"Use of an independent source of data to the contextualise main study or use of quantitative analysis to provide a sense of relative importance (e.g. qualitative plus quantitative to set the case in a broader context; qualitative x quantitative analysis is to provide a sense of relative importance)"
Studying different aspects	"Quantitative to look at macro aspects and qualitative to look at micro aspects"
Aiding interpretation	"Use of qualitative data to help explain relationships between quantitative variables (e.g. quantitative/qualitative)"
Solving a puzzle	"Use of an alternate data collection method when the initial method reveals inexplicable results or insufficient data"

5.4.3 Research Method Adopted

This research adopts a mixed methods approach to allow for a subjective, interpretive analysis and a statistical analogy. Few studies have been implemented on BIM in Jordan, with no previous research on BIM implementation in the public construction sector in Jordan. Therefore, this research is exploratory in nature. Both qualitative and quantitative methods were needed for the nature of this research (see Table 5.2). Mixed methods sequential procedures were adopted in this research (see Table 5.4), and the study started by applying a quantitative approach with a larger sample to investigate the feasibility of BIM in the public sector in Jordan. Moreover, it also aimed to identify the key issues in BIM implementation. Then, the qualitative methods were adhered to by implementing a detailed exploration of the BIM practitioners regarding certain issues raised from the questionnaire study and literature review. Equal priority was given to both the quantitative and qualitative data regarding the data collection and analysis. Data integration was considered with some combination of the collected, analysed and interpreted data. More details about the research strategy, data collection methods and methods of analysing the data will be discussed in the following sections.

Table 5.4: Reasons for choosing a mixed methods research (Creswell, 2003)

Implementation	Priority	Integration	Theoretical Perspective
No Sequence Concurrent	Equal	At data collection	Explicit
Sequential – Qualitative First	Qualitative	At data analysis	
Sequential – Quantitative First	Quantitative	With some combination	Implicit

5.5 RESEARCH STRATEGY

A researcher adopts a research strategy to design a process, which is conducted to achieve the research objectives (Saunders et al., 2009). There are various strategies available to researchers such as experiments, surveys, grounded theory, case studies, ethnography and action research (Creswell, 2007; Yin, 2009). Each of these strategies has pros and cons. However, the chosen strategy should be the one where the research objectives can be most thoroughly and efficiently addressed (Naoum et al., 2007).

Three main aspects need to be considered to select a suitable research strategy, form appropriate research questions, control behavioural events and decide whether or not the focus is on contemporary events (Yin, 2003). Table 5.5 represents the features of the different research strategies in terms of these three key aspects.

Table 5.5: Different research strategies (Yin, 2003)

Research strategy	Research question formation	Control of behavioural events	Focus on contemporary events
Experiment	How, why	Yes	Yes
Survey	Who, what, where, how many, how much	No	Yes
Archival analysis	Who, what, where, how many, how much	No	Yes/no
History	How, why	No	No
Case study	How, why	No	Yes

This research does not require control over behavioural events as the researcher cannot intervene in the participants' thoughts and views about delivering public buildings in Jordan. On the other hand, the research concentrates on contemporary events, which are the delivery of public buildings using BIM in Jordan. Moreover, as mentioned above, few studies have been carried out on BIM in Jordan, with previous research on BIM implementation in the public construction sector in Jordan being non-existent. Therefore, this research is exploratory to understand the context of the problem by asking the question of 'how BIM is currently implemented under existing procurement approaches in the Jordanian public sector?'; this will enable an understanding of the current situation, identify the problems and propose changes to improve BIM implementation, and thus reap the benefits involved.

Therefore, this research adopted the use of a survey because this approach, above all the others, fits with the nature of this research, and thus the research objectives and questions. Moreover, the limitations inherent in a case study and action research approaches in their lack of generalisability made it impossible to select these approaches (Gerring, 2007; Yin, 2009).

5.5.1 Research Survey

Surveys are commonly associated with deductive reasoning, rather than inductive when they positioned within the positivist paradigm, which is common in the business and management research fields (Saunders et al., 2009). This kind of survey method is usually used to answer 'who', 'what', 'where', 'how much' and 'how many', rather than 'why' and 'how', and it also concentrates on testing hypotheses (see Table 5.5). Survey methods of this nature are based on statistical sampling and are rarely on a population survey (Fellows and Liu, 2015). Table 5.6 highlights the common advantages and disadvantages of the quantitative elements in using surveys.

Table 5.6: Potential advantages and disadvantages of the quantitative elements in surveys (Fellows and Liu, 2015)

Potential advantages	Potential disadvantages
The survey can provide a relatively quick and substantial amount of data if good response rates are achieved	There might be a lack of connection to real human experience or broader theories and issues
Surveys can be easy to carry out since they do not necessarily require fieldwork and data entry (since online surveys can be self-administered)	The focus on breadth, rather than depth for its validity can be considered to be a significant issue for small-scale studies
A comparison can be made by repeating the survey in the future or in a different setting	The focus on static snapshots of points in time, rather than process and change can be problematic
Surveys can provide generalisable results with an appropriate sample	Checking how well the research questions were understood by the respondents is often not possible. Therefore, issues such as accuracy and truthfulness are raised
	The occurrence of bias and error in the sampling might be reflected in the findings that do not accurately reflect the population

Other types of the survey methods can use elements of the interpretative paradigm and inductive reasoning. These types aim to find a relationship between the respondents' characteristics and their opinions and behaviours (Balgheeth, 2016). Moreover, surveys were found to be a suitable way of gathering data about people's thoughts, actions and beliefs (Martin and Guerin, 2006). There are four main instruments for collecting data through the survey method: questionnaires, interviews (structured and semi-structured), attitude scale and standardised tests (Al Awad, 2015). This research has used questionnaires and interviews as tools for primary data collection in addition to the literature review for secondary data. These tools will be further discussed in Section 5.7.

5.6 RESEARCH TIME HORIZONS

There are two types of time horizons for conducting research: cross-sectional and longitudinal research. A cross-sectional approach is a 'snapshot' while a longitudinal one is over a period of time, such as in a 'diary' (Saunders et al., 2009). This research is cross-sectional since the data are collected once, at a given point in time about a particular phenomenon from the participants' viewpoints. The reasons for this choice are related to the targeted population in this research as they mainly hold managerial roles in their organisations, and it is unlikely that their consent would be obtained for participation in a longitudinal study. Another reason is that there are certain time constraints inherent in PhD research, as noted by many authors.

5.7 RESEARCH DESIGN

Figure 5.6 clarifies the research design phases that have been followed in this thesis. The following represent the main four phases:

- In Phase 1, an exploratory study (a questionnaire survey) was conducted to investigate BIM feasibility for public buildings in Jordan, which led and informed Phase 2 by confirming the feasibility of BIM utilisation in the public sector in Jordan and the importance of procurement approaches in this utilisation.
- In Phase 2, semi-structured interviews were conducted among BIM practitioners in the public sector in Jordan to obtain further insight and knowledge on BIM utilisation, current procurement methods and sustainability approaches.

- In Phase 3, a framework for enhancing BIM implementation and thus delivering sustainable buildings was developed from analysing the literature and data collected in Phases 1 and 2.
- In Phase 4, the developed framework was validated through semi-structured interviews with BIM practitioners in Jordan.

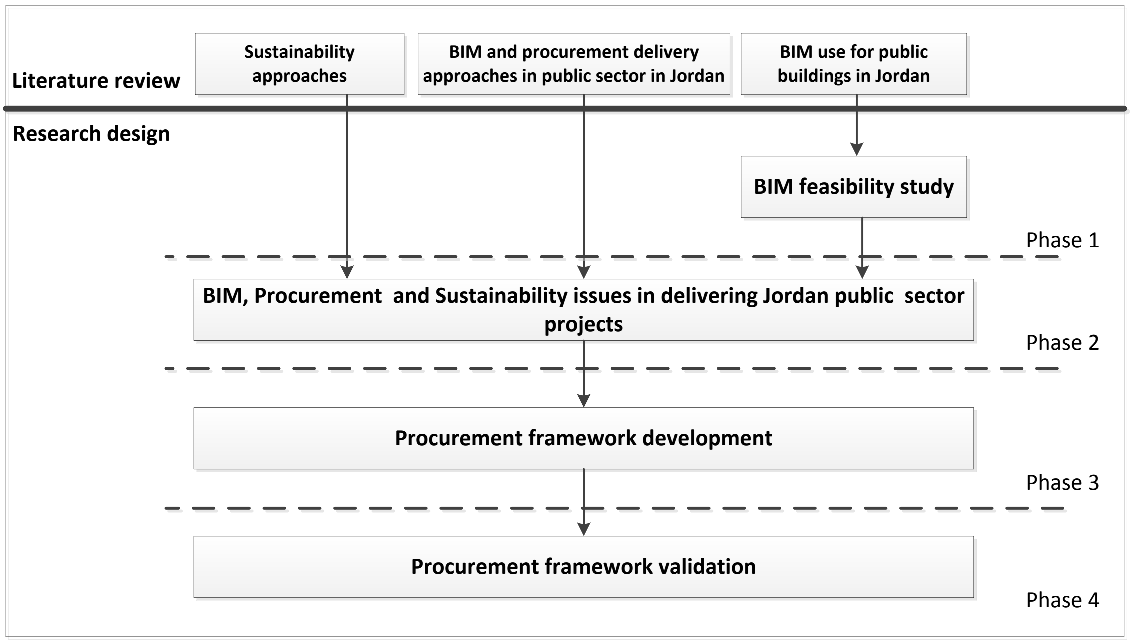


Figure 5.6: Research design

The following sections will provide more in-depth information about the research methods adopted in this thesis.

5.7.1 Literature Review

Davis (2005, p. VIII) described the process of reviewing the literature as a symmetric and systematic pattern of workflow in which it starts with a plan to search the literature, finds the literature, choses and evaluates the literature, and then possesses the literature. However, the literature review should not be developed to the point of distorting the thesis formation (Denholm and Evans, 2007, p. 212).

In this research, reviewing the literature was based on three interrelated axes. Firstly, a review was carried out of the current literature on sustainable development and sustainable construction strategies worldwide and in the public sector in Jordan. In this, the literature revealed that public buildings in Jordan have poor performance in terms of sustainability and also problems associated with the time, cost and quality of construction.

Moreover, despite the existence of many sustainable strategies, research on achieving sustainable buildings through project management approaches is still lacking. Far less research has focused on these issues in developing economies, particularly in the Middle East.

The second part was about reviewing the literature on BIM implementation and its effect on delivering sustainable buildings. In this, the literature explored different BIM definitions, BIM maturity levels, applications and the most effective and theoretical practices for implementing BIM to enable a learning from these successful studies of BIM when implemented by different construction stakeholders. The literature also explored the available support for BIM implementation for delivering sustainable buildings by introducing the 'Sustainability BIM Triangle'. This provides evidence that BIM implementation supports designing and delivering sustainability buildings in different project phases, from planning to demolition, and BIM supports for various sustainability assessment tools. In the third part, the literature on the construction procurement approaches including the definitions, classifications, processes and types were explored. It also looked at the construction procurement approaches' effect on BIM implementation for achieving sustainable buildings.

The analysis of the literature revealed the need for sustainable public buildings in Jordan, the BIM implementation supports for constructing sustainable buildings projects, the effect of different procurement approaches on BIM implementation. However, BIM and the impact of procurement approaches on BIM implementation are not currently explored in the public construction sector in Jordan. Therefore, there was a need to explore BIM theory and the impact of procurement approaches on BIM implementation through questionnaire surveys and interviews in the context of the public sector in Jordan.

5.7.2 Phase 1: BIM Feasibility Study

This phase was conducted to ascertain BIM's appropriateness and to identify current barriers for implementing BIM for public building projects in Jordan. The questionnaire survey acted as an exploratory type of research. Questionnaires were used because large amounts of information can be collected from a large number of participants over a short time span. Moreover, the data collected through the questionnaires can be easily quantified through a software package, thus measuring changes by comparing and contrasting the results with other research outcomes (Fellows and Liu, 2015).

5.7.2.1 Sampling Method

There are two types of sampling: probability and non-probability/purposive (Bryman and Bell, 2007; Dawson, 2002, p. 48). Probability represents the process whereby each of the sample members has an equal chance of being chosen while purposive sampling represents the process in which the samples do not have the same opportunity to be chosen; moreover, generalisation in this type is not a priority. Probability sampling can be divided into simple random sampling, stratified random sampling, systematic sampling and multi-stage cluster sampling (Bryman and Bell, 2007). Non-probability/purposive sampling has also been classified into three methods: quota sampling, snowball and convenience. Furthermore, there is a total population sampling, which is located under purpose sampling. This type assumes that the sample is the total population. It is more common when the numbers of cases or participants are relatively small (Etikan et al., 2016).

Choosing an appropriate and suitable sampling method is a crucial step in questionnaire surveys (see Table 5.4). Page et al. (2012, p. 70) explained that “a sample size calculation justifies the proposed study and in doing so demonstrates that the study has the ability to support the statistical analysis required to answer the research question”. To collect and reach a variety of viewpoints from construction professionals in the Jordanian public sector, three groups were targeted, that is the public client, public consultants and public contractors. The public client is represented by MPWH and GTD for their roles in delivering public building projects (see Section 2.5.2.2). MPWH and GTD consist of 20 departments such as the Planning and Project Management Unit, the Support Operations Management and the Management of Buildings Technical Studies. Each of these departments is responsible for an aspect of the delivery of public buildings in Jordan. Therefore, the total population sampling method was chosen for the public client group.

Public consultants and contractors were targeted because of their crucial roles in delivering public buildings; moreover, the consultants and contractors accounted for the highest number of BIM users in the Middle East (BuildingSMART, 2011); therefore, the data can be seen as more reliable. Due to the high numbers in the sampling population, stratified random sampling (Teddlie and Yu, 2007) was used for the public consultants and contractors, which combines stratified sampling with random sampling. Stratified random sampling is a method of sampling that consists of dividing a population into groups known as strata. The strata are formed based on the members' shared characteristics and attributes. The strata in this research were formed based on the public clients, MPWH and GTD, the classifications for the contractors and consultants, as follows:

- Contractor strata and substrata: the study adopted the Jordanian Government classification as it is mentioned in the Works By-Law: Section 8 Article 23, A:

> The classification of the construction contractors in the various types of works shall be made within the classes or grades according to the financial, technical and administrative qualifications, equipment and experience in the execution of works pursuant to the instructions issued by the Council of Ministers, which define the classification requirements, conditions and classes. (The Hashemite Kingdom of Jordan, 1986).

MPWH and GTD classified the contractor works in Jordan, according to Government works by-law No. 71 for the year 1986, Section 8, Article 23. The same article in point E, stated that these "construction contractors' classification tables, which were issued by the Minister, shall be adopted for the execution of all governmental works in the Kingdom" (The Hashemite Kingdom of Jordan, 1986, p. 24). This provides the necessary validity for using this classification when targeting the public sector in Jordan and for generalising the research findings. The study used this classification to divide contractors into substrata (see Table 5.7).

Table 5.7: Number of contractors (Jordan Government Department, 2016)

Contractors	**Category**				
	Grade 1	**Grade 2**	**Grade 3**	**Grade 4**	**Grade 5**
Speciality	**Buildings**				
Number	**80**	**68**	**136**	**_**	**_**
The maximum size of the project allowed to bid for (million JD)	**_**	**7**	**3**	**1**	**0.25**

- Consultants' strata and substrata: the MPWH and GTD classified the public consultants into four groups according to their building speciality, that is first-grade class A, first-grade class B, second grade and third grade (see Table 5.8).

Table 5.8: Number of qualified consultants (Jordan Government Department, 2016)

Consultants	Category			
	First Grade class A	**First Grade class B**	**Second Grade**	**Third Grade**
Speciality	Buildings			
Number	18	11	3	0

Table 5.9 represents the combined strata of three major stakeholders in the public building sector: the public client, consultants and contractors, and it presents the total population for each stratum. A list of all the MPWH departments, public consultants and contractors are published online on the GTD department website.

Table 5.9: Questionnaire strata

Research Strata	MPWH & GTD	Contractors/ Grade			Consultants / Grade			
	HoD	**1st**	**2nd**	**3rd**	**1st A**	**1st B**	**2nd**	**3rd**
Population	20	80	68	136	18	11	3	0
Total population	20	284			32			
Sample size	20	164			30			
Number of sent questionnaires	20	164			30			

5.7.2.2 Questionnaire Administration

There are different approaches in which the questionnaire survey can be distributed via the Internet, post, phone and by hand. Table 5.10 represents a comparison of the different approaches. In this research, two methods were used. For the public client representative, the questionnaires were distributed by hand due to the relatively low numbers in the sample, to maximise the response rate and to enable the researcher to distribute the questionnaires easily as all 20 departments are located in one building. For the public consultants and contractors, the Internet was used to distribute the questionnaire survey. It was achieved through the use of ‘Survey Monkey’.

Table 5.10: Different questionnaire survey approaches (Silverman; 2004; Knight and Ruddock, 2008; Ahmad, 2013)

Questionnaire	Internet	Phone	Post
Cost involved	A minimal cost attached to the process of forwarding questionnaire surveys. There are many free online survey websites.	The cost is at its maximum when conducting phone interviews, depending on the line called and the phone line used to make the calls.	A higher cost is involved in posting the questionnaires, which are usually sent out with returned stamps and envelopes.
Communication flexibility (control)	More information tabs are provided using online surveys for more clarification.	There is an opportunity to explain or clarify any complications.	It does not provide further clarification.
Communication speed	It is fast, as quick as the press of a button.	Respondents have to be available to participate, otherwise it is a fast communication method.	Delays should be expected depending on the postage type.
Data analysis time	Faster.	Less time intensive.	Time-consuming.
Data analysis	Online surveys can be easily or automatically analysed by some capable software.	Manually organised.	Manually organised.
Data access	The data can only be accessed through the Internet.	A document might need to be forwarded before the phone survey.	The received surveys are easily accessible.

Data quality	The quality of the data would be as expected.	The quality of the data can be affected by the network.	The quality of the data would be as expected.
Data storage	The data is easily managed.	The data has to be recorded.	Data in high numbers could be difficult to manage

5.7.2.3 Questionnaire Sections

The questionnaire with closed-ended questions was developed based on previous and similar research carried out on BIM awareness, its status and the benefits and barriers (NBS, 2011; Kim, 2014). The questionnaire questions were reviewed by the research supervision team in the University of Portsmouth, and also by a lecturer in the University of Jordan to eliminate any misleading questions, ambiguity and potential response difficulties. Then, the questions were reviewed and updated.

The questionnaire comprised 15 questions designed under five main sections (see Table 5.11) to elicit information about BIM in the public sector in Jordan. These sections explored levels of awareness of BIM, its current status, the benefits and barriers, the feasibility of BIM adoption for the public sector and the procurement approach used in BIM public projects. Identifying BIM implementation barriers in the Jordanian public sector was the focal point of this phase, which had the potential to affect the direction of this research. A question was added at the end of the questionnaire (see Question 16) asking the respondents to provide their details if they would like to participate in the next stage of the study. The questionnaire is in Appendices C and D.

Table 5.11: Questionnaire sections

Section Number	What	Why
1	Profile of respondents	To ensure the respondents' appropriateness for the survey
2	Current status and awareness of BIM	To understand how BIM is currently used in the public sector in Jordan and for which building type and project
		To find out the potential use of BIM; it is essential to identify if there is a demand or an awareness of BIM among public practitioners and public clients in Jordan
		To find out whether adopting BIM in Jordan should be top-down (refers to the government push BIM adoption) or bottom-up (refer to the grass-root adoption of BIM without a coercive mandate), and to identify if there is a gap in driving BIM in the public sector
3	Benefits and barriers to BIM use in public projects	To identify if they are aware of BIM's potential benefits for delivering public building projects in Jordan
		The focal point of this phase was to identify barriers to BIM implementation for delivering public building projects in Jordan
4	Feasibility of BIM adoption for the public sector	To reveal how the participants consider BIM at present
5	Procurement approaches used in public projects	To identify what type of procurement approaches are used in delivering public buildings in Jordan

5.7.2.4 Method of Questionnaire Survey Analysis

A questionnaire survey analysis is categorised into two different groups, which are descriptive and inferential statistics (Farrell, 2011). The descriptive statistics result in expressive analysis through applying approaches such as mode, average, ranking and mean. The inferential statistics are conducted through correlational statistics and probability. The main features for each of the questionnaire groups are presented in Table 5.12.

Table 5.12: Methods of questionnaire survey analysis (Farrell, 2011)

Descriptive statistics' features	Inferential statistics' features
Confident intervals	Using correlation coefficients to measure validity and internal reliability
Standard score: the Z score	The chi-square test
A measure of the spread: range, standard deviation and variance	The difference in the mean test: the 't' test
Normal distribution: measures of central tendency (mean, median and mode)	The difference in means, correlations or both
Ranking	Correlations

A descriptive questionnaire analysis was used in this research to describe the questionnaire survey participants' opinions about the feasibility of BIM implementation in the public sector in Jordan.

A Likert scale has been implemented in the questionnaire survey questions and analysis to describe the collected data for this research. Two types of Likert scale were used and presented in Tables 5.13 and 5.14. These scales were chosen according to the nature of the questions in the distributed questionnaire.

Table 5.13: Weighting factors used in the analysis of the Likert questions (Type 1)

Likert scoring scale	**Too Low**	**Low**	**Average**	**High**	**Too High**
Weighting factors	1	2	3	4	5

Table 5.14: Weighting factors used in the analysis of the Likert questions (Type 2)

Likert scoring scale	**Least Beneficial**				**Most Beneficial**
	Least Barriers				**Most Barriers**
Weighting factors	1	2	3	4	5

5.7.3 Phase 2: BIM, Procurement and Sustainability Issues in the Jordan Public Sector Projects

This phase is a result of the questionnaire survey findings in Phase 1, which verified the desire for the public client, consultant and contractors to use BIM to deliver public building projects. The questionnaire survey also identified the barriers and challenges to implementing BIM in the Jordanian public sector. The type of 'procurement approach' was one of the major barriers and challenges for implementing BIM in the public sector in Jordan. Therefore, this phase was undertaken to understand the current procurement strategies and approaches, the BIM processes and how the procurement strategies and approaches affect BIM implementation in the public sector in Jordan. Moreover, this phase assisted the researcher in exploring the current practices, issues and challenges to delivering sustainable buildings.

Interviews are a suitable approach for collecting in-depth primary data, which a study can analyse (Easterby-Smith et al., 2008). On the other hand, a relationship between the interviewer and the interviewees can be created which could affect the interview outcomes. Therefore, a stable relationship should be created between the interviewer and interviewees. Denzin and Lincoln (1998, p. 174) expressed that it is preferable if there is "a constructive, organised, well structured, sensible and stable relationship between the interviewee and the interviewer during the interview process to collect impartial, equitable and unbiased data".

5.7.3.1 Interviews Types

There are three types of interviews: structured, unstructured and semi-structured (Creswell, 2013). Structured interviews usually use closed-ended questions and are strongly related to quantitative research. Denscombe (2007) describes these as a form of face-to-face questionnaire. Unstructured interviews can be compared to a conversation that is directly related to the research where ideas are developed by the interviewee following their sequence of thought. A semi-structured interview is taking a middle stand between unstructured and structured interviews. In this type, a list of themes and questions need to be covered, but the order of the questions' may vary depending on the conversation flow, thus allowing additional questions to be added to explore other aspects of the research questions (Saunders et al., 2009). In this phase, semi-structured interviews were adopted to collect in-depth information about BIM phenomena. Open-ended questions and questions oriented towards BIM implementation, procurement approaches and sustainability practices were posed by the researcher.

5.7.3.2 Sampling Method

The sampling methods explain the process by which suitable elements (organisations and/or people) were chosen. The purpose 'quota sampling' method was used as the interviewees were selected, which depended on their previous experience in the BIM process, procurement approaches and delivering sustainable buildings; moreover, the target was to get interviewees representing the three major stakeholders: the public client, consultants and contractors. Phase one (the BIM feasibility study) assisted the researcher in identifying the possible interviewees that have the necessary and related experience. 29 respondents were already using BIM. All of those had previous experience in procurement approaches and delivering sustainable buildings as the BIM feasibility study targeted managerial level professionals. Moreover, they were registered in one of the organisations that had been labelled by the Jordanian Green Building Council as one of the major players in sustainability in Jordan. Therefore, an invitation to participate in an interview was sent to these 29 BIM practitioners (see Appendix E). 12 of them agreed to be interviewed (see Table 5.15).

Semi-structured interviews were conducted with the project managers, BIM managers, contract managers, construction managers and the tender managers that had been working on public building projects with costs ranging between one million to billions of Jordanian Dinners (JD). The interviewees were selected from four areas of work (public client, public consultant, public contractor and construction management).

Table 5.15: Stakeholders' information

Organisation size	Participants	Department/ Company	Position	No. of years' experience	Size of the projects
M	P1	Public client/ design department	Project manager	18	Hundreds of million JD
M	P2	Public client	Project manager	15	1-50 million JD
S	P3	Public client/ GTD	Tender manager	24	1-50 million JD
S	P4	Public client	Project manager	10	1-20 million JD
M	P5	Consultant	BIM manager	8	20-100 million JD

S	P6	Consultant	Contract manager	36	1-629 million JD
M	P7	Consultant	Project manger	23	1-260 million JD
S	P8	Construction management	Construction manager	45	5-200 million JD
S	P9	Construction management	Project manager and construction manager	18	Several billion JD
M	P10	Contractor	Contract manager	13	1-20 million JD
M	P11	Contractor	Project manager	8	1-80 million JD
S	P12	Contractor	BIM regional manager	9	20m-4.5 billion JD

5.7.3.3 Interview Design

This research adopted semi-structured interviews as mentioned in the previous sections. However, both open-ended and closed-ended questions were used due to the need for in-depth data and for the purpose of clarity (in the statistical data). Open-ended questions were used to allow the stakeholders to give information on what and who is involved, and also when, how and why things are performed. As no clear answer was found in the literature review findings on how procurement influences the implementation of BIM to achieve sustainable buildings in the public sector in Jordan, closed-ended were used in certain specific contexts. Therefore, closed and open-ended questions were deemed appropriate and were used for collecting the data. To control the process of the interviews, Swetnam and Swetnam, (2007, p. 68) claimed that the following guidelines should be followed:

- prompt interviewees for clarification, but do not direct them;
- be formal and open;
- do not be superior with the interviewees;
- avoid sarcasm;
- treat all interviewees equally;
- avoid volunteering to support interviewees with answers;
- be patient; and
- follow a systematic approach and develop further.

5.7.3.4 Interview Approach

Face-to-face semi-structured interviews were conducted with the list of stakeholders in Table 5.15. Two pilot interviews were conducted to validate and refine the interview questions. Then, the interview questions were updated. As the interviews were conducted in Jordan, the interview questions were translated into Arabic, which is the official language in Jordan.

Interviewee approvals for participation were received; then, the researcher visited the participants in their workplace, and each of the participants was interviewed individually. Each of the interviews lasted between forty-five minutes and one and a half hours. The funnel approach was implemented during the interviews, which very broad questions were firstly asked, then it was progressively narrowed down the scope of the interviews question until the end, and so there were four stages to the interviews (Oppenheim, 2000):

(1) The introductory questions:

- These questions were oriented towards obtaining background information from the interviewees, such as their previous experience, size of their organisation and the size and type of the projects usually undertaken.

(2) The transitional question themes:

- BIM status, benefits and barriers; and
- BIM impact on delivering sustainable buildings.

(3) The main question themes:

- procurement approach impact on BIM process implementation;
- types of procurement approaches to deliver public building projects in Jordan;
- tender processes;
- key stakeholders' involvement and responsibilities;
- improvement measures for BIM implementation in Jordan;
- barriers to deliver sustainable public buildings; and
- significant procurement factors to tackle sustainability issues.

(4) A closing question for the participants to add any further points.

5.7.3.5 Interview Transcribing Process

Transcribing interviews is the process by which the collected data is translated into text. This could be from the face-to-face, online or phone recorded interviews. The transcribing process in this research comprised five steps: the first was recording the interviews; the second was to transcribe the recorded interviews in Arabic using Microsoft Word; thirdly, the interviewees were allowed to ensure the validity and reliability of the interview process; fourthly, the content of the transcript was translated into English. Finally, both the Arabic and English transcripts were passed onto two Arabic PhD researchers in the School of Civil Engineering and Surveying in the University of Portsmouth to check the validity of the translations from Arabic to English. Although this process was time consuming, it led to the outcomes and results being doubly verified as the data were validated in Arabic and English. In fact, this part had a significant effect in identifying the common patterns and themes. In total, the recorded interviews resulted in 70 pages of transcription in both Arabic and English.

5.7.3.6 Interview Analysis

Once the interviews were recorded and transcribed, it was essential to develop a general strategy for analysis (Yin, 2003). Interview analysis is complex and critical because of the large amount of available data for analysis. The qualitative data analysis was illustrated by Dainty (1998) as a process of describing, connecting and classifying the primary data. This process depends on three key features (Renner, 2003):

- the aims and objectives to be achieved;
- the needs of those who will use the information; and
- the available resources.

The content analysis technique was used as a basis for the interview analysis. Green and Thorogood (2004) stated that content analysis is suitable for conducting exploratory research in an area where not much is known to enable the common issues from the data to be reported. Content analysis follows three steps: understanding the interview data; focusing on the analysis and categorising the information; and identifying patterns among the categories (Renner, 2003).

After deciding the technique, the researcher needs to choose whether to analyse the data manually such as with a 'manual colour coding' or with the help of a software programme such as NVivo. NVivo is the principle software programme for qualitative analysis. Despite the long learning curve to be able to use this software, especially considering the time constraints during a PhD, NVivo was employed since it enabled the varying patterns to be stored and broken down into various thematic headings and subheadings.

5.7.4 Phase 3: Framework Development for the Public Sector in Jordan

This aim of this phase was to develop a framework based on the collected data from the interview analysis and the literature review based on a problem-solving approach. Qualitative research answers the questions related to what, why and how (Bryman, 2004). Phase 2 (the interviews) was an exploratory study where questions in the form of what, why and how were posed to BIM practitioners in Jordan. Therefore, specific tasks, stakeholders' involvement and additional information to implement BIM effectively under the existing procurement approach in the public sector in Jordan should be identified through the interviews. Additional questions could cover the barriers, constraints and possible solutions in the eyes of the BIM practitioners in the public sector in Jordan. The literature will be used to reflect on the barriers and issues raised in the interviews as the research has adopted this problem-solving approach. After identifying the tasks, processes, stakeholders and the additional information required, all the defined variables, sequences, stakeholder involvement and additional information were integrated and combined into a framework.

5.7.5 Phase 4: Framework Validation

The framework validation aims to refine and examine the suitability of the proposed framework for construction in the public sector in Jordan. The validity, reliability and identification of the gaps that can improve the proposed framework were the basis for the validation process.

5.8 DATA VALIDITY AND RELIABILITY

The aim of obtaining validity and reliability is to assess the research quality. In the Cambridge online dictionary, validity is defined as "the state of being acceptable or reasonable”, whereas reliability is defined as something which is “accurate or able to be trusted” (Cambridge University Press, 2018).

5.8.1 Validity

Validity is obtained by employing a process of measuring concepts that focus on validating the research. Validity can be divided into five groups (Bryman and Bell, 2007, p. 165):

- Concurrent validity: is when the research deals with the criteria based on subjective perspectives, so the research analysis needs to be taken further.
- Face validity: is also called logical validity. It is simply a form of validity where a subjective and superficial assessment is carried out to ensure that the measurements reflect the content of the concept in question. Feedback and comments from experienced professionals in the field can be used.
- Convergent validity: is when a researcher wants to measure certain ideas and concepts by using different research methods and by comparing the outcomes. For example, time wastage due to road closures can be analysed through observation or questionnaires to verify the process.
- Construct validity: is when the research intends to adopt hypotheses from existing theories and presume that they apply to the concept in hand. For example, in a cause and effect situation, easting junk and getting fat. However, this example is not applicable to all cases where this approach can be invalidated or misguided.
- Predictive validity: involves testing a concept for a certain construct and then comparing the results with other results that are going to be obtained in the future.

5.8.2 Reliability

Reliability can be defined as the degree to which the findings can be accurate. It is related to issues of measures. Three different factors have been stated by Bryman and Bell (2007, p. 163) which can be used to measure the reliability of a concept. These are described in the following:

- Internal reliability: is a measure based on key indicators that should lead to consistency. It depends on the correlations between different objects in the same test.

When measuring a concept, if the relevant indicators score opposite or they are not consistent, then an internal unreliability should be recorded.

- Stability reliability: is a measure of the repeatability of a test over time. Stability requires obtaining the same results if a concept is measured over a period of time. On the other hand, if the outcome is different due to the time factor, a variation should be registered.
- Inter-observer consistency: defines the necessity for consistency when deciding how to deal with concept analysis. This is commonly requested when more than one body of research is involved. For example, in research when qualitative data is collected, a decision should be made on how the primary data is categorised.

5.8.3 Validation and Reliability Adopted

The questions employed in the data collection are clear and simple due to the use of scientific theories. The reliability of the primary data is shown in the usage of the existing literature to support the research findings and to make recommendations for future research.

The types of validity methods relevant to this research include concurrent, face, convergent and construct validity. The researcher conducted validation interviews with tender managers, project managers, BIM managers and construction managers working in the public building sector in Jordan. Table 5.17 describes the validity and reliability of this research according to the Bryman and Bell (2007, p. 165) validity classifications.

Table 5.16: Adopted validity and reliability measures

Issues	Measures employed
Concurrent validity	For example, the BIM feasibility study findings showed that public procurement approaches are one of the main barriers to implementing BIM in the public construction sector in Jordan (see Chapter 6) whereas the interviews were used to find out how and why public procurement approaches affect BIM implementation (see Chapter 7).
Face validity	The contents of the proposed framework were verified by conducting interviews with construction professionals in the public sector in Jordan (see Chapter 8).

Convergent validity	The use of different research methods to obtain the data showed a strong correlation between the different data results. An example is the distribution of questionnaire surveys by hand and through Survey Monkey (online). Another example is the reuse of some of the questionnaire questions in the interviews, in the case of the BIM barriers which enabled an exploration and confirmation of the research outcomes.
Construct validity	Existing theories were explored and used to develop a constructive approach towards the findings. Moreover, different data sources (public clients, contractors and consultants) were employed as well as the use of questionnaires and interviews to confirm the research outcomes. The literature verified some of the research findings.
Reliability	The literature review, BIM feasibility study (the questionnaires) and interviews were used sequentially through the process of this research. The findings from the literature review support some of the findings from the primary data.

5.9 RESEARCH ETHICAL CONSIDERATIONS

An ethical review process is required by the University of Portsmouth for any research that involves human participants to ensure that the relevant ethical issues are fully considered in view of the participants' well-being throughout the research. The process requires an application to be submitted for ethical approval before conducting the research. Therefore, an application involving the study description, with the aim and objectives, methodology, methods, sampling methods, invitation letters, consent forms and participant information form was submitted to the ethical committee at the Faculty of Technology in the University of Portsmouth. The committee read through the application to find out whether the researcher had fully considered all the ethical issues and the appropriate and sufficient information had been provided to the participants.

As a result, ethical approval for this research was received in the form of 'favourite opinion'. This approval in addition to the consent form and participants' information sheet are attached in Appendix A.

5.10 CHAPTER SUMMARY

This chapter presented the research methodology and research design to achieve the goals of this research. The use of BIM for delivering building projects in Jordan has received little academic interest, especially in public building projects. Therefore, this research is exploratory in nature. Surveys and a problem-solving approach in the form of strategies were adopted in the development of a framework for public building projects in Jordan based on the philosophy of pragmatism. The following chapters will present the findings of each of the four phases of the research design, as discussed in Section 5.7.

CHAPTER 6: BIM FEASIBILITY STUDY

6.1 INTRODUCTION

This chapter is Phase 1 of the research design, as introduced in the previous chapter. This chapter presents and discusses the results of the BIM feasibility study in the public sector in Jordan based on the questionnaire survey method. The questionnaire survey was used to determine the BIM feasibility for the Jordanian public building projects, and it acted as an exploratory piece of research.

The closed-ended questions in the questionnaire were developed based on previous research implemented on BIM awareness, its current state, the benefits and barriers (NBS, 2011; Kim, 2014). The questionnaires were used because large amounts of information can be collected from a large number of participants within a short period of time. Also, the data collected through the questionnaires can be easily quantified through a software package, thus measuring the changes by comparing and contrasting them with previous research findings (Fellows and Liu, 2015).

In order to collect the varying viewpoints from the construction professionals in the Jordanian public sector, the Jordanian MPWH and GTD departments were targeted because of their roles in delivering public construction projects. The questionnaires were also sent to their registered contractors and consultants. This is because the consultants and contractors accounted for the highest number of BIM users in the Middle East (BuildingSMART, 2011); therefore, the data received would seem to be more reliable.

6.1.1 Response Rate

The sample size and response rates were calculated (see Table 6.1). As the questionnaires were distributed through Survey Monkey, a Survey Monkey sample size calculator was used with a confidence level of 95% and 5% margin of error to calculate the number of questionnaires to be sent out to the contractors and consultants. This calculator is based on the following formula:

$$\text{Sample Size} = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1 + \left(\frac{z^2 \times p(1-p)}{e^2 N}\right)}$$

Population Size = N | Margin of error = e | z-score = z

For MPWH and GTD, the questionnaires were distributed by hand to the project managers in each MPWH department, as stated above.

Table 6.1: Questionnaire statistics (based on the MPWH classification for consultants and contractors (see Section 5.7.2.1))

Research Strata	**MPWH & GTD**	**Contractors/ Grade**			**Consultants / Grade**			
	HoD	**1st**	**2nd**	**3rd**	**1st A**	**1st B**	**2nd**	**3rd**
Population	20	80	68	136	18	11	3	0
Total population	20	284			32			
Sample size	20	164			30			
Number of questionnaires sent	20	164			30			
Number of completed questionnaires	20	87			18			
Number of valid questionnaires	20	85			17			
Response rate	100%	52%			56.7%			
Time taken to collect data	60 days							

6.1.2 Questionnaire Sections

A Likert-type scale was used to describe the collected data for this research (see Section 5.7.2.4). The respondents were requested to provide their opinions on the level of their BIM awareness, how they implemented BIM, BIM implementation drivers and the benefits and barriers to BIM implementation in the public construction sector in Jordan. The questionnaire comprised 15 questions, and it was structured under five main sections (see Table 6.2).

Table 6.2: Questionnaire sections

Section Number	What	Why
1	Profile of respondents	To ensure that they were appropriate for the survey
2	Awareness and current status of BIM	To understand how BIM is currently used in the public sector in Jordan and for which building type and project
		To find out the potential use of BIM, it is essential to identify if there is a demand and an awareness of BIM among public practitioners and public clients in Jordan
		To find out whether adopting BIM in Jordan should be top-down (refers to the government push BIM adoption) or bottom-up (refer to the grass-root adoption of BIM without a coercive mandate), and to identify if there is a gap in driving BIM in the public sector
3	Benefits and barriers to BIM use for public projects	To identify if they are aware of BIM's potential benefits in delivering public building projects in Jordan
		To identify the barriers to BIM implementation for delivering public building projects in Jordan
4	Feasibility of BIM adoption for the public sector	To reveal how the participants consider BIM at present
5	Procurement approaches used in BIM public projects	To identify what type of procurement approaches are used in delivering public buildings in Jordan

It is worth mentioning that an additional question was asked at the end of the questionnaire about whether or not the participants were willing to contribute to an additional data collection stage (Phase 2) of this research.

6.2 QUESTIONNAIRE FINDINGS

Section 1: Profile of the Respondents

The respondents were spread across the major stakeholders in the public sector in Jordan, including public client representatives, public consultants and contractors operating in Jordan. From Figure 6.1, it can be seen that the contractors were the highest number of respondents with a percentage of 69.7%, followed by the public client at 16.4% and the consultants at 13.9%. This is due to the total population of each group and the method of questionnaire distribution, as shown in Table 6.1. It is worth mentioning that this research adopted the public sector classification for public contractors and consultants (see Section 5.7.2.1).

From Figure 6.2, it can be seen that almost all the respondents on the contractor side are working in small- or medium-sized companies, but one respondent stated that he works for a large construction company. On the consultant side, 82.36% work in small- or medium-sized companies, 11.76% are in a large company and 5.9% work in small-sized companies. This is because small- and medium-sized companies were targeted in this research as they more accurately represent the local market in Jordan. These companies tend to manage one stage or element of the overall building process and respond to the local market needs (ECTP, 2008). This approach also enabled the gathering of information from the companies which have the most knowledge of current market trends and design software. These are also the target groups for the manufacturers of BIM software (Al Awad, 2015).

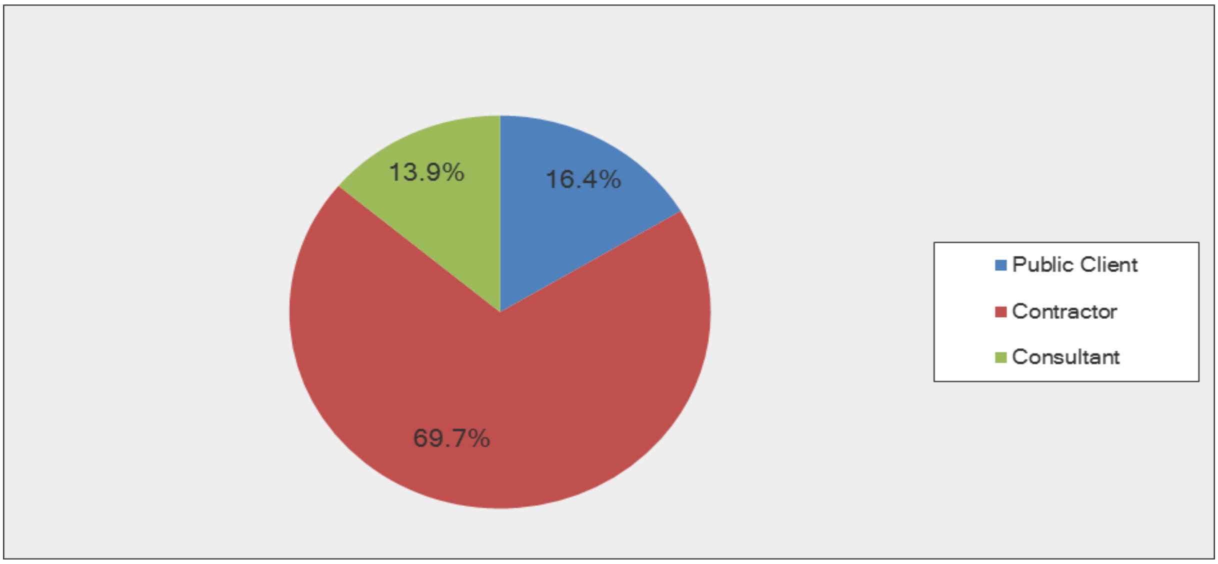


Figure 6.1: Respondents' role

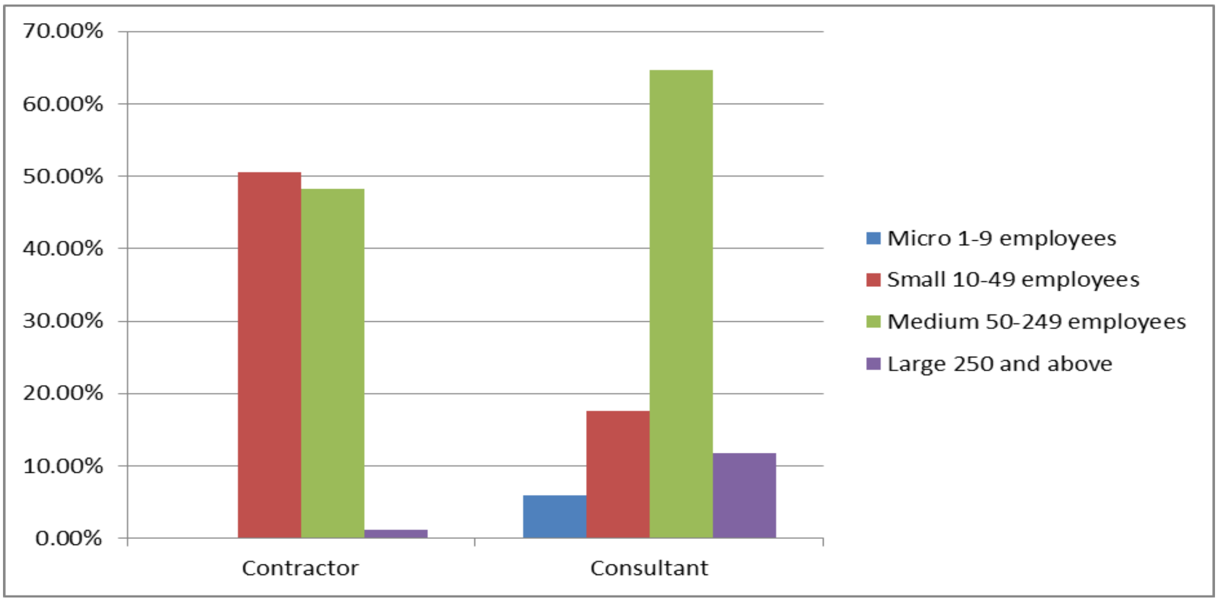


Figure 6.2: Size of respondents' company

The respondents were then asked about their years of experience in the Jordanian public sector, which varied from less than 5 years to more than 20 years, giving an indication of the range of experience levels in the Jordanian public sector. 14 stated that they have less than 5 years' experience, 58 reported that they have between 6 and 10 years' experience, 39 had between 11 and 20 years and 11 claimed to have more than 20 years of experience (see Figure 6.3).

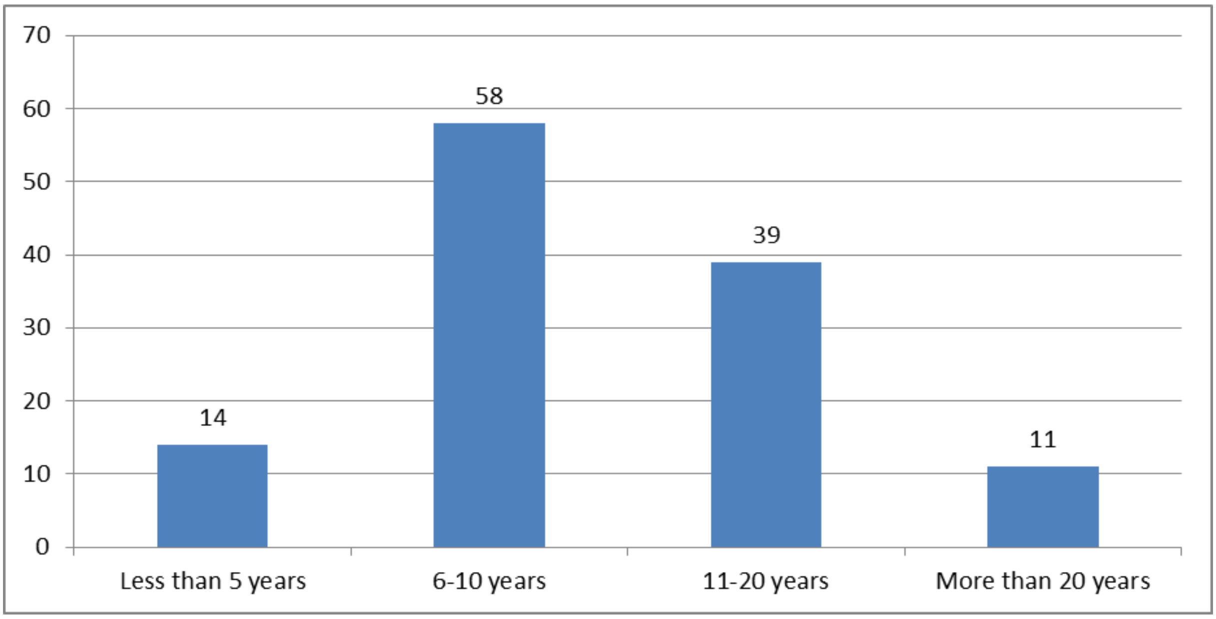


Figure 6.3: Years of respondents' experience in the Jordanian public building sector

Section 2: Awareness and Current Status of BIM

The respondents were asked if their workplace uses BIM in delivering construction projects in Jordan. One participant skipped the question. The majority of the respondents (76% or 92 responses) are not currently using BIM. 13.22% of the respondents (16 responses) have just adopted and started using BIM. The study showed that 9.92% (12 responses) are using BIM for small-sized projects, but only 0.83% (1 response) uses BIM for every project (see Figure 6.4).

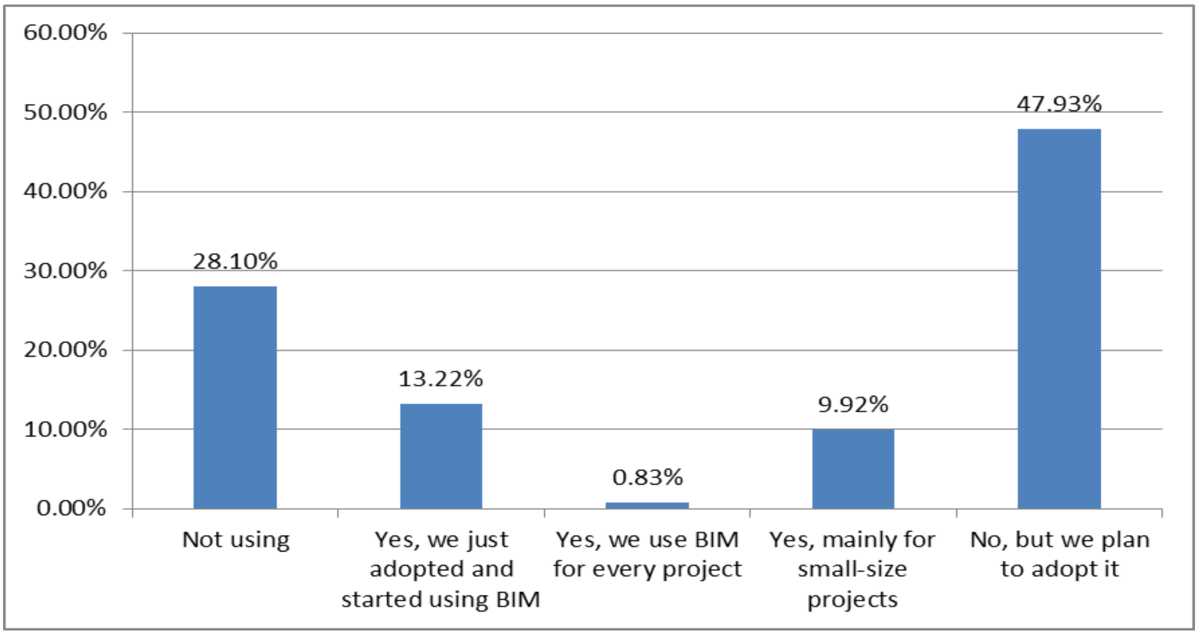


Figure 6.4: BIM adoption level in the public sector in Jordan

Table 6.3 shows the difference between the BIM adoption levels in the public client, consultants and contractors who work within the public construction sector in Jordan. MPWH and its 18 departments are the most important public bodies that are responsible for the implementation of the central governmental construction projects in Jordan (Al Assaf, 2017). These departments are divided according to the scope of work within the public sector, such as new builds, maintenance and refurbishments, buildings, roads, designing and project management. The data revealed that 5 departments, that are 25% of the public client representatives, have just adopted and started using BIM. The researcher found that the departments responsible for the new construction projects have just started to use BIM.

For the consultants, 70.6% have employed BIM while 29.4% have not. However, for the contractors, 87.07% have not used BIM, and only 13% have used it. Therefore, it can be said that there is a BIM adoption gap between the consultants and contractors in the construction public sector in Jordan.

Table 6.3: BIM adoption level between public client, consultants and contractors

	Public Client	**Contractor**	**Consultant**
No, we do not use BIM	30.00%	30.60%	5.88%
Yes, we have just adopted and started using BIM	25.00%	9.40%	23.53%
Yes, we use BIM mainly for the small-sized projects	0.00%	2.35%	47.06%
Yes, we use BIM for every project	0.00%	1.18%	0
No, but we plan to adopt BIM	45.00%	56.47%	23.53%
Adopted and implemented BIM	**25.00%**	**13.0%**	**70.6%**
Not adopted and implemented BIM	**75.00%**	**87.0%**	**29.4%**

For the 29 responses (23.97%) who had used BIM (see Figure 6.4), they were further asked what functions they used BIM for. Figure 6.5 shows the results. Apart from using BIM for pilot projects, the majority stated that they had used BIM for visualisation to present the design in 3D.

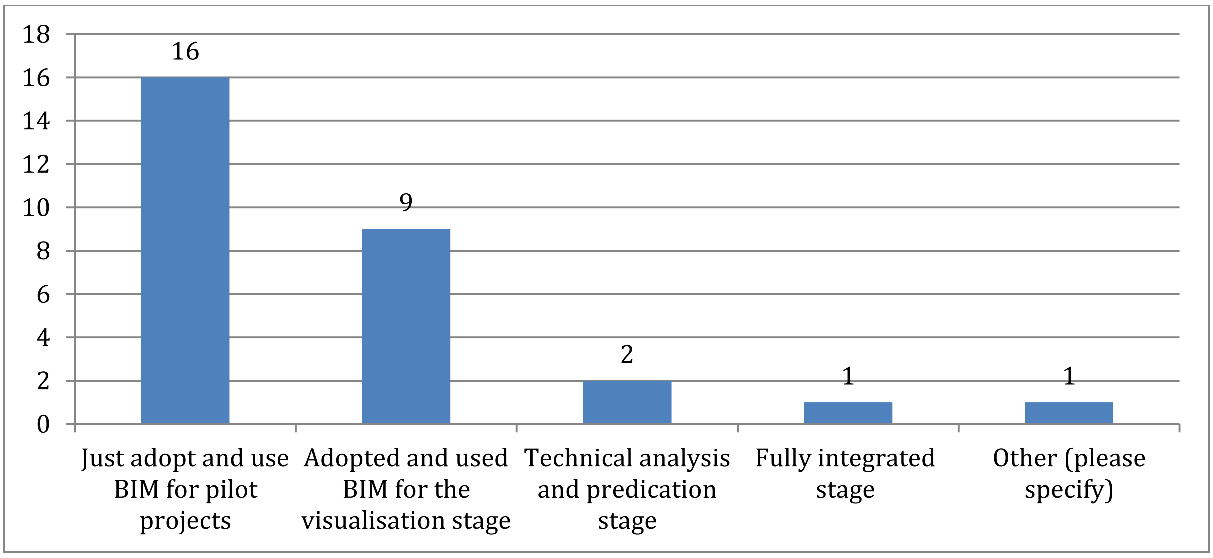


Figure 6.5: BIM adoption stages

The respondents were also asked whether they were willing to continue using BIM. The majority of the 20 responses were undecided because 16 of them had only just adopted BIM for the pilot projects. On the other hand, 9 respondents stated that they liked BIM and were willing to continue using it. None of the respondents stated that they were going to stop employing BIM in the public construction sector in Jordan.

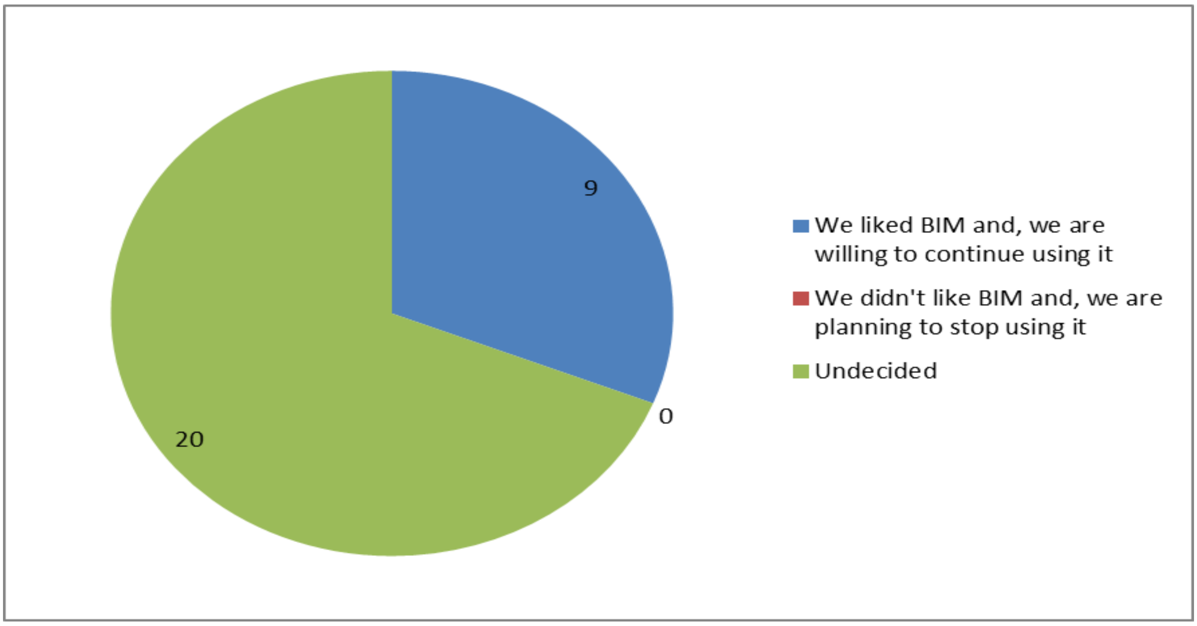


Figure 6.6: Respondents' opinions about using BIM

Public buildings are classified under the headings of: government (office buildings), healthcare (hospitals), education (schools) and residential (housing) (see Table 2.5). The respondents who used BIM in their projects were asked about which type of building they utilized BIM for. The results are shown in Figure 6.7. Most of the BIM use in the public sector is for non-residential constructions in the form of office buildings (82.76%). This indicates the frequency of this type of building compared to the others in the public sector. 17.24% (5 responses) specified other types, such as prisons.

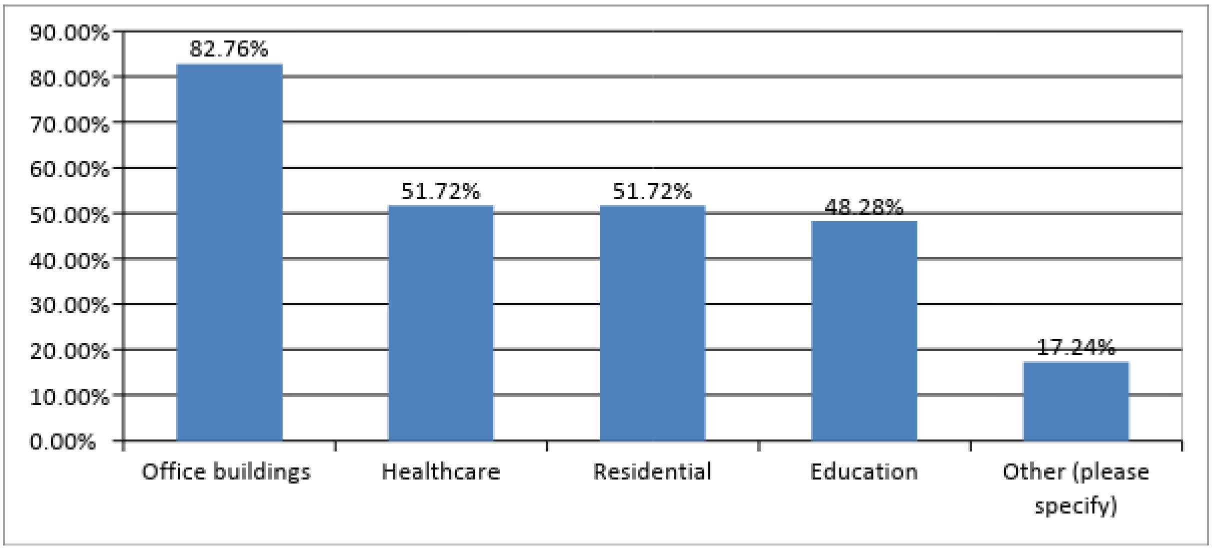


Figure 6.7: Type of buildings that BIM was used to deliver

The consultants and contractors were chosen based on their significant experience in delivering public building projects. Therefore, they were asked to rank the level of BIM awareness or rather desire for BIM in their public clients. A Likert scale was used from 1 (very low) to 5 (very high). As shown in Figure 6.8, 73.5% of the respondents claimed that BIM awareness or desire in the public client is below average. Therefore, it can be said that there is a lack of awareness and demand for BIM implementation from the public client.

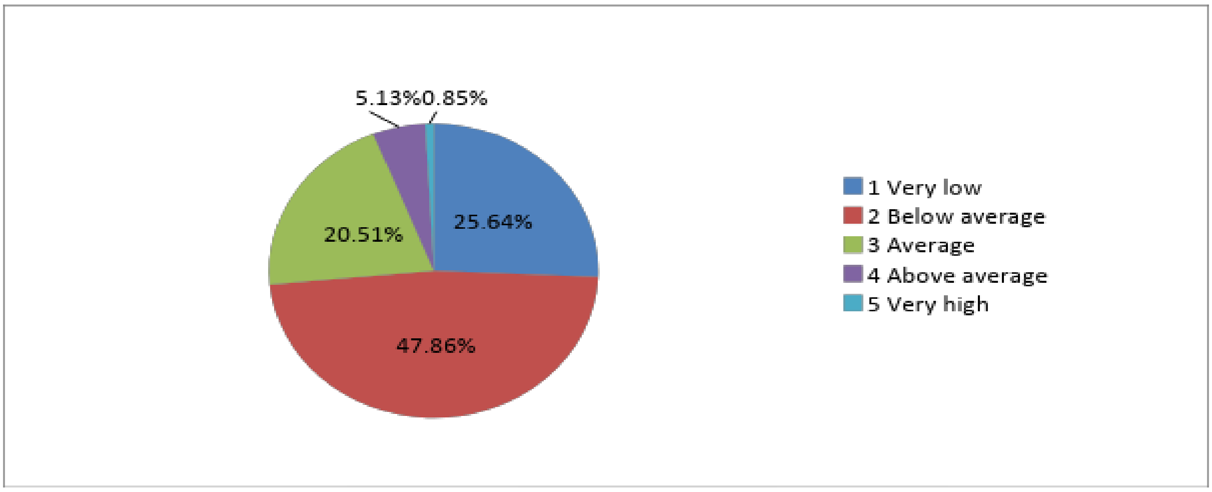


Figure 6.8: Consultants and contractors' levels of BIM awareness and desire in the public client

The respondents were then asked about who should drive the implementation of BIM in Jordan. The highest number of respondents at 55.74% stated that it is the joint responsibility of the government and the industry. 20.5% claimed that it is only the government's responsibility whereas 16.9% placed the responsibility on the construction associations. 4.1% stated that large construction companies should drive BIM implementation, and only 3.3% reported that the private client should drive the implementation of BIM in Jordan (see Figure 6.9). Therefore, it can be said that the government has a crucial role in driving BIM implementation, not only in the public construction sector, but also in the private construction sector.

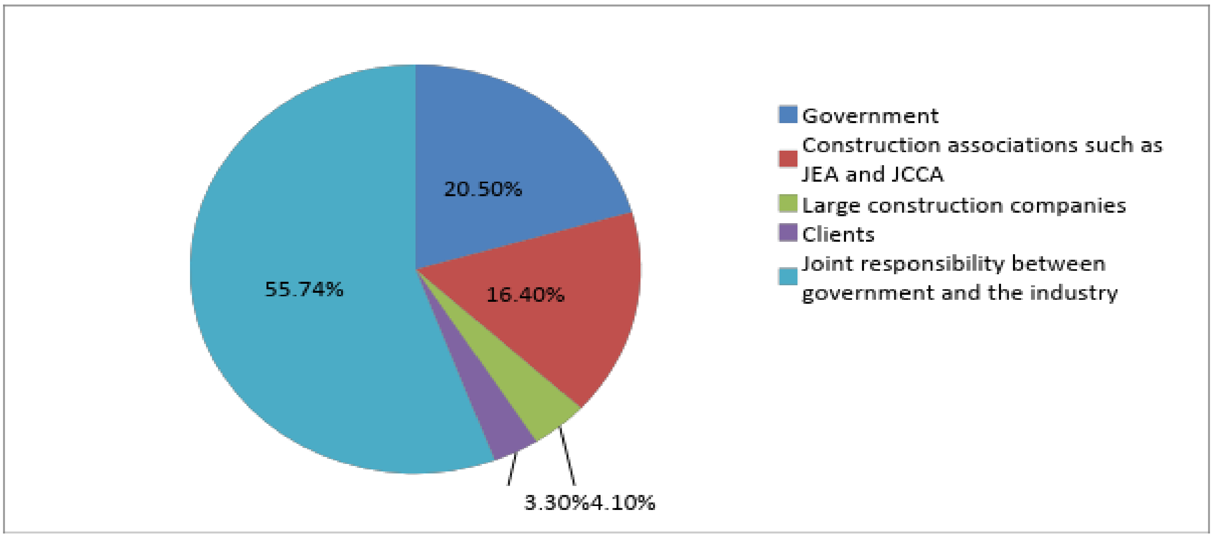


Figure 6.9: BIM implementation driving authorities in the Jordanian buildings sector

Section 3: Benefits and Barriers to BIM Use for Public Building Projects

The researcher wanted to find out what the perceived or potential benefits were in BIM implementation for the delivery of public buildings in Jordan. The aim was to identify whether the respondents were aware of the potential benefits of BIM usage and to assess their attitude towards this technology. Therefore, a well-documented list of BIM benefits (see Section 3.3.1) was used.

The respondents were asked to rate these benefits on a Likert scale from 1 (the least beneficial) to 5 (the most beneficial). 6 respondents skipped this question, and 116 responded. The weighted average was calculated, and the benefits were ranked from 1 to 11 where 1 is the most beneficial, and 11 is the least beneficial (see Table 6.4). The component 'better design and multi design alternatives' has the greatest potential benefit when implementing BIM in the public sector in Jordan whereas improving safety has the least potential benefit. Enhancing the sustainability of the public buildings was ranked 5 out of 11, indicating the key stakeholders' levels of awareness of the potential for BIM in delivering sustainable buildings.

Table 6.4: BIM implementation benefits for the public sector in Jordan

BIM benefits	**Rank**					
	Public Clients		**Public Consultants**		**Public Contractors**	
	19 Respondents		**17 Respondents**		**80 Respondents**	
	Ranking	**Weighted average**	**Ranking**	**Weighted average**	**Ranking**	**Weighted average**
Better design/multi design alternatives	1	4.05	1	4.25	2	4.15
Reduced project time and cost	2	4.00	5	3.82	1	4.17
Improved decision-making process (better visualisation and 'what if' scenarios)	3	4.00	2	4.24	4	3.95
Improved collaboration in design and construction	4	3.95	4	4.06	3	3.95
Sustainability enhancement	5	3.89	3	4.18	5	3.94
Reduced claims or litigation (risks)	6	3.84	6	3.76	6	3.54
Improved quality	7	3.84	10	3.40	9	3.44
Improved operations and maintenance (facility management)	8	3.74	8	3.59	7	3.49
Improved construction process and efficiency	9	3.58	7	3.71	8	3.46
Predictive analysis of performance	10	3.21	9	3.53	10	3.02
Improved safety	11	2.74	11	2.91	11	2.29

This question was followed by an open-ended question on any other BIM benefits that the respondents wished to add. The following were added by the questionnaire respondents: 'improve communication between the technical team and the public client'; have 'better coordination with the different parties'; 'reduce conflicts and changing orders and accordingly variation orders during construction'; and 'reduce construction waste'. The answers to both questions showed that the respondents are well aware of the BIM benefits even if they are not implementing BIM.

A further aim of the survey was to investigate BIM implementation barriers. The respondents were provided with a list of BIM implementation barriers based on previous research, as outlined in Section 3.3.2. The respondents were then asked to scale their answers for each barrier to BIM implementation in the public construction industry in Jordan. A 5-point Likert scale was used from 1 (the least related barrier) to 5 (the most related barriers). Six respondents skipped this question, and 116 responded. The weighted averages for the BIM barriers were calculated for each group (the public clients, consultants and contractors), and then the barriers were ranked from 1 to 11 for each group (see Table 6.5). The main five barriers for BIM implementation, as stated by the respondents and agreed by different groups, are 'additional resources and expenses', 'procurement strategies', 'a lack of BIM skills, education and training', 'complexity (long hours to develop a BIM model)' and 'a lack of a comprehensive framework or implementation plan'. This question was followed by an open-ended question on any other BIM barriers that the respondents wished to add. The respondents provided no additional BIM barriers. This could be because most of the BIM users in the public sector in Jordan have only started using BIM recently on their pilot projects, or they have used it only for visualisations to present the design in 3D (see Figure 6.5).

Table 6.5: BIM implementation barriers to the public sector in Jordan

BIM Barriers	Rank					
	Public Clients		Public Consultants		Public Contractors	
	19 Respondents		17 Respondents		80 Respondents	
	Ranking	Weighted average	Ranking	Weighted average	Ranking	Weighted average
Additional resources/ expenses	1	4.00	2	3.65	1	4.60
Procurement approach	2	4.00	3	3.65	2	4.26
Lack of BIM skills, education and training	3	3.95	4	3.41	3	4.11
Complexity (long hours to develop a BIM model)	4	3.95	1	3.71	5	4.08
Lack of a comprehensive framework or implementation plan	5	3.84	5	3.41	4	4.11
Culture change	6	3.79	7	3.27	9	4.00
Attitude and awareness (resistance to change from 2D drafting practices)	7	3.79	8	3.27	7	4.03
Organisational challenges among construction professionals	8	3.76	6	3.40	8	4.01
Lack of a legal framework (model ownership and legal contract)	9	3.72	9	3.24	6	4.08
Lack of interoperability	10	3.68	11	3.06	10	3.99
Lack of standards	11	3.58	10	3.18	11	3.86
Increased risk and liability	12	3.58	12	2.82	12	2.76

Section 4: BIM Feasibility in the Public sector

Respondents were asked about the BIM feasibility for the Jordanian public sector. A Likert scale was used from 1 (too early) to 5 (too late). Six respondents skipped this question, and 116 responded. As can be seen in Figure 6.10, more than half of the respondents (55.17%) indicated that now is an appropriate time to adopt BIM since they need it. Almost 40% of the respondents said that they have been late in adopting BIM, but that there was still a possibility to catch up with this technology. Only 2.6% reported that it was too late whereas 4.31% said it was early to talk about the adoption of BIM. None of the respondents said it is too early to adopt BIM and that the industry is not ready for BIM adoption. This indicates that now seems to be the appropriate time to properly consider BIM implementation.

The respondents to question 10 were asked to give reasons for their answers about whether BIM adoption and implementation is too early, early, timely, late or too late. The following includes some of their reasons:

> "It is timely because mainly in Jordan, the business and the volume of investments in the construction sector have become significant and improving the efficiency of this sector becomes crucial."

> "It is timely due to the lack of resources in the country; BIM will optimise materials, energy, water usage."

> "It is timely in order to avoid the many mistakes that are happening now in construction and wasting time."

Answers to both questions give an indication of the feasibility of BIM in the Jordanian public sector and the need for this technology.

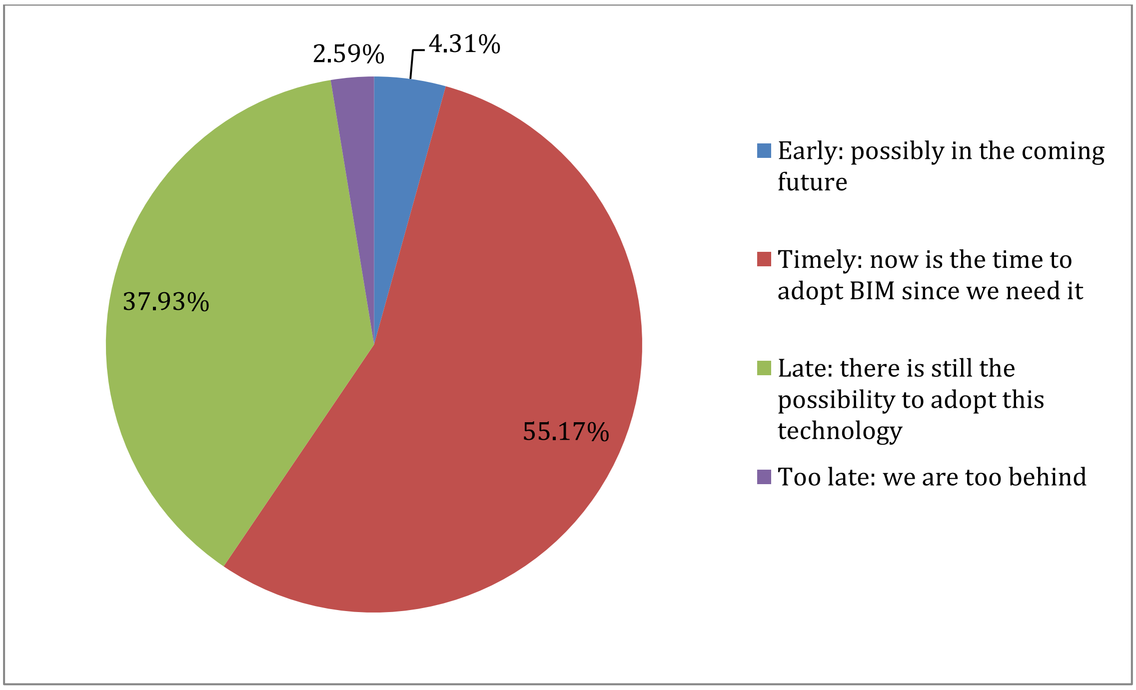


Figure 6.10: Public industry current situation towards BIM adoption

Section 5: Procurement Approaches Used in the Public Sector in Jordan

Finally, the respondents were asked about the type of procurement approach they used when delivering the public buildings in Jordan. 122 responded to this question. 77% stated that DBB was used. DB came second with 16.4%, and only 6.5% claimed that had adopted CM as a procurement approach to deliver public building projects. None of the respondents stated that IPD was used to deliver public buildings (see Figure 6.11).

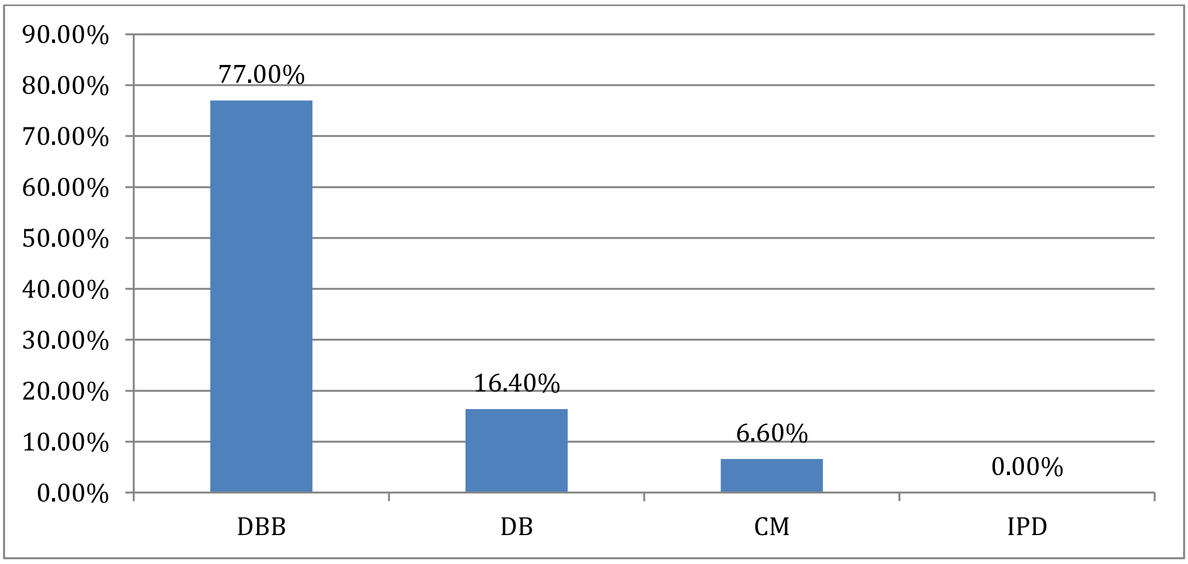


Figure 6.11: Procurement approaches adopted for delivering public buildings in Jordan

6.3 DISCUSSION

The construction industry is the largest industry in Jordan, and the building sector accounts for more than 33% of the country's energy consumption since Jordan is not an oil producing country. BIM has been considered to be one of the most effective organisational and technological innovations in the AEC. Moreover, BIM has the potential to achieve more sustainable construction processes, and thus enhance the construction industry performance. The findings of the BIM feasibility study demonstrated in this chapter reveal certain key points regarding BIM implementation in the public sector in Jordan, which are detailed in the forthcoming sections.

6.3.1 Need for BIM

Jordan and GCC were surveyed by BuildingSMART (2011) about the penetration of BIM. The survey results suggest that the penetration was "moderate", and 25% of the participants were "familiar" with the BIM processes, but only 5% were using it

(BuildingSMART, 2011). Comparing BuildingSMART's (2011) statistics to the results of this research, it can be stated that BIM adoption in Jordan is on the rise for many reasons, including the fact that the Jordanian government itself embarked on BIM in 2011. Moreover, the number of foreign construction companies has increased, with 898.1 million JD of construction works compared to 619.1 million JD worth of work for local construction companies in Jordan (JCCA, 2016). Studies showed that the competitive edge of the foreign firms over their local counterparts resulted from their ability to deliver a higher quality of work with a timely completion because of their superior project management and technological expertise (Ofori et al., 2013). Therefore, it is believed that foreign companies were able to assist in the introduction of many innovative technologies, such as BIM.

BIM adoption and implementation in the public sector in Jordan is expected to increase over the coming years as none of the respondents who adopted BIM in the public sector in Jordan mentioned that they did not like BIM, nor that they intended to stop using it. Moreover, only 4.3% of respondents said that it is too early to adopt BIM whereas 93.1% of the respondents either expressed that BIM adoption is timely because they need it now or that although they have been late in implementing BIM, there is a possibility to catch up. Therefore, these results demonstrate the need for BIM in the public sector.

The main reasons why the respondents believe that there is a need for implementing BIM in the Jordanian construction industry was stated as: "it is timely in order to avoid the many mistakes that are happening now in construction and wasting time"; "it is timely due to the lack of resources in the country"; "BIM will optimise materials, energy, water usage"; and "due to the increased volume of investment in the industry". These indicate that the public stakeholders understand the likely benefits of adopting and implementing BIM in Jordan even if they are not implementing it themselves.

6.3.2 Gaps in BIM Adoption and Implementation

Although the Jordanian government was the first in the Middle East to take the BIM oath, and that it was part of the agreement in 2011 with BuildingSMART and JCCA to promote BIM in Jordan, no standards, protocols or guidelines have been developed by the Jordanian government, and there are no mandates to use BIM for the public projects, as the literature review revealed.

The first gap revealed in the questionnaire survey is the one between the primary government role of pushing BIM in the public sector in Jordan and its actual awareness and desire to implement BIM. Despite the fact that 76.24% of the respondents claimed that the government has a key role in driving BIM adoption and implementation in the public sector, 73.5% of the respondents stated that the desire for BIM amongst the public client is below average or very low. Similarly, Al Awad (2015) conducted a survey on SMEs in the Jordanian construction industry, and the majority of the respondents were of the opinion that there is a need for the government to step up and drive BIM adoption.

This research has also found that there is a gap between BIM adoption and implementation by consultants and contractors in Jordan as 87% of the contractors are not using BIM whereas 70.6% of the consultants are using it. Gerges et al. (2017) explained that the contractors' financial issues are behind that lack of BIM usage, which has resulted in the slow growth of BIM implementation in construction projects in Jordan.

6.3.3 Barriers to BIM Implementation

The focal point of this phase is to identify the barriers to BIM adoption and implementation in the Jordanian public construction industry. A well-documented list of barriers to BIM adoption and implementation worldwide (see Table 3.7) was used to ask the participants about their views on these barriers in the Jordanian context. Some of the major barriers to adopting and implementing BIM in Jordan have been identified as: 'additional resources and expenses', the type of 'procurement approach', a 'lack of BIM skills, education and training', a sense of 'complexity (in the long hours required to develop a BIM model)' and a 'lack of a comprehensive framework or implementation plan'.

For the 'additional resources and expenses', many construction industry professionals have been deterred from adopting BIM due to the perceived high initial cost of implementing it as any new technology costs money (Giel, 2010). In the Middle East, BIM contractors look at this type of technology as an additional cost (Gerges et al., 2017). Furthermore, Nanajkar and Gao (2014) investigated the status of BIM in India, and they concluded that the cost of the software was perceived as the main barrier to adopting BIM.

For the 'procurement approach' barrier, the current regulatory frameworks, and in particular the contract procurement strategies, which have a major impact on the success of BIM use, may at times obstruct, rather than support the employment of BIM (Holzer, 2015). The majority of the public projects in Jordan were awarded with a DBB contract procurement method as 77% of the respondents stated that they had been using DBB to deliver their projects. This procurement approach has been the predominant approach for delivering construction projects in Jordan and the region for decades. Although BIM implementation through the DBB procurement approach can improve the overall process, it cannot express all the BIM potential benefits due to the structure of this approach (Salmon, 2012). This, therefore, could hinder the project stakeholders from implementing BIM in a collaborative environment in order to obtain the full benefits. Indeed, the contractors' late involvement is not ideal because of their limited contribution to the design process (Roginski, 2011; Eastman at al., 2011, p. 10).

The third barrier is the 'lack of BIM skills, education and training'. This finding is similar to the research by Ahmed (2014), who also identified the main barriers to implementing BIM in Qatar, a Middle Eastern country, as 'the availability of skilled professionals' and 'the knowledge about BIM'. The fourth barrier is 'complexity'. As a result of the lessons learned from the early adopters of BIM, Howell (2005) stated that the size and complexity of the files that BIM creates, represent a major barrier. The fifth barrier is the 'lack of a comprehensive framework or implementation plan'. Howard and Bjork (2008) stated that there is an absence of a framework or implementation plan into which BIM can fit.

6.3.4 Ways of Overcoming the Gaps and Barriers to BIM Adoption and Implementation

This study has confirmed that government acceptance of BIM is fundamental to the success of BIM adoption and implementation in Jordan. Therefore, there is a need to conduct workshops to educate all the government departments and other stakeholders in the public sector on 'model-based' deliverables and its benefits. Political pressure influences BIM adoption and implementation in many countries. In Jordan, most of the respondents reported that the government should play a key role in driving BIM. Therefore, the enforcement of BIM adoption and implementation by the government will assist in overcoming many BIM barriers, such as the 'resistance to change' barrier. Moreover, the government can encourage BIM adoption and implementation by giving grants to consultants or contractors that implement BIM. Furthermore, there is a need as well to determine the cost savings of implementing BIM in the public sector in Jordan and to show the returns on the investments (ROI) of paying additional fees.

Apart from the political drive, BIM is a collaborative platform; thus, receiving the maximum benefits from its implementation requires a collaborative environment between all disciplines. Different procurement approaches can achieve different collaboration levels by establishing the relationships between the involved parties and tasks throughout the building lifecycle (Laishram, 2011). Therefore, there is a need to align the various procurement approaches used in the Jordanian public construction industry with the novel opportunities offered via BIM.

6.4 CHAPTER SUMMARY

The questionnaires revealed that BIM use in the public sector is rising. Moreover, the findings ascertain the feasibility of BIM use in the Jordanian public sector, and that it is timely to adopt BIM. The questionnaires also revealed that most of the construction professionals in the public sector in Jordan are well aware of the benefits of BIM. On the other hand, most of the public consultants and contractors stated that the government has a key role in implementing BIM in Jordan. However, 73.8% of them reported that the government awareness and desire to implement BIM is below average. Therefore, the main barriers to BIM implementation in the public sector in Jordan are represented by this lack of government demand in addition to the 'additional resources and expenses' required, getting the appropriate 'procurement approach', the 'lack of BIM skills, education and training', the 'complexity' and finally the 'lack of a comprehensive framework or implementation plan' (see Table 6.5). The 'additional resources and expenses', 'complexity' and 'lack of BIM skills, education and training' are not within the scope of this research because these barriers require a level of national awareness and the implementation of relevant training plans to overcome these barriers. However, the 'procurement strategy' and 'lack of a comprehensive framework and implementation plan' are the focus of this research. Therefore, this research moves on to Phase 2, which investigates the BIM barriers in more depth, specifically how and why the 'procurement approach' and the 'lack of a comprehensive framework and implementation plan' affect BIM implementation.

CHAPTER 7: BIM, PROCUREMENT AND SUSTAINABILITY ISSUES IN JORDANIAN PUBLIC SECTOR PROJECTS

7.1 INTRODUCTION

The findings presented in Chapter 6 have verified the feasibility of BIM use in the Jordanian public sector, and that it is timely to adopt BIM. The questionnaire survey also identified the particular barriers and challenges to implementing BIM in the Jordanian public sector. The 'procurement approach' and the 'lack of a comprehensive framework or implementation plan' were among the major barriers and challenges to implementing BIM in the public sector in Jordan. Therefore, BIM implementation will be investigated through the lens of a public procurement strategy.

A set of semi-structured interviews were conducted with the BIM practitioners to obtain a better understanding of BIM, procurement and sustainability issues in the public sector in Jordan. The focus of this chapter is on these interviews and the qualitative data analysis from the interviews. The method of data collection, the data collected and the analysis of this data will be discussed. In previous chapters, the nature of research was identified as exploratory. In the same vein, the interviews were undertaken with key BIM practitioners in the construction public sector in Jordan to explore the current construction procurement approach and its effect on BIM implementation. Sustainability considerations were also explored.

7.1.1 Aim and Objectives of the Interviews

The aim of the interviews was to investigate the current practices and common issues regarding BIM implementation in the Jordanian construction public sector through the lens of the procurement approach adopted.

The objectives of the interviews were set on delivering public construction projects in Jordan and were focused essentially on gaining insight into the following:

- BIM delivery issues in the Jordanian public projects including BIM status, the processes involved, the drivers and the benefits and barriers.
- The current construction procurement approaches implemented in the Jordanian public sector including the tender processes and stakeholders' involvement in the public projects lifecycle.

- The main challenges in the adopted construction procurement approaches that affect the implementation of BIM.
- How to overcome BIM procurement issues.
- Issues of delivering sustainable buildings in the public sector in Jordan.

The above objectives were attained by sending out an invitation letter about conducting the interviews with a comprehensive guide to the prospective interviewees. This was to introduce this research topic and define the aim and objectives of the interview.

7.1.2 Interview Sampling

A total of 12 interviews were conducted in May 2017 and June 2017 with those with a high level of managerial expertise in the public sector in Jordan. The interviewees were selected depending on their previous experience of BIM processes, procurement delivery approaches and delivering sustainable buildings. In Chapter 6, the Phase 1 data collection (from the BIM feasibility study) assisted the researcher in identifying the possible interviewees that have the necessary and relevant experience. As seen in Figure 6.4 (Chapter 6: BIM Feasibility Study), 24% of the respondents were using BIM, which represents 29 of the BIM practitioners interviewed. All of these have substantial experience in procurement approaches and in delivering sustainable buildings since the BIM feasibility study was targeted at managerial level professionals. Moreover, the selected candidates were registered in one of the organisations called by the Jordanian Green Building Council as one of the major players for sustainability in Jordan (see Figure 2.5). Therefore, an invitation to participate in an interview was sent to 29 BIM practitioners. 12 BIM practitioners agreed to being interviewed.

Semi-structured interviews were conducted with these project managers, BIM managers, contract managers, construction managers and tender managers that have been working on public projects sized between 1 million and 4.5 billion Jordanian dinars (JD)(between 1.08 million and 4.87 billion pound sterling). The interviews covered four disciplines: public bodies, consultants, construction management and contractors (see Table 7.1).

Table 7.1: Interview participants

Organisation size	Participants	Department/ Company	Position	No. of years' experience	Size of the projects
M	P1	Public client/ design department	Project manager	18	Hundreds of million JD
M	P2	Public client	Project manager	15	1-50 million JD
S	P3	Public client/ GTD	Tender manager	24	1-50 million JD
S	P4	Public client	Project manager	10	1-20 million JD
M	P5	Consultant	BIM manager	8	20-100 million JD
S	P6	Consultant	Contract manager	36	1-629 million JD
M	P7	Consultant	Project manger	23	1-260 million JD
S	P8	Construction management	Construction manager	45	5-200 million JD
S	P9	Construction management	Project manager and construction manager	18	Several billion JD
M	P10	Contractor	Contract manager	13	1-20 million JD
M	P11	Contractor	Project manager	8	1-80 million JD
S	P12	Contractor	BIM regional manager	9	20m-4.5 billion JD

7.1.3 Interview Analysis Method

Two pilot interviews were conducted with one lecturer at the University of Portsmouth and another lecturer at the University of Jordan to validate and refine the interview questions. Then, the interview questions were updated, according to their suggestions. As the interviews were conducted in Jordan, the questions were translated into Arabic, the official language in Jordan. The interview questions are in Appendix F. Two key stages were followed to prepare the interview data to be analysed:

Stage 1 – Conducting the interviews: This began by obtaining the interviewees' approval for participation. The researcher then visited the participants in their workplace, and each of the participants was interviewed face-to-face individually. Each of the interviews lasted between 45 and 90 minutes. The interviews were conducted with the BIM experts listed in Table 7.1.

Stage 2 – Transcribing the interviews: the transcribing process comprised five steps: recording the interviews; transcribing the recorded interviews in Arabic using Microsoft Word; the interviewees ensuring the reliability and validity of the transcripts from the interview process; translating the content of the transcripts into English; finally, two Arab PhD researchers in the School of Civil Engineering and Surveying at the University of Portsmouth checking the validity of both the Arabic and English transcripts and the translation from Arabic to English. Although this process was time consuming, it led to the outcomes and results being doubly verified as the data were validated in Arabic and English. In fact, it also resulted in being able to identify the common patterns and themes in the data analysis. In total, the recorded interviews resulted in 70 pages of transcription in both Arabic and English. A sample of the transcript is in Appendix G.

The richness and diversity of the resulting data required a robust analysis. For instance, BIM is understood and implemented differently by distinct individuals and organisations with varying backgrounds. Therefore, the transcripts of the interviews were analysed using a content analysis approach. This approach can be used to identify and examine phrases and words within the available data. Thereafter, certain themes and connections can be created to explain the findings, attaching meaning and importance to the data analysed. It was suggested by Renner (2003) that in order to analyse and interpret the data, three questions need to be asked: what are the major lessons? What new things did you find? And, what will those who use the results be most interested in knowing? These questions will be answered in the discussion in Section 7.8.

7.1.4 Analytical Tool Used to Analyse the Interview Data

The NVivo, version 11.3, data management software was used in this study to analyse the collected interview data. The software was downloaded from the University of Portsmouth's free access application website. Four steps were used in the software to analyse the data:

1. Interview data sources were inserted into NVivo: interviews transcripts and participant demographics were inserted into NVivo, as seen in Figure 7.1.

2. Interview data were organised and coded: obvious topics were abstracted from the transcript interviews. This includes organising and grouping the related ideas into nodes.
3. Interview data were analysed, and queries were run by the researcher. This step involved the initial merging of the nodes and running queries, so it allowed for a further investigation into the more complex aspects of the nodes; this complies with Bryman's (2008) suggestions. The final node structure is shown in Figure 7.2, which represents the NVivo screenshot entitled "thematic coding framework". Five main issues emerged from the nodding process: 'BIM implementation issues in the public sector in Jordan'; 'construction procurement in the public sector in Jordan'; 'procurement approaches for BIM implementation in the public sector in Jordan'; 'key improvement measures for better BIM implementation'; and 'construction public projects' performance'. Each of these issues has major themes and sub-themes that emerged from analysing the data. The nodes were streamlined and arranged in a hierarchical order to tolerate greater analytical coding for the researcher and by using queries in NVivo.
4. Answers to the questions were drawn from the interview data.

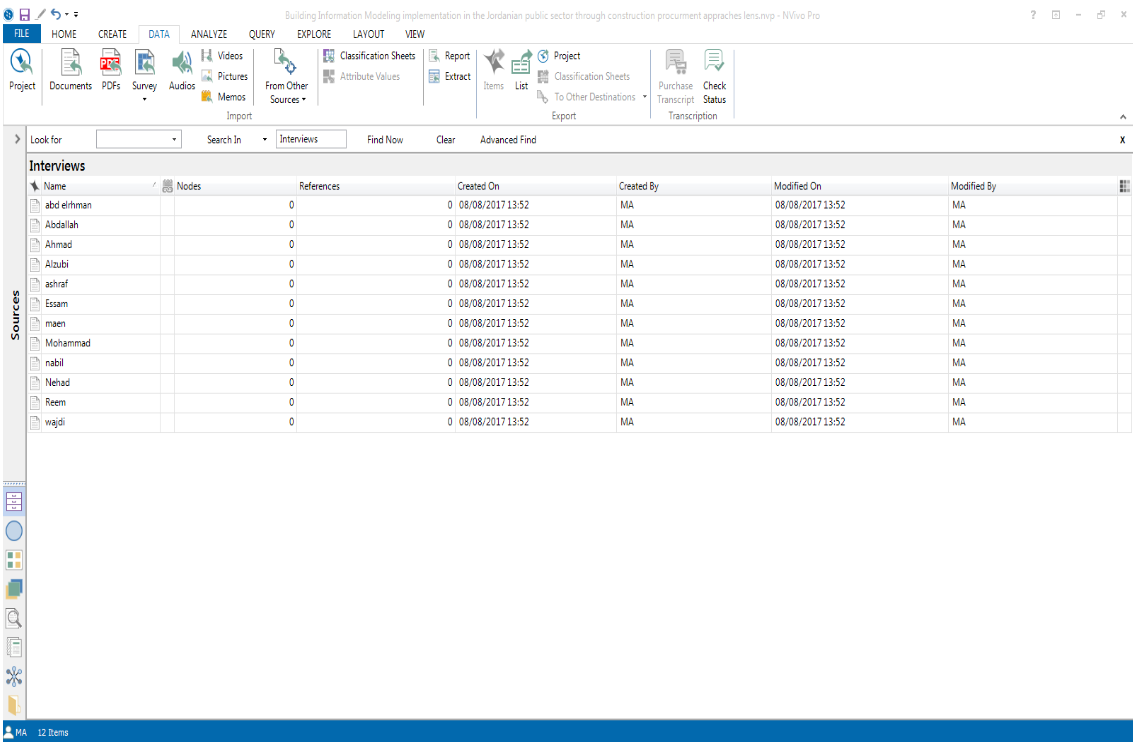


Figure 7.1: Step one of the interview analysis – data source entered

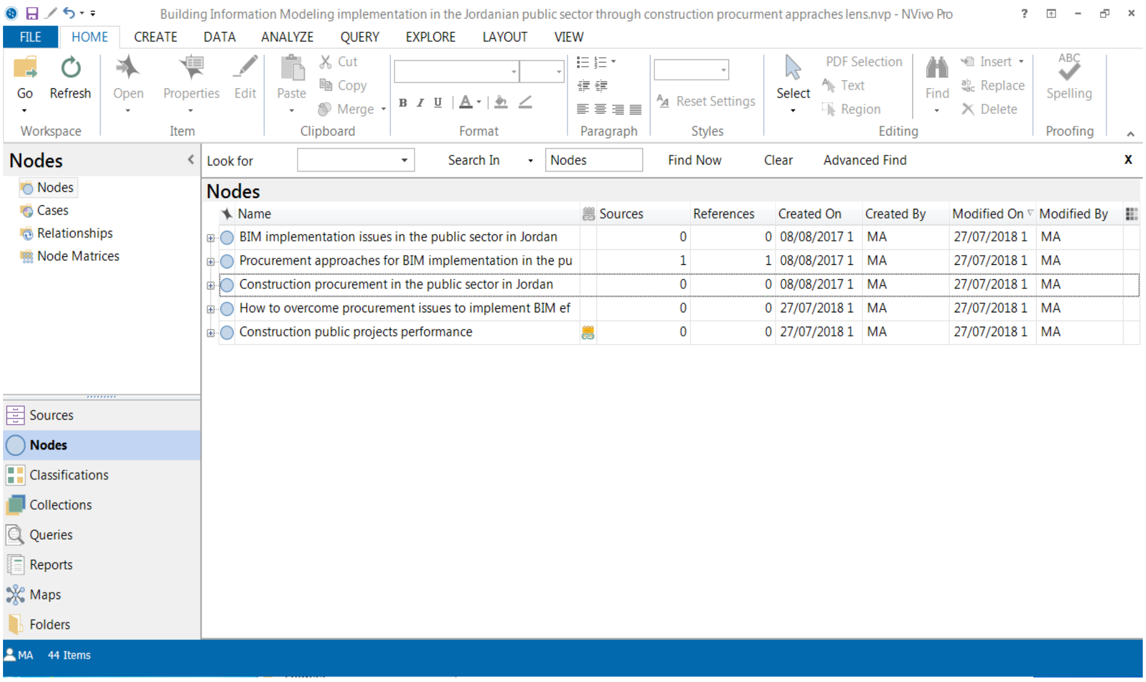


Figure 7.2: Step two of the interview data analysis - data was coded and organised in NVivo

7.2 INTERVIEWS: THE MAIN FINDINGS

The main findings from analysing the interviews qualitatively are provided in this section. Table 7.2 represents the key findings in the form of main issues, key themes and sub-themes. The following sections discuss these issues separately.

Table 7.2: Interviews' key themes and findings

MAIN ISSUES	KEY THEMES	SUB THEMES
BIM implementation in the public sector in Jordan	• BIM status • BIM process • BIM drivers • BIM benefits • BIM for sustainability • BIM barriers	• BIM is mainly implemented in the design phase for 3D visualisation and clash detection • BIM processes are fragmented • Lack of government demand • Perceived benefits from implementing BIM in construction in the public sector in Jordan • Business and legal, technical and organisational BIM barriers (Table 7.2) • Procurement approaches are one of the major barriers to BIM implementation
Construction procurement in the public sector in Jordan	• Procurement approaches adopted • Issues associated with the currently adopted	• Traditional procurement is the most common approach • Most of the public building projects have been delivered using a one-stage tender under the traditional procurement approach

	procurement approaches ● Main tasks and stakeholder involvement	
Procurement approaches for BIM implementation in the public sector in Jordan	● Procurement approaches adopted for BIM-based projects ● Best fit procurement approach for BIM implementation ● Construction procurement approach issues that affect BIM implementation	● Traditional procurement approaches are the most commonly used for BIM-based building projects. ● DB and IPD are the best fit for BIM implementation ● Key issues for effective BIM implementation are: a lack of procurement processes for BIM implementation; unclear roles and responsibilities; late stakeholders' involvement; rigidity of the tender process; limited pre-qualification list; and unclear guidance on the needed BIM level of details (LODs) over the project lifecycle
Key improvement measures for better BIM implementation	● Critical steps and action ● Procurement delivery approaches up take for BIM ● BIM meetings ● BIM units	● Changing procurement approach and guidance on BIM training and education are the key steps to implementing BIM ● DB and IPD are the optimal procurement approaches for BIM implementation. However, there are many issues to implementing these approaches in Jordan ● BIM meetings are needed to enhance collaboration and communication ● Contractors started to train BIM units to be involved early in the design stages
Public sector construction projects' performance	● Performance assessment pre and post project completion ● Metrics used in public construction projects ● Sustainable construction in the public sector	● Cost, time and quality are the most used metrics ● The existence of a performance gap between design intent and the final building product ● Adopted procurement approaches, financial support, policies and legislation and compliance and certification are among the major barriers for achieving sustainable buildings in Jordan ● Sustainability procurement factors under a preferred procurement approach have been identified

7.3 BIM IMPLEMENTATION IN THE PUBLIC SECTOR IN JORDAN

The interview analysis revealed many issues experienced by BIM practitioners in the public construction sector in Jordan. Issues such as the current usage of BIM, adopted fragmented BIM processes, BIM drivers, BIM benefits and the main barriers to implementing BIM. The following sections discuss each of these issues.

7.3.1 BIM Status

Interview participants were asked about BIM implementation in Jordan, P5 (a BIM manager) and P12 (a BIM regional manager) in consultant and contractor companies commented that: "the main letter in BIM is the I; everything is to maintain the I and to keep it available to everyone involved in the project"; "BIM is all about the letter, I; if we give correct input for the software, then we will get the required output".

Interview participants commented on the current usage of BIM in the public sector in Jordan. P2 expressed that "most BIM practitioners in Jordan use the modelling tool to get the sections and elevations and then export them to Auto cad (2D)". Another, P7, stated that "the main goal for the BIM model in Jordan is clash identification". This has confirmed the survey results in Figure 6.5 that visualisation and clash detection are the main applications of BIM in the public sector. P7 also added that "there are many projects delivered using BIM in terms of the design, but very few have delivered construction through BIM". P12 agreed by stating that "BIM has been adopted only by consultants in most of the projects". Therefore, it can be said that BIM implementation in the public construction sector in Jordan has been used mostly in the design phase for the purpose of visualisation and clash detection.

7.3.2 BIM Process

BIM has been implemented in a fragmented way through two main BIM processes as reported by the interview participants. These processes can be summarised as follows:

Process one: P3, P6 and P8 confirmed that most of the projects delivered utilising BIM followed these stages:

1. The consultants build the BIM model in the design stages.
2. They export the designed BIM model into 2D drawings.

3. The contractor then bids based on these 2D drawings, and the construction work is carried out based on these 2D drawings.

Process two: The other BIM-based process was confirmed by P4, P6 and P7 as the following:

1. The consultants build the BIM model.
2. They export the designed BIM model into 2D drawings.
3. The contractor bids based on these 2D drawings.
4. The contractor builds his own BIM model based on the drawings to calculate the quantities and to detect any clashes.

These BIM fragmented processes are adopted for many reasons (issues) exist in the Jordanian public building sector, as stated by the interview participants. These issues:

1. The procurement system most used in the public sector in Jordan is DBB. This type of procurement is fragmented in nature, and the stakeholders' involvement and responsibilities are separated in the design and construction phases. This, therefore, leads to the late involvement of the contractor and sub-contractors in the delivery process and the adoption of fragmented BIM processes.
2. In terms of the rigid tender procedures, P8 claimed that "fragmented BIM process are adopted due to the rigid system in tendering in the governmental tendering procedures" as the pricing is based on the 2D drawings. In BIM-based projects, these drawings are extracted from the 3D BIM model and are sent to the bidders. The bidders in turn do not have access to the model.
3. The permit loop includes JEA, JCCA, MPWH, CCD and the Amman municipality. P7 commented that "these parties cannot audit the BIM models; therefore, each time that you need to obtain the permit, you need to print it on 2D drawings".
4. The lack of BIM competency with the contractors is also one of the reasons for using these BIM processes as few contractors have delivered public buildings using BIM.

7.3.3 BIM Drivers

The majority of the interview participants claimed that BIM implementation in Jordan is a top-down approach in which the government addresses BIM at a strategic level. P12 stated "the starting point to influence BIM implementation in Jordan should be the government"; P4 confirmed this by claiming that "the public sector will push the private sector to use BIM". P9 and P11 also added respectively that "the government needs to propose BIM usage to the other stakeholders" and "the government is the party who initiate the projects and employ the whole team and decide whether to use BIM or not". This is in accordance with the survey results in Chapter Six (see Figure 6.9) and a study that has been performed by Al Awad (2015). However, the interview participants confirmed that there is a lack of government demand, which also agrees with the survey conducted in Chapter six, as shown in Figure 6.8. P1 commented that "the agreement which was in 2011 between JEA, JCCA and MWPH on promoting BIM was just paperwork with no actions".

The interview participants reported that the first step to implementing BIM effectively is by having a law on implementing BIM. P8 stated that "the government associations such as JEA, JCCA need to enforce the usage of BIM by having a law on implementing BIM and employing a BIM specialist. The government is represented by the MWPH".

On another governmental level, P5 (a consultant) expressed that "efforts were made by the early BIM implementers in Jordan to work with the Greater Amman Municipality (GAM) to influence BIM implementation in other municipalities like Dubai. Meetings, workshops and seminars were conducted in GAM workplaces to influence BIM implementation. These meetings, workshops and seminars showed that people are educated on BIM. However, BIM implementation should start from a higher position like MPWH".

On the other hand, P12 (a contractor) claimed that the government role should not only be to enforce BIM for its own projects, but also in the public education system, such as with students in undergraduate and post-graduate related courses: "at the moment, our fresh graduates don't know about BIM; the government needs to push and ask for it to be included even in the undergraduate programmes. So, associations, education bodies, the private sector, and most importantly the government, all have shared responsibilities".

7.3.4 BIM Benefits

The construction public sector in Jordan has many perceived benefits from implementing BIM. One of the main BIM benefits that have been expressed by most of the interview participants is the BIM contribution to enhancing the poorly coordinated design drawings when delivering public building projects. P8 stated that a "public project can be delivered without BIM. However, BIM utilisation will aid in avoiding a lot of clashes in the coordination between different stakeholders". P4 added that "BIM was utilised because it overcomes the coordination problems in the traditional type of design". P5 also stated that "BIM will enhance the design process, and it will produce well-coordinated designs. Therefore, it will reduce the issues that can cause changes, disruptions and delays".

Another BIM perceived benefit is enhancing the collaboration between project stakeholders. P9 claimed that:

> BIM will improve the collaboration in design and construction through enhancing the project stakeholders' relationships and patterns to produce and exchange the project information by using this platform for the project's whole lifecycle.

BIM implementation will reduce the time and cost of the public building projects through the time and cost savings from the information exchange. P6 stated that:

> In supply chain management, the wastage of information in the conventional way will occur between different stakeholders at the same stage, and between different stages, as for example, the contractors have complained that although the building's lines and drawing are usually completed, the whole information was not delivered due to the information wastage which happens in the design phase.

P5 expressed that "BIM has changed the way information is exchanged; it becomes easier using BIM tools with less time and money wastage on information exchange compared to the traditional ways". P9 added that this will lead to a reduction in the project delivery time and cost. P7 also expressed that "BIM benefits are in terms of minimising time and cost, and enhancing the quality of the final product".

In terms of the cost, P12 expressed that:

> In Jordan, construction projects are usually highly uncertain in terms of cost. This is why we are going for BIM; it's to know everything; what do we need? Forecast and hiding prices that we will not be able to see it until we run the BIM 4D simulation; that's why the 4D in BIM is a very major aspect that we use and need.

P8 also added that "when BIM is implemented, more accurate cost estimations (measurement and quantity) can be calculated. Cost estimations will be accurate with an error as low as 2%".

BIM can also improve the decision-making process, as expressed by the interview participants. P4 expressed that "BIM for sure can improve the decision-making process because convincing the project sponsors and end-users based on the modelled project is easier than with the 2D drawings".

7.3.5 BIM Effect on Sustainability Performance

Most of the respondents stated that BIM has a significant potential to contribute to public building sustainability performance. This confirmed the questionnaire survey (see Table 6.4) in which the questionnaire respondents placed sustainability enhancement as one of the main five benefits of BIM implementation. Further to this, P4, P7, P11 and P12 identified BIM as the core aspect of sustainability.

The interviewees were also asked about how BIM contributes to sustainability performance. Answers can be classified under two main aspects: visualisation and sustainability analysis. For the visualisations, P3 and P5 claimed that BIM's ability to provide visual building information will have a positive effect on the decision-making process. This will minimise the changing orders and reworking, thus obtain a better building performance.

For the sustainability analysis, the interview participants highlighted that the ability to integrate BIM with other performance analysis software to perform different scenarios will lead to more sustainable and better performance buildings; P12 stated that:

> We aim for cutting costs, minimising changes, clashes on site and wastage as the construction industry has the highest percentage of waste among all the other industries in Jordan. We have 27% wastage on any project, so for sustainability, the first run of the energy model gives us an indication of how the building is going to run in hot and cold weather, and how effective the envelope of the building has been designed through BIM.

7.3.6 BIM Barriers

In spite of the benefits reported above, BIM implementation in the Jordanian public sector has faced business and legal, technical and organisational problems:

7.3.6.1 Business and Legal Problems

Barrier 1: Adopted procurement approach

The procurement approach is considered to be one of the major challenges and barriers to implementing BIM in the public sector in Jordan. Most of the participants said that the chosen procurement approach does have a direct impact on the success of BIM implementation. Moreover, the others claimed that to fully implement and perceive the full benefits of BIM, a procurement approach that enhances collaboration between stakeholders is needed. A detailed discussion about the adopted procurement approaches and their effect on BIM implementation will be presented in Sections 7.4 and 7.5

Barrier 2: Additional resources and expenses

The interview participants were asked to provide the barriers faced when implementing BIM in the public sector in Jordan. The majority of the 12 participants reported that the initial investment cost is one of the main barriers. P5 stated that "the problem with BIM implementation in Jordan is that they consider it to be an increase in investment". P6 added the reason for considering BIM as an increasing cost and additional expense "is due to the traditional way of working which depends on the lowest cost". P4, a project manager on the public client side, added that the "consultants and contractors will be investing in hardware and software in BIM projects that they can avoid by using the conventional way of working".

Barrier 3: Lack of a legal framework

The interview participants claimed that the legal barriers are among the main BIM implementation barriers in the public sector in Jordan. P5 and P7 highlighted the importance of having amended forms of contract. P5 stated that "there is a lack of amended forms of construction contract that goes with BIM implementation". P7 further argued that "as there is a lack of BIM demand from the government, other stakeholders will not be bothered to create any form of contract for BIM implementation". Copyright and ownership of BIM models are also among the main barriers to implementing BIM in Jordan, and they should be included in the main contract, as expressed by P7 and P12.

Barrier 4: Lack of an existing framework and implementation plan

P9 expressed that a "lack of public client awareness and demand for BIM has led to the absence of a standardised approach, framework or plan to implement BIM". P4 expressed the significance of having a framework or implementation plan for BIM in order to have better building performance: "the most important thing in construction is the quality of the drawings, and as a public client representative working on BIM, I think it's important to have clear communication channels with the consultants, contractors and suppliers". He added that "by not having this, the process performance will be reduced due to a misunderstanding between the parties; and, therefore, the final product will not perform as expected".

7.3.6.2 Technical Problems

Barrier 1: No standard BIM library

In terms of an existing BIM library in Jordan, the interview participants reported that there is a lack of standardised BIM library. Therefore, P6 claimed that two methods are used for collecting material information to import into a BIM model. Firstly, suppliers are asked about the specification of certain items, then the information is imported and saved in the BIM library. The second way is to browse the Internet for BIM components for this certain item. He added that "this is easier, but we browse and import to the BIM model without consulting the contractor or their sub-contractors as they are not on board yet".

7.3.6.3 Organisational Problems

Barrier 1: Changing the payment mechanism

Changing the payment mechanism was considered to be a barrier for the government to implementing BIM. P12 suggested that "BIM implementation will hold the project back; more time and money will be spent on the design and preparation stages to make the construction stage shorter in time compared to the conventional approach by reducing the rework and having more accurate drawings". P11 (a contractor) described changing the payment mechanism as a barrier to BIM implementation: "it's considered a barrier to BIM implementation to spend more time and money on the design as it's not the way that the sector is used to working". He added that "the flow of the money then, of course, will be completely different between BIM and the conventional approaches. So, if this issue is not well understood by both sides, the public client and his supply chain, major conflicts will occur in the payment mechanism, planning and scheduling of the project".

Barrier 2: Culture change

The interview participants expressed that the resistance to change is one of the main BIM barriers in Jordan. P3 stated that "it starts with the culture, as for example many engineers in Jordan still use hand drawings for small projects". These people need to be educated about the new tools. He added that "the problem is to make BIM a culture and style". On the other hand, P9 expressed that "legally, there is no obligation to make someone work on, for example, auto cad or any software".

Barrier 3: Current audit process

Another barrier to BIM implementation is the permit loop, as expressed by P5 and P6. The permit loop in a Jordanian construction project includes JEA, JCCA, MPWH, CCD and the Amman municipality. These parties cannot audit BIM models, as the interview participants claimed; therefore, each time the consultants or contractors need to obtain a permit, they need to print a design out in 2D drawings. This will consume more time, cost and effort. Thus, the full benefits of BIM will not be recognised by the project stakeholders; therefore, to implement BIM, there is a need to change the way JEA, JCCA, MPWH, CCD and the Amman municipality review and audit the design. Moreover, these audit units need to be trained, so they can audit the design through a BIM model.

Barrier 4: Lack of qualified contractors

There is a shortage of qualified contractor companies compared to the consultant companies, as shown in Table 6.8. This issue has been outlined by the interview participants, that is the public client representatives, consultants and contractors. P5 (a consultant) reported that "I know many big consulting firms in Jordan have started to utilise BIM, but I don't know so far about the contractors who have the capability to use

BIM". P7 (a consultant) also added that "there is a lack of Jordanian contractors experienced in BIM implementation and pricing".

P3 (a public client) stated that there is a need to have a transitional period in BIM implementation in the public sector where more contractors' engineers get trained on the BIM approach. He added that "because of this, most of the public projects were delivered using BIM for only 3D visualisation and clash detection as contractors usually bid and deliver projects in the conventional way". P4 (a public client) reported that "due to the low numbers of qualified contractors who work on BIM, they ask for a lot of money to deliver using a BIM model".

On the contractor side, P12 commented that "it's a costly approach because the contractors who do it are very few, and they are taking advantage of that. So, there is not much competition in choosing the contractors working on BIM". On the other hand, P10 added that "the increase in cost will be saved in the construction if they went through clash detection, 4D, 5D and 6D simulation. The public client will be saving much more than the increase in up-front cost". He added that "in the near future, more construction companies will adopt BIM; therefore, competition will increase and prices for implementing BIM by the contractor will decrease".

The contractors' competency is behind the lack of implementing BIM in the construction phase. P8 stated that "you need a contractor who is well trained in using the designed BIM model because he has to prepare and submit a final technical and financial offer based on the designed BIM model". As a result, the interview respondents suggested a transitional period of time for the public contractors to train their staff in BIM implementation.

On the other hand, BIM contractors are taking advantage of the current situation in Jordan. P9 (a construction manager) commented that "in one of the projects, we asked the main contractor to use BIM to deliver the project; he asked for 300,000 JD to build a BIM model"; P12 (from a contractor company), agreed with this by stating that "the contractor usually asks for a lot of money to implement BIM because the people who do it are very few, and they are taking advantage of that".

7.4 CONSTRUCTION PROCUREMENT IN THE PUBLIC SECTOR IN JORDAN

The procurement approach is considered to be one of the major challenges and barriers to implementing BIM in the public sector in Jordan. This has firstly expressed by the public major stakeholders in the questionnaire survey (see Table 6.5) and BIM practitioners in the interviews (Section 7.3.6). Therefore, the following sections will discuss the issues related to the adopted construction procurement approaches.

7.4.1 Types of Construction Procurement Approaches

The interview participants were asked to state the types of procurement approaches used in the public projects as well as the percentage for each approach (see Table 7.3). The most commonly used procurement approach in the public sector in Jordan is DBB with an average of 76% of all those used in the public building sector. According to FHWA (2005), the traditional method of DBB is the most widely used procurement approach worldwide. This type of procurement has been widely criticised due to its fragmentised nature as there is a total separation between the responsibilities and risks by the consulting and the contracting sides.

Table 7.3: Procurement approaches in the Jordanian public industry

Procurement approaches	Percentage												
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	Average
DBB	70%	80%	80%	80%	70%	70%	80%	70%	80%	90%	70%	70%	76%
DB	20%	10%	20%	20%	30%	20%	10%	30%	20%	10%	20%	20%	19%
CM	10%	10%	0%	0%	0%	10%	10%	0%	0%	0%	10%	10%	5%

The interview participants stated many reasons for adopting DBB to deliver public building projects. One of the main reasons is the certainty of the cost that this approach offers to the government. P6 (a consultant) reported that:

> The design will be fully completed; and, therefore, the public client will know how much it will cost before going to the construction phase. Therefore, he will choose to continue if he has enough funding or not and choose accordingly.

Resistance to change is also among the main reasons P7 (a consultant) claimed that:

> The government is used to doing business in a certain way, and they will be resistant to change to new tools or ways of working because they don't know the benefits, how to implement it or why to choose one approach and not another.

On the other hand, the DB and CM procurement approaches were used by the government for a few significant projects as one of the interviews participants, P6 (a consultant) stated that, "20% of the projects that I mentioned before on being awarded with the DB or CM procurement approaches on public projects are only big unique projects such as the 'airport new building' and the 'fast lane bus'".

Only 19% of the public projects in Jordan utilised DB. This is due to many reasons. For instance, P2 stated it was because of a "lack of public client control beyond awarding the contract" in this approach; P6 reported it to be due to a "lack of experience and understanding of the DB processes as they are not fully aware of what is happening in the business", and P8 claimed that "there are few construction companies that are capable of working in the DB approach".

Another reason is that as there are few qualified contractors capable of working on the design and build, according to P9, the "contractors tend to hire external consultants to work on the design development". P7 added that the:

> Projects that have been completed using DB approach were done so by assigning outsourced consultants, and this is because there is not one company in Jordan able to do the design and construction using in-house resources.

He also reported that:

> Hiring outsourced consultants will lead to the poor implementation of the DB approach as it will not overcome the issues that this integrated project delivery approach is supposed to, such as the collaboration and coordination issues.

Further to this, P6 expressed that:

> Implementing such an approach in Jordan is similar to the design-bid-build approach because the main contractor bids for the DB of a certain project, then

> once they are awarded the contract, they establish a contract with the external consultant companies to design the project; then they will have a contract with the sub-contractors to carry out the construction work. The role of the main contractor becomes one for the project manager to manage and control the process of delivering.

These views on DB provide further evidence to support Moore and Dainty's (2000) and Muriro's (2015) findings; they clearly stated that such an approach does not deliver the necessary integrated culture in the project; more specifically, the roles and responsibilities under DB were similar to being under a traditional design-led procurement method.

CM is the least adopted approach due to a range of barriers in the public sector. These barriers include a rigid tendering system. As such, P8 reported that "there is a rigid system in tendering in the governmental tendering procedures". Moreover, P8 added that "there was no real definition for a CM firm as they are used to having a contractor registered in the contractor association, and consultant firm and client". In terms of the contract forms commonly used, P9 reported that:

> The contract itself that is used by the MPWH is based on the FIDIC contract. This type of contract deals with the main contractor, the engineer (the designer and supervision) and the owner. It is, therefore, easier to implement CM in the private sector.

7.4.2 Tender Process

According to the 'Government Works By Law No. (71) of 1986, Article 9', the tender offers should be submitted as technical and financial offers, which can be in two separate envelopes, or in one envelope if the tenderer wishes that the technical and financial offers are studied and evaluated together. The technical tender includes a method statement, an outline of their capabilities, the staff and their CVs, the quantity and the methods used to calculate it and a list of suppliers. The financial tender constitutes the prices offered for the job. Moreover, it is stated in Article 8 that most of the 'invitations to tender' are through a public announcement in at least two of the local daily newspapers, or they are handed to the contractors or consultants who are approved by the employer to be invited to tender on the recommendation of the Chairman of the Committee (The Hashemite Kingdom of Jordan, 1986).

The interview participants were asked about the type of tender strategy used by the public client when delivering public building projects. As the DBB is the dominant procurement approach adopted to deliver such projects, most of the interview participants stated that a single-stage tender strategy was the most frequently used to deliver public building projects in Jordan. However, few buildings projects were delivered using the two-stage tender strategy. The following describes the issues faced by the key stakeholders in the adopted tender strategies.

P7 (a consultant) reported that “after bidding for a project on either approach (publicly announced or by invitation), the public client will choose depending on the lowest cost that complies with the minimum specifications”. P5 (a consultant) agreed by stating that “the public client will choose depending on the price that fits his budget, and in most cases, they go to the lowest price with not much attention on the quality”. P11 (a contractor) added another issue about limiting the space for innovation in the process as the focus of the bidders is only on minimising the cost to win the project; he stated that “the government choice depends mainly on the lowest price that meets the specification included in the design; this process will produce no space for innovative contractors”. Moreover, as expressed by P3 (a tender manager in the public sector), the public client strategy in Jordan is always to achieve the lowest capital prices that comply with the required quality through competitive tender processes: the “DBB approach will increase competitiveness in the bidding process, and therefore achieve lower prices.”

Another issue that has been highlighted by the interview participants is the pre-qualification list prepared by the public client. P6 (a consultant) claimed that “pre-qualification leads to submitting the tender, then pricing the tender and awarding the contract”; he added that “many conflicts and issues that arise from the procurement approach is due to the pre-qualification list for consultants or contractors that have been written by the public client as the majority of the pre-qualification lists are too limited, and anyone can pass and apply for the job”. For public construction projects in Jordan, P2 and P4 stated that MPWH qualifies consultants and contractors on the basis of their expertise. This includes the buildings and civil engineering projects on roads, bridges and water, they have worked on.

7.4.3 Key Tasks and Stakeholders' Involvement and Responsibilities

The interview participants were provided with an empty table of the RIBA (2013) stages. They were requested to fill in the table according to their previous experience in delivering typical public projects. As seen in table 7.4, the key tasks and key stakeholder involvement were agreed upon by the interviewees for a typical public construction project under the dominant construction procurement approach (DBB).

Table 7.4: Key tasks and key stakeholder involvement throughout the procurement process

RIBA (2013) Plan of Work Stages	DBB	
	Key Tasks	Key Participants
Stage 0: Strategic definition	• Public Client requirements • Public Client business case	• Project sponsor (PS) • MPWH • PM
Stage 1: Preparation and brief	• Tender documentation for consultants • Brief development • Identify project targets	• MPWH • PM • Consultants
Stage 2: Concept design	• Consultants and sub-consultants to develop a concept design • MPWH and PM to approve it	• Consultants and sub-consultants • PM • MPWH
Stage 3: Developed design	• Consultants and sub-consultants to develop a detailed design • MPWH and PM to approve it	• Consultants and sub-consultants • PM • MPWH
Stage 4: Technical design	• Consultants and sub-consultants to develop a technical design • MPWH and PM to approve it	• Consultants and sub-consultants • PM • MPWH
Stage 5: Construction	• Contractor and sub-contractors to undertake the work • Consultants (the supervision) to undertake the quality control of the delivered work • PM and MPWH to approve it	• Contractor and sub-contractors • Consultants (the supervision) • PM • MPWH

Stage 6: Handover and close out	• Consultants (the supervision) to request for the inception and verifying the compliance based on an inception testing procedure (ITP). There is ITP for every kind of work • Contractors to record any unmet work • PM to carry the evaluation process by checking the compliance of the final as-built drawing with the contract drawings • PM and MPWH to approve it	• Consultants (the supervision) • Contractors • PM • Public clients
Stage 7: In use	• Contractors to hold the defect liability for the structural work for 10 year and the MEP work for 2 years • MPWH (the facility management) to occupy the building	Contractors

The key issues with the stakeholders' involvement were clarified by the interview participants. Late stakeholder involvement and assigning two different consultant teams (the design and supervision) were among the main issues. P1, P6 and P9 considered the late involvement of the contractor as one of the main issues when using DBB. P9 stated that "DBB is the most procurement approach adopted by the public client. However, it is a fragmented approach with no or very limited involvement of the contractors or sub-contractors in the design phase". P6 added that this will affect the development of the design in that "if we keep the design stage for the consultants, they will design away from the technology, availability of materials and build ability". Moreover, when asking about the reasons for the contractor late involvement, P6 said "it is because the public client does not understand or accept bringing the contractor into the design phase without a tendering process, which is usually after stage 4". On the other hand, P1 is a project manager in the design department in MPWH, she says "I prefer to involve the contractor early in the design phase as the contractors usually bid low to win the project, and then raise claims through variation orders". P4 added that:

> If the contractor is assigned to construct the job early in the design stage, their contribution will be valuable, of course. They might reduce the risk of rework resulting in a lack of coordination between the different parties and form a constructive point of view.

The other main issue raised by the interview participants is having different consultant teams during the design and construction phases. Design consultants are involved in the design stage to develop the public client design and to supervise the consultants involved in the quality assurance during the construction and handover stages. P8 was the first interview participant to point out the issues related to the consultants' involvement in the design and supervision by stating that:

> There are two types of consultant teams: the design and supervision. A lack of involvement of the supervision team in the design stage will lead to a lack of understanding of some of the design aspects, such as the types of materials used. Moreover, poor communication and involvement of the supervision team in the design process will certainly affect the project performance in terms of wasting time, cost and quality.

P7 (a project manager) added that:

> The main issue with the DBB approach is the late involvement of the contractor; therefore, the relationship between the contractors and consultants will start in the construction phase. Assigning the design consultants to a supervisory role will eliminate any conflicts related to the design documents.

P12, on the contractor side, also stated that:

> As a contractor, we usually get poorly coordinated design drawings, and when we try to build them, we usually have a lot of time and material wastage occurring during this stage, leading to a lot of variation orders and claims; therefore, we usually hire consultants to work with us onsite to overcome these issues […] Having design consultants in a supervisory role will assist in minimising the waste in time and materials when redesigning the poorly coordinated design drawings.

7.5 PROCUREMENT APPROACHES FOR BIM IMPLEMENTATION

7.5.1 Procurement Approach Effect on BIM Implementation

The interview participants were asked whether the procurement approaches affect BIM implementation. They were divided into two opposing viewpoints:

1. The procurement approach has a direct impact on the successful implementation of BIM. P8 reported that the "type of procurement affects the implementation of BIM, of course". P11 added that "of course, the selected procurement approach will affect the usage of BIM considering the supply chain, the mentality and culture of procurement, how we are going to procure and when we going to procure". He continued by saying that

"there is a gap between implementing BIM and understanding BIM and procurement in Jordan".

2. BIM can be implemented under any procurement approach. However, to maximise the BIM benefits, a collaborative procurement approach is needed. P5 expressed that the:

> Procurement approach does not affect the implementation of BIM as the employer can enforce the stakeholder to use it. However, to maximise the utilisation of BIM, we need a procurement approach that facilitate collaboration between the project stakeholders.

It can be said that both arguments show the importance of construction procurement for the implementation of BIM. This is whether procurement approaches are essential for the successful implementation of BIM, or whether it is necessary to maximise the benefits achieved through implementing BIM.

7.5.2 Types of Procurement Approaches when Implementing BIM

As mentioned in Figure 6.11 and Table 7.3, more than three quarters of the procurement approaches used in the public sector are traditional DBB. This, therefore, provides further understanding of the procurement approaches used when BIM was implemented in the Jordanian public sector. P2, P3, P6, P7 and P8 stated that BIM was only implemented under DBB to deliver the public building projects in Jordan. They reported that this is because BIM has only been recently introduced to the JCI, and so it has not yet been explored with other procurement approaches.

7.5.3 Construction Procurement Approaches Issues that Affect BIM Implementation

The interview participants were asked about the issues associated with the adopted procurement approach, and the procurement processes that affect the implementation of BIM. Six main issues were provided, and each of these issues will be illustrated by quotations from the interview transcription, as in the following.

- **Issue 1: Lack of procurement process for BIM implementation**

The interview participants stated that because there is a lack of existing BIM standards in Jordan, procurement processes for BIM implementation are missing. P2 reported that "the absence of structure and a standardised procurement process has affected the 'know how' to implement BIM throughout the procurement process". P8 added that "the first step to implementing BIM is by having a standardised procurement process not only to follow, but also to educate the public stakeholders on how BIM should be implemented".

- **Issue 2: Unclear roles and responsibilities for BIM-based projects in the public sector in Jordan**

The interview participants identified that there are unclear roles and responsibilities for the project stakeholders for BIM-based building projects, and that this is one of the key issues in the current procurement process. This is because there is an absence of BIM standards in Jordan. The interview participants stated that the reason for such issues is that BIM has only been recently adopted to deliver public buildings in Jordan. Therefore, BIM implementation is not yet at the stage of having set standards. Moreover, the construction industry, management systems and procedures are not mature for BIM implementation.

- **Issue 3: Late stakeholder involvement, lack of contractor involvement in the design phase and assigning two different consultant teams for the design development and construction supervision**

BIM was mainly implemented under DBB. Therefore, the lack of contractor and sub-contractor involvement in the design phase is one of the major barriers to effective implementation of BIM, as stated by the interview participants. P6 said that "no one here understands or accepts bringing the contractor into the design phase without the tendering process, which is usually after stage 4". In BIM-based building projects, it has been commented by P2 (a public client) that late contractor involvement in the project lifecycle was reflected in the fragmented nature of the BIM processes in Jordan; this led the contractors to build and use BIM models from scratch.

On other hand, P12 (a contractor) claimed that:

> The biggest issue with DBB is the contractors' expectations to be in the same position as the consultant team who have been on the project for a while; so by having the contractor on board early in the project lifecycle, greater opportunities for understanding the dynamics of the project will occur.

P4 (a public client) expressed another issue in that:

> Usually, the contractor submits a very low bid with the intention of recovering their losses through claims and variation orders […] by including the contractors early in the design phase through BIM, not only can this predatory bidding be eliminated, but also a more accurate estimation of final cost and completion time can be achieved.

- **Issue 4: Rigidity of the tender process**

Tendering is a significantly important step under a procurement approach. The interview participants stated that the tender process adopted by the public client is rigid, and it is necessary to adhere to it. P8 reported that "there is a rigid system of tendering in the governmental tendering procedures". These processes are explained in Section 4.6 and Section 7.4.2.

- **Issue 5: Limited pre-qualification list**

P2 and P4 stated that MPWH qualifies consultants and contractors on the basis of their speciality, that is their experience in buildings and civil engineering projects, such as with roads, bridges and water. However, the interview participants criticised the limited nature of the pre-qualification list for consultants and contractors for BIM-based building projects. They stated that there is a need to extend this list to BIM-based projects. This will be discussed further in Section 7.6.5.

- **Issue 6: Unclear guidance on the required BIM level of development (LOD) over the project lifecycle**

An interesting issue that has been highlighted is the necessary level of development (LOD) throughout the procurement process. P1 commented that:

> Now, BIM is not part of the tender stage. However, if BIM becomes an essential part in the public procurement process, guidance is necessary on the LOD required for procuring the delivery team.

Moreover, P7 stated the following:

> There is a sentence that we keep repeating: How much information do we need to implement BIM at each stage. Sometimes, too much information could cause too much confusion.

P12 also expressed that "the major challenge we face in implementing BIM in our projects is how much information and what developments do we need at each stage of the project".

Based on the above, one of the main and important lessons learnt from the interviews is that in order to improve the implementation of BIM in the public sector in Jordan, a standardised procurement process that addresses the above procurement issues is needed. Improvement measures suggested by interview participants are discussed in the following sections.

7.6 KEY IMPROVEMENT MEASURES FOR BETTER BIM IMPLEMENTATION

7.6.1 Critical Steps and Action

The participants were asked about the critical steps and action necessary for implementing BIM. 8 out of 12 chose to change the way that the government procures its buildings for an increased sense of collaboration between the stakeholders. The rest of the interview participants (4 out of 12) expressed the view that guidance on BIM training and education is vital to start implementing BIM more effectively when delivering public buildings in Jordan.

7.6.2 Procurement Approaches for a More Effective BIM Implementation

The procurement approaches that best suit BIM implementation are the ones that facilitate an increased collaboration between project stakeholders, as stated by the interview participants. For governmental building projects, the contractors represented by P10 and P12, claimed that DB is the optimal method for implementing BIM. On the other hand, P6 and P7 (the consultants) said DB and IPD are the optimal procurement delivery approaches for implementing BIM. However, as confirmed by P3 (a tender manager), an IPD approach was not used in the public sector.

Moreover, P9 reported that:

> Construction companies should be transferred to DB contractors because if they have the know-how, then the unfair relations that exist between the consultants, the CM and the contractors will be eliminated, especially in terms of the contract.

However, the DB approach has been criticised by the interview participants for the limited involvement of the public client beyond the tender stage. Furthermore, as mentioned in Section 7.4.1 about the participant views on the DB approach, it was stated that an integrated culture had failed when implementing BIM through the DB procurement approach; further to this, the roles and responsibilities remained the same as when using the traditional design-led procurement method. This is because the contractors tend to hire external consultants and sub-contractors and act as the project manager.

7.6.3 BIM Meetings

P5, P7 and P12 stated that in order to enhance the collaboration and communication between the different stakeholders during the procurement process, a BIM start-up and BIM progress meetings are required early in the design phase. In the BIM start-up meetings, all the project stakeholders, that is the public clients, client representatives, consultants (the design and supervision), risk managers, construction managers and contractors, are gathered together. P12 claimed that:

> As a BIM expert, I think an initial BIM meeting is needed where all the stakeholders sit at the same table. On the other hand, progress meetings should occur weekly so that everyone can go through the 4D simulation and provide their comments.

7.6.4 Early Contractor Involvement by Establishing Contractor BIM Units

Late contractor involvement and lack of contractor competency in BIM were among the main issues for BIM implementation. The interview participants (P2, P3, P5 and P12) stated that the contractors in Jordan started to establish what is called a 'BIM unit' to offer consultation services and to get involved in the design phase. P2 and P3 claimed that a transitional period is necessary whereby the contractors' engineers are trained in the BIM approaches. P5 (a consultant) said that "we proposed that the contractors should have a BIM unit that we can provide training for. This BIM unit will act as a consultant or designer". P5 and P12 stated that this unit would be the starting point for shifting the industry to notice the importance of the involvement of the contractor during the design phase, and to overcome the lack of contractor competency in BIM. P8 reported that:

> This step, after a while, will enable the government or the employer to understand that for a better performance of the process and final product, the contractor needs to be involved in the design phase.

P12 also added that “many contractors established BIM units because the private and public clients in Jordan started requesting BIM to deliver their projects”.

The lines of communication in the contractors’ BIM units were described by the interview participants. These BIM units are to be used during the BIM implementation transitional period. BIM units on the contractors’ side will take consultation from the sub-contractor firms and facility management units, and from the public client organisations during the design phase. After BIM becomes the norm, the selection criteria will be changed. P3, P4 and P8 stated that it could be beneficial for the companies that have these BIM units as the their profiles will be seem more robust in terms of their capacity to implement BIM, and thus it will increase these companies’ chances of being chosen by the MPWH.

P2, P3, P5 and P12 expressed their views, respectively, on these BIM units in the following:

- In regard to its contractual status, this unit can be part of the design phase and can be working for payment at the same time. Therefore, as stated by the other interview participants, this unit will have expertise in: consultations, design reviews and feedback.
- These units can be named as ‘contractor as a consultant’.
- They can offer the best solutions in terms of the technology, availability of materials and constructability in the development of the design.

7.6.5 Appointment of Experienced Consultants and Contractors

According to the BIM managers in the consultant and contractor companies (that is P5 and P12) and a project manager from the public client side (P2), when constructing the delivery team in BIM-based projects, the MPWH and PM should create the pre-contractual conditions for choosing the consultants and contractors. The pre-contractual conditions include general information, software experience and a project information plan (PIP). PIPs include a BIM assessment form, an IT assessment form and a human resource assessment form. These forms should be sent out to the entire list of classified consultants and contractors; the classified consultants and contractors are chosen depending on the MPWH classification. These forms are used for assessing the consultants and contractors when the project has been chosen to be delivered using BIM. Moreover, the capacity of the companies selected to work with BIM will be assessed. These steps lead to appointing a project delivery team within the area of architecture, structure, MEP, contractor and sub-contractor works. These forms were firstly introduced and requested by the UK government under Section 6.3 of the British standard (PAS 1192-2:2013).

7.7 PUBLIC CONSTRUCTION PROJECT PERFORMANCE

7.7.1 Performance Assessment Pre-Completion and Post-Completion

The participants were asked about how the public building projects are evaluated during the design and construction phases. P1, P5 and P7 claimed that the evaluations are through the contract administration. This is through:

- The quality management using quality and control forms.
- Weekly and monthly reports.

The quality and control forms are used to:

- Record any unmet work.
- Request for inception and to verify the compliance based on the inception testing procedure (ITP). There is an ITP for every kind of work.
- Help submit the method of statement before carrying any works.

P1, P4 and P5 reported that the building performance is assessed post-completion through an evaluation process by checking the compliance of the final as-built drawings with the contract drawings; then, a report will be prepared including the following:

- Missing items from the as-built drawings.
- Manuals.
- Testing system commission.
- Outstanding works.
- Minor or major defects.

The interview findings revealed that BIM had not been used for performance assessment pre- or post-completion. This is because BIM been mostly been used in the design stage for visualisation and clash detection, as described in Figure 6.5 and Section 7.3.1.

7.7.2 Metrics Used in Public Construction Projects

The metrics that are mostly used in the public projects are cost, time and quality. P9 agreed by stating that "most of the projects in the public sector were evaluated by cost, time and quality"; P7 added that:

> It depends, in fact, on the type of project, so if it is a project that is out of the ordinary, such as the new Queen Rania airport, then other metrics might be used, but, generally speaking, 80% of the public building projects use the basic metrics: time, cost and quality.

P3 claimed that the metrics depend on the project's success criteria used by the different project stakeholders. As a government employee reported, "the common criteria involve the financial reality of doing business, meeting appropriate schedules, minimising legal claims and for the project to be completed on time and within the budget".

7.7.3 Performance Gap

The performance of the public construction projects has been criticised by the interview participants. P9 reported that a performance gap exists. P12 stated that "PS and MPWH usually begin with specific requirements for building projects. However, they are often not delivered as requested". This quite often leads to disputes between the public client, consultants and contractors, as P9 has claimed.

P5 and P12 said that the main reasons for the performance gap are the changes made by the public client to both the design and the construction phases. The interview participants stated that there are always variations in the JCI in the design and construction phases. P8 said that "most of the changes are during the design phase because it is more flexible than the construction stage. Moreover, the public client knows that changes made during the construction phase will cost more". P1 confirmed this by stating that "the performance gap is caused mostly by the design phase as the contractor will follow the design documents". P4 (a public client) added that:

> If you sit with a contractor, he will say that there are a lot of design mistakes due to the lack of coordination. In fact, some of the contractors have an engineering office onsite to correct the design errors or to complete the consultant shop drawings. It's the consultants' duty to produce the shop drawings, but sometimes the contractor might find a lot of mistakes in the final design drawings.

Therefore, there is a need for the documents stating the employer requirements to be well defined early in the delivery process. Moreover, the interview participants also stated that in order to enhance the performance of the building and minimise the performance gap, project targets need to be clearly defined early in the delivery process.

7.7.4 Sustainable Buildings in the Public sector

Sustainability is new to Jordan and the surrounding area. The following are key themes found in the data analysis:

- The existence of barriers to sustainable practices.
- The sustainability factors under the preferred procurement delivery approach.

7.7.4.1 Barriers to Sustainable Practices

The interview participants expressed the view that sustainability is an important subject in Jordan. However, they stated that in building performance, the focus is on the triangle, that is cost, time and quality, and this is due to the barriers described in the following parts.

Barrier 1: Public procurement approaches

The most frequently used procurement approach in the public sector is DBB. P6 stated that the "competitively sealed bidding processes under DBB is mandated and awarded based on the lowest priced bid"; he further added that "to win the contract, I need to present the lowest price, which means less sustainable practices". On the public client side, P3 (a tender manager) commented that "we have concerns about continuing to use the traditional procurement approach, which means calling for the lowest price as the cost maintenance and operations are not taken into consideration".

P9 claimed that:

> One of the key factors for increasing the probability of meeting the sustainability goals is the early involvement of the contractor, which is not the case when delivering public projects in Jordan as DBB is the dominant procurement approach in the public sector.

Barrier 2: Financial support

Higher costs coupled with the governmental lack of push and funding were among the major barriers to introducing sustainability technologies, as stated by the interview participants. P11 said that "it's the government's responsibility to push and ask for sustainable buildings. As the contractor, it represents extra costs, but once it's at the mandatory stage, we go ahead and do it". P3, P6 and P12 added that, currently, sustainable construction practices are necessary, but not obligatory in both the public and private construction sectors.

Barrier 3: Policies and legislation

The interview participants stated that there is a lack of existing policies and legislation that govern sustainable construction. P5 expressed that "this can result in major shortages in the protection and monitoring of the impact of the construction projects on the environment".

Barrier 4: Compliance and certification

The interview participants expressed the view that there is a lack of compliance and certification standards that are suitable for both the public and private construction sectors in Jordan. P12 stated that "in spite of having the Jordanian Green Building Council that tries to promote sustainability, there is no accreditation of sustainability in Jordan. Therefore, we sometimes follow the LEED accreditation".

7.7.4.2 Sustainability under the Preferred Procurement Approach

The interview participants were asked about how the environmental and sustainable issues should be addressed in their preferred procurement approach. Nine factors were provided, ranked from 1 (the least important) to 5 (the most important). Six factors were found to be significant to enhance sustainability in building projects in the public sector in Jordan.

Table 7.5: Sustainability factors under the preferred procurement approach

Procurement sustainability factors	**Mean**	**Ranking**
Highlighting sustainability in the project brief as a primary aim	5+4+5+4+4+3+4+5+5+5+3+5/12 = 4.31	1
Integrating sustainability requirements into contract specifications and conditions (including specifying any project-specific sustainability requirements)	4+3+5+5+5+4+4+5+4+3+4+4/12 =4.25	2
Emphasising the importance of sustainability in tender evaluations and selection procedures	5+4+5+4+4+3+5+4+5+5+3+3/12 = 4.17	3
Requirements and incentives for the supply side to demonstrate a commitment to sustainable development through policy and implementation	4+5+3+5+4+5+3+4+4+4+3+4/12 = 4.0	4
Requiring the supply side to demonstrate the capability to deliver sustainability requirements	3+4+3+4+4+5+3+4+4+5+3+4/12 = 3.83	5
Encouraging tenderers to suggest innovative solutions and approaches that support the public client's overall sustainability objectives	3+3+4+4+5+3+5+4+3+3+4+3/ 12= 3.67	6
Provision of incentives and rewards based on sustainability performance throughout the project lifecycle	2+3+3+2+4+3+3+2+3+3+4+3/ 12= 2.91	7
Ensuring that payment mechanisms take account of whether sustainability requirements are delivered	2+2+3+2+4+3+2+1+3+2+4+3= 2.58	8
Requiring the employment of a properly trained workforce within the supply side	1+1+2+1+3+3+3+2+3+4+2+3/ 12= 2.33	9

P2, P5 and P6 added to the provided list above, that there is a need to have an iterative process in developing the design to enhance the design integration and sustainability outcomes.

7.8 DISCUSSION

BIM implementation has increased in the public sector in Jordan, as shown in Chapter 6. Moreover, in the future, BIM's usage will certainly increase because the key public construction stakeholders stated that it is timely to implement BIM. Also, the government can influence the implementation of BIM in Jordan.

Recommendations from the literature were considered about whether it is necessary to change the way that clients procure their buildings or whether it is requisite to develop a supplement to the existing contract and procurement documents to facilitate BIM adoption. Therefore, reviewing and evaluating the current performance of the procurement process in the public sector in Jordan is important. The literature revealed that there is a lack of studies on BIM implementation and procurement processes in the public sector in Jordan (see Section 3.4.2). Therefore, a BIM feasibility study was conducted (see Chapter 6). However, there was a need to further investigate certain BIM issues. Figure 7.3 represents the data generated themes from analysing the interviews, and how these themes are interrelated. Thus, the upper part of Figure 7.3 represents the BIM adopted processes, BIM benefits and BIM barriers in the public sector in Jordan.

The procurement approach was found to be a major barrier for BIM implementation. This verifies the results of the BIM feasibility study (see Table 6.5) and the literature review (see Section 4.3). This is because BIM is adopted only under DBB for many reasons as described in Section 7.4.1. The use of DBB has resulted in implementing two fragmented BIM processes. The key issues under the DBB approach that led to such fragmented BIM processes are outlined in Figure 7.3, highlighted in red. To overcome the currently adopted procurement delivery approach issues, a framework tackling the issues that affect BIM implementation is required; otherwise, the other option is to change the current public procurement delivery approach to a more integrated one, such as DB or CM. The latter is faced with many challenges, such as a lack of public client experience in 'how to' implement different procurement delivery approaches, the current rigidity of the governmental tendering system, the lack of a real definition for a CM firm and the currently used type of contracts. Therefore, this research aims to develop a framework that can smoothly introduce BIM to the existing public procurement approach.

Figure 7.3: Interview analysis findings

According to Renner (2003), after conducting the interviews, three main questions should be answered as part of discussing the results. These are:

- What are the major lessons?
- What new things did you find?
- What will those who use the results be most interested in knowing?

7.8.1 What are the Major Lessons?

- BIM implementation in Jordan should be a top-down approach, and the government should address BIM at a strategic level. The lack of government support and availability of BIM standards and guidelines are among some of the hurdles to a higher level of BIM adoption in Jordan. The clear message was that in the absence of attention from policy makers and the government, construction companies are not interested in adopting BIM.
- BIM is mostly used in the design phase for visualisation and clash detection. On the other hand, BIM has not been used for performance assessment in the pre-completion and post-completion phases.
- BIM practitioners have started to realise the BIM benefits in delivering public buildings in Jordan. Enhancing sustainability performance, providing coordinated design drawings and limiting cost uncertainty is among the perceived benefits of BIM.
- Two fragmented BIM processes have been identified. BIM is used in the design phase only, and two separate BIM models are built in the design and construction phases by the consultants and contractors.
- The adopted procurement approach is seen by the three stakeholders as the reason why there are such fragmented BIM processes. In addition, the current procurement approach is considered to be one of the major challenges and barriers to effectively implementing BIM in the public sector in Jordan. Most of the participants stated that the chosen procurement approach does have a direct impact on the success of BIM implementation; by contrast, the others felt that to fully implement BIM and to gain the full benefits of BIM, a procurement approach that enhances collaboration between stakeholders is needed. DB and IPD are considered by the interview participants as the closest fit with BIM implementation.
- DBB, DB and CM are the procurement approaches adopted in the Jordanian public sector. DBB is the dominant approach for delivering public building projects in Jordan, according to the interview participants. The reasons for using DBB are:

1. The culture of the construction industry.
2. The existing rigid system in the governmental tendering procedures, explained by interview participants as relating to the need for the public sector to be

accountable to the public, and thus have an open competitive bidding process where the awarding criteria is based on price only.

3. The lack of experience and knowledge on how to apply other procurement approaches.
4. Few construction companies have in-house design teams to deliver the DB procurement approach.
5. There is no real definition of a CM firm.
6. The contract form itself, which is based on the FIDIC contract, deals with the main contractor, the engineer (the designer and supervision) and the owner (the government).

- Time, cost and quality are the most frequently used metrics when delivering public buildings in Jordan. On the other hand, sustainability is important. However, it is still optional.
- The main cause for the performance gap is the unclear public client requirements, resulting in significant changes during the design phase.

7.8.2 What New Things Did You Find?

- The procurement approach has a significant effect on BIM implementation and achieving sustainability in the public sector in Jordan.
- The main six contractual procurement factors that affect sustainability outcomes are: highlighting sustainability in the project brief as a primary aim; integrating sustainability requirements into the contract specifications and conditions (including specifying any project-specific sustainability requirements); emphasising the importance of sustainability in the tender evaluations and selection procedures; the requirements and incentives for the supply side to demonstrate their commitment to sustainable development through policy and implementation; requiring the supply side to demonstrate their capability in delivering sustainability requirements; and encouraging the tenderers to suggest innovative solutions and approaches that support the public client’s overall sustainability objectives.

7.8.3 What Are those who Use the Results Most Interested in Knowing?

- The adopted fragmented BIM processes are followed because of the adopted procurement approach (DBB), rigid tender procedures, permit loop including JEA, JCCA, MPWH, CCD and the Amman municipality and the lack of contractors' BIM competency.

- Changing the procurement approach for an increased level of collaboration between the stakeholders was considered by the participants as a critical step towards implementing BIM. The DB approach is seen as the optimal procurement approach for implementing BIM. However, the clear message from the key BIM practitioners in the public sector is that a fundamental change to a more collaborative procurement approach is not possible due to technical, cultural and economic issues. Barriers to implementing the DB approach were raised by the participants:

1. lack of construction companies that can design and construct in Jordan;
2. contractors tend to hire an external consultant team and work together; and
3. public clients lack involvement in the design and construction phases.

- CM was applied only to a few complex projects (see Figure 6.11 and Table 7.2). The reasons for not implementing CM are:

1. lack of public client experience in 'how to';
2. rigid system in tendering in the governmental tendering procedures;
3. no real definition of a CM firm; and
4. type of contract used.

- The effect of the current procurement approaches and processes for BIM implementation in the Jordanian public sector are:

1. lack of procurement processes for BIM implementation;
2. unclear roles and responsibilities in BIM-based projects in the public sector in Jordan;
3. late stakeholder involvement, a lack of contractor involvement in the design phase and assigning two different consultant teams for the design development and construction supervision;
4. rigidity of the tender process;
5. limited pre-qualification list; and
6. unclear guidance on the necessary BIM level of development (LOD) over the project lifecycle.

- The suggested measures to overcome some of the issues associated with the current procurement approach that affect BIM implementation are as follows:

1. appointment of experienced consultants and contractors;

2. establishment of BIM units inside the contractor organisation, and being involved in the development of the design;
3. conducting BIM meetings to overcome the coordination and communication problems; and
4. national training efforts in BIM processes.

- The adopted procurement approach is considered to be one of the major barriers to sustainability practices in the public sector in Jordan due to late contractor involvement and the focus on the lowest price bid.

7.9 CHAPTER SUMMARY

This chapter is one of two chapters on the data analysis. In Chapter 6, the desire for the public clients, consultants and contractors to use BIM to deliver public projects has been verified. However, the focal point of the survey was to ascertain BIM feasibility for the public building sector in Jordan and to identify the BIM implementation barriers. The current public procurement strategy was one of the major barriers and was ranked at number two after the 'additional resources and expenses'. Therefore, this chapter provided an analysis of the findings from the interviews undertaken as Phase 2 of the research, outlined in the methodology section in Chapter 5. It has focused on BIM implementation in the Jordanian construction public sector through the lens of the construction procurement strategy. The main construction procurement issues that affect BIM implementation have been identified. Changing the current procurement approach to a more collaborative and integrated approach, such as DB, CM and IPD, is required. However, the interview participants argued that this is not possible due many reasons such as lack of public client experience in 'how to', and rigid system in tendering in the governmental tendering procedures. Therefore, a framework that tackles the current procurement approach issues is necessary. The next chapter will present the framework development, validation and discussion.

CHAPTER 8: FRAMEWORK DEVELOPMENT, VALIDATION AND DISCUSSION

8.1 INTRODUCTION

The sustainability performance of buildings, particularly in developed countries, has been the subject of considerable research including the sustainable design process, tools for sustainable assessments of buildings and building design regulations (see Section 2.4.4). However, research on achieving sustainable buildings through a project management approach is still lacking. Far less research has focused on these issues for developing economies, particularly in the Middle East. For example, public buildings in Jordan have been criticised due to their poor performance in terms of their sustainability and the problems associated with the time, cost and quality of construction (see Section 2.5.2.4). This research investigated BIM implementation and procurement approaches from a project management point of view to identify and explore their effect in delivering sustainable buildings in the context of Jordan.

In Chapter Three, the 'Sustainable BIM Triangle' was introduced which suggests that BIM adoption and implementation support sustainability in the different project phases, from planning to demolition in addition to a sustainability assessment. However, in order to implement BIM, the procurement approach has to be outlined in advance, as clearly stated in many governmental construction strategies and standards. Therefore, the deployment of a construction procurement approach that supports BIM implementation in a specific context represents a major concern (see Section 3.5.2). Reviewing the literature revealed two main viewpoints in dealing with this concern:

- A profound procurement change is necessary for BIM implementation (Volk et al., 2014), particularly to deliver the necessary collaborative platform that brings together multiple stakeholders over the project lifecycle (Pcholakis, 2010; Laishram, 2011). Therefore, it has been stated that clients are likely to change the way that they procure buildings when implementing BIM to ensure a more integrated and collaborative working process (Foulkes, 2012). IPD was hailed as the ideal procurement approach that allows the project stakeholders to achieve 'full BIM collaboration' (Cleves and Dal Gallo, 2012) and efficient BIM-based processes.

- Others have argued that profound changes and transforming the construction industry radically to a BIM-enabled collaborative project environment are a challenging task (Howard and Bjork, 2008). Therefore, a common misconception has been identified by many researchers on the need to change the entire construction practices at once to adopt BIM practices (Kim, 2014). Instead, researchers recommend identifying work processes to develop a framework for BIM implementation that synchronises with the currently adopted procurement process in a specific context (Porwal and Hewage, 2013; London et al., 2008).

In the context of the Jordanian public sector, the interview participants agree with the latter argument due to the issues associated with changing the entire procurement approach, as mentioned in Section 7.4.1. The traditional procurement approach is the main one for delivering public buildings in Jordan. Therefore, this research proposes a framework for better BIM implementation under the traditional procurement approach with an emphasis on sustainability performance.

8.2 FRAMEWORK DESIGN AND DEVELOPMENT

8.2.1 Aim of the Framework

The proposed framework aims to deliver a more effective BIM implementation under the currently adopted procurement approach in the public sector in Jordan with an emphasis on sustainability performance. In particular, the proposed framework is applicable at the strategic or rather project management level for delivering public buildings in Jordan. Therefore, the content of the proposed framework will be of particular interest to project managers working public clients (represented by the MPWH and GTD), public consultants and public contractors. It is expected that the proposed framework will assist the key stakeholders in public construction to overcome the existing construction procurement issues that hinder the effective implementation of BIM, and thus sustainability. Moreover, the framework may be of interest to the private sector when it comes to implementing BIM.

8.2.2 Framework Development Methodology

The problem-solving approach has been adopted to develop the proposed framework. This approach is used to explore and understand the means for minimising the issues in view of a certain situation. This approach aims to address a specific situation in which what is happening is less than desirable, and it intends to rectify it (Straker, 1995). One of the simplest techniques to explain this approach is through the DRIVE technique (see Table 8.1). This technique has been successfully implemented in construction (Gamage, 2011; Serpell and Alarcon, 1998). A Construction Process Improvement Methodology (CPIM) was developed by Serpell and Alarcon (1998) to improve the construction processes, which is based on these DRIVE techniques. It was also demonstrated by Serpell and Alarcon (1998) that the successful implementation of the developed methodology would improve the project-related process performance.

Table 8.1: DRIVE techniques (DTI,n.d)

Define	The scope of the problem and the criteria by which success will be measured, and the agreed upon deliverables and success factors
Review	The current situation, understanding the background, identifying and collecting information about the performance, identifying problem areas, improvements and 'quick wins'
Identify	The improvements or solutions to the problem, and the required changes to gain and sustain the improvements
Verify	The improvements bringing about benefits that meet the defined success criteria, prioritising and piloting the improvements
Execute	The implementation of the solutions and improvements, planning a review, gathering feedback and reviewing

The key principles of the DRIVE technique and CPIM methodology are diagnosing the current issues (that is whether the current practices are less than desirable), and to identify and propose improved measures. These principles will be discussed in detail in the following section.

8.2.3 Framework of the Themes' Development

This section provides an overview of the framework of the development of the themes at the various stages. This research adopted a problem-solving approach as a methodology to develop the framework. Two main points are discussed below. Firstly, the key construction procurement attributes and challenges identified by analysing the literature and the interviews with the key BIM practitioners in the public sector in Jordan. Secondly, the proposed solutions to the challenges were identified from the interview analysis and the literature. This section is concluded by the development of certain framework themes, as shown in Table 8.4.

Key challenges for effective BIM implementation and enhancing sustainability outcomes in the public sector in Jordan

Table 8.2 represents the key findings on the implications of construction procurement for BIM implementation and enhancing sustainability. The first column represents the key construction procurement attributes necessary for effective implementation of BIM and enhancing sustainability (see Sections 4.3 and 4.5). The second column represents the key challenges of the current construction procurement approach that affect BIM implementation and the capacity to enhance sustainability in the public sector in Jordan, as discussed in the interview analysis (see Section 7.5.3).

Table 8.2: Key procurement attributes and challenges for effective BIM implementation and enhancing sustainability performance in the public building sector in Jordan

After the literature review	After the interviews
● Integrated design process. ● Clear roles, responsibilities and communication lines. ● Early key stakeholder involvement ● Team technology- and sustainability-based competency. ● Levels and methods of communication. ● Integrated project teams consisting of client, designers and constructors. ● Compatibility with the project groups' 'team characteristics'. ● Common goals and collaborative decision-making. ● Iterative design process of modelling and reappraisal.	● Lack of procurement processes for BIM implementation. ● Unclear roles and responsibilities. ● Late stakeholder involvement, lack of contractor involvement in the design phase and assigning two different consultant teams for the design development and construction supervision. ● Limited pre-qualification list. ● Rigidity of the tender process. ● Unclear guidance on the necessary BIM level of development (LOD) over the project lifecycle ● Lack of sustainability considerations in the procurement process.

Possible solutions for construction procurement challenges to improve BIM implementation and sustainability in the public sector in Jordan

A detailed analysis of the interviews is presented in Chapter 7. The design phase, as a consequence of producing poorly coordinated design drawings, is the main issue affecting the performance of the public buildings in Jordan in terms of cost, time, quality and sustainability (from the interviews). Moreover, environmental, economic and social sustainability also depends on the subject matter of design (Chong et al., 2017). Therefore, managing the design stages (using the RIBA stages 0-4) was the focus of the procurement framework development. The following are the proposed solutions to the issues stated in the above table to implement BIM effectively and enhance the performance of the public buildings in Jordan.

- **Lack of procurement processes for BIM implementation**

The literature was used in the framework development by identifying the features related to BIM, procurement and the sustainability processes. A clear structure and compatibility with the existing standards and practices are amongst the basic attributes in the proposed framework. Therefore, three British-based guidelines are used in developing the framework:

- The RIBA Plan of Work 2013 (RIBA, 2013).
- The RIBA Overlay BIM Plan of Work (RIBA, 2012).
- Green Overlay to the RIBA Plan of Work (2011).

These guidelines are used because of the lack of standards, regulations and guidelines specific to the JCI (AlKilani, 2012), the lack of standards, regulations and guidelines for BIM implementation in Jordan (see Sections 6.3 and 7.3.5) and the absence of rigid governmental actions, such as policies, strategies and plans for delivering sustainable buildings (Tewfik, 2014). On the other hand, the significant economic relationship between the Middle East and the UK has led to the dominance of British architects, consultants, contractors and project managers in that region (Gerges, 2016). Moreover, RIBA established an international chapter called the 'RIBA Gulf Chapter' for members in Jordan, UAE, Bahrain, Saudi Arabia, Kuwait and the Sultanate of Oman. This chapter is actively engaged with a diverse and very significant number of RIBA and non-RIBA practitioners to support and communicate with RIBA members overseas. It is believed that the RIBA has spread in popularity and lead to the increased adoption of the RIBA Plan of Work in Middle Eastern countries (RIBA Gulf Chapter, n.d). Furthermore, the interview participants demonstrated their knowledge and proficiency of the RIBA (2013) Plan of Work.

The RIBA Outline Plan of Work 2013 (RIBA, 2013) is used to establish the different work stages. The RIBA Overlay BIM Plan of Work (RIBA, 2012) is used to identify the core tasks and activities of BIM implementation. Finally, the Green Overlay to the RIBA Plan of Work (2011) is used to identify the key sustainability tasks.

- **Unclear role and responsibilities**

The existence of these unclear roles and responsibilities added to the lack of standards and regulations when implementing BIM, as mentioned in Section 3.4.2. The development of clear roles and responsibilities among the key project stakeholders for information exchange is important for employing BIM effectively (Kim, 2014). A framework has been proposed by Hjelseth (2010) for managing the project information for a BIM-based construction project (see Table 8.3). In this framework, the primary and secondary roles of the key project participants for each level in the BIM model were identified throughout the project lifecycle based on the International Organization for Standardization (ISO) 22263:2008 lifecycle stages. However, this framework is too broad to apply to a certain construction sector without customising the roles amongst the key project stakeholders; therefore, the key project stakeholder roles in the proposed framework were identified by Hjelseth (2010) and through the interviews to comply with the current working processes in the public sector in Jordan, and thus the local market in Jordan.

Table 8.3: Framework for key roles and responsibilities for a BIM-based project (Hjelseth, 2010)

BIM Orders	Phases	Roles	Lifecycle Stages
Demand BIM Draft	• Pre-project	• Owners (primary) • Architects (secondary) • Engineers (secondary) • Contractors (secondary)	• Portfolio requirements conception of need • Outline of feasibility • Substantive feasibility
Draft Model	• Pre-construction	• Architects (primary) • Engineers (secondary) • Contractors (secondary)	• Outline of the conceptual design • Full conceptual design • Coordinated design (and procurement)
Detailed Model	• Construction	• Contractors (primary) • Engineers (secondary)	• Production in formation • Construction

As-Built Model	● Post-construction	● Contractors (primary) ● Engineers (secondary)	● Operation
Facility Management	● Hand-over and use life	● Facility Manager	● Maintenance ● Disposal

- **Late stakeholders' involvement, lack of contractor involvement in the design phase and assigning two different consultant teams for the design development and construction supervision**

Late contractor involvement and procuring two different consultant teams for the design and supervision (in the construction phase) (see Section 7.5.3) are among the main criticisms for the current procurement approach for BIM-based projects in the public sector in Jordan. Involving the contractor in the design phase is necessary in order to overcome the existing fragmented BIM processes in Jordan, and thus being able to implement BIM more effectively and enhancing the public buildings' sustainability performance. The contractors started to establish BIM units inside their companies to work on BIM-based projects (see Section 7.6.4). This is due to the lack of public contractors' competency on BIM and also the increased demand for BIM implementation in the public sector in Jordan (see Sections 7.3.5.3 and 6.3).

The interview analysis revealed the need to involve the contractors' BIM units in the design stages on a fee basis due to the rigid tender system. This is because securing the contractors' involvement for the pre-contractual services on a competitive basis will assist in obtaining the necessary input on constructability, sequencing and subcontractor selection (ACIF and APCC, 2015) as well as providing the best solution in terms of the technology and availability of materials (taken from the interviews). The roles of responsibility for the BIM units are in consultation, the design review and feedback (see Section 7.6.4). Moreover, the early involvement of the contractor in the design stages will enhance the buildings' sustainability performance; Swarup (2011) clearly stated that "the constructor should be on board by the design development phase, contractually or informally" for successful sustainability outcomes. Moreover, Enache-Pommer and Horman (2009), Horman et al. (2006), Lapinski et al. (2006), 7 Group and Reed (2009), Riley et al. (2004) and Robichaud and Anantatmula (2011) stated that better outcomes would be achieved from the early involvement of the key participants. They also argued that the level of integration during the design stages would be increased by the contractor's early involvement.

No restrictions on the type of construction procurement approach were reported in the procurement regime in Jordan. The procurement regime is governed primarily by the Government Works Regulation No. (71) of 1986, issued pursuant to Articles 114 and 120 of the Constitution, and by the 'National Procurement Legislation'. However, as mentioned in Section 4.6, the technical services (consultants) and works' tenders (the contractors) are mentioned as separate stages. Therefore, these laws lean towards two separate agreements between the government-consultants and the government-contractors.

Therefore, this research proposes the use of a two-stage tender strategy under the traditional procurement approach to involve the contractors earlier in the design stage for effective BIM implementation in Jordan. A two-stage tender strategy is used when there is a need to involve the contractor early in the design phase, which was illustrated by the BIM practitioners in the public sector in Jordan for effective BIM implementation. Moreover, the two-stage tender strategy has been employed previously in the public sector in Jordan, but without implementing BIM (see Section 7.4.2) (Alkelani, 2012). On the other hand, completely changing the procurement approach to a DB one or to CM to involve the contractor early in the process also faces many challenges, as discussed in Section 7.4.1.

Other benefits related to adopting the two-stage tender strategy under the traditional procurement approach, according to Rawlinson (2006), include: focusing on issues of constructability and economical construction during the late design stages; achieving a more accurate final account and close to the contract sum as the second stage of the tender is based on better understanding the scope of the work and all the information; the ability to develop the design in conjunction with the main contractors and sub-contractors; enhancing the project risks identified within a timescale where action can be undertaken; and minimising the main contractual bidding costs.

The two-stage tender strategy can be used as part of the RIBA (2013) stages by involving the contractor early in the design stages, but where the first stage of the tender occurs during the RIBA stages 2 or 3 (Garner, 2014). Then, the preferred contractor joins the design team on a consultancy basis using PCSA to complete the design as a team before presenting a bid at stage 4.

- **Limited pre-qualification list**

Pre-qualification is an essential step in construction procurement, and it has a significant impact on project performance (Aje, 2012). As part of the public tender process for selecting consultants and contractors, pre-qualification was criticised by the interviewees for the limitations it has in assigning BIM consultants and contractors to implement BIM effectively (see Section 7.5.3). This led to the assignment of unqualified consultants and contractors that were biding low in order to win the projects with the intention of recovering their losses through possible claims and variation orders. Therefore, the proposed framework will tackle this issue by extending this list to include general information (the Jordanian government tender instructions, 1987), past project experience (Porwal, 2013), sustainability competency (Sourani, 2013) and the Project Information Plan (PIP) (see Section 7.6.5) (BSI, 2013). PIP includes a BIM assessment form, an IT assessment form and a human resource assessment form. This pre-qualification assessment list should be applicable to the consultant and contractor appointments. An example of BIM assessment form is in Appendix H.

- **Rigidity of the tender process**

The tender stage in the public sector in Jordan has been criticised for its rigidity. Therefore, the tender stage in the proposed framework must comply with the Government Works By Law no. (71) of 1986. Article 9 of this law states that the tender offers should be submitted as technical and financial offers. A technical tender includes general information, such as the method statement, the capabilities available, the staff and their CVs and a list of suppliers. The financial tender comprises the offered prices.

- **Unclear guidance on the necessary BIM LOD over the project lifecycle**

The BIM LOD for each stage in the procurement process is identified as an issue for effectively implementing BIM in Jordan (taken from the interviews). The LOD has been identified as an important and critical issue since it represents the model information at specific stages, and it is linked to the practical application of BIM (Wu and Issa, 2014). Moreover, it is important to identify the required LODs for procuring the project team (interview analysis). Therefore, the BIM model LOD over the RIBA stages were adopted from the literature and included in the proposed framework (AIA, 2013; CIC, 2013). The different LODs were described in Section 3.2.5.4.

- **Lack of sustainability considerations in the procurement process**

Despite the importance of embedding sustainability into the procurement process, the academic literature is lacking (Preuss, 2009), especially in the public sector (Brammer and Walker, 2011). One of the first and most important studies was conducted by Sourani (2013) with a view to enabling the public client to better address sustainable construction in developing procurement strategies. Nine factors were identified, and 6 out of the 9 factors were found to be important when implementing public projects in Jordan to enhance and achieve sustainable building projects (see Section 7.7.4.2). These factors are used for the development of the proposed framework

Moreover, the interview participants added the requirement of having an iterative process of modelling and reappraisal at the design stage to achieve an integrated and optimal design, and thus enhance the buildings' sustainability (see Section 7.7.4.2). This is confirmed by the suggestions by Masterman (2002), Bower (2003), Hamza and Greenwood (2007) and HEEPI, SUST and Thirdwave (2008).

As a result, Table 8.4 represents the framework development themes for the public sector in Jordan taking into consideration all of the above possible solutions that were identified from the interviews and the literature.

Table 8.4: Framework development for the public sector in Jordan

<table>
<tr><td colspan="6">Framework themes</td></tr>
<tr><td>Work Stages (RIBA, 2013)</td><td>Stage 0: Strategic Definition</td><td>Stage 1: Preparation and Brief</td><td>Stage 2: Concept Design</td><td>Stage 3: Developed Design</td><td>Stage 4: Technical Design</td></tr>
<tr><td>Tasks identified based on the interview analysis and modified based on RIBA Overlay BIM Plan of Work (RIBA, 2012), the Green Overlay to the RIBA Plan of Work (2011), the building design management (Gray and Hughes, 2001) and early BIM partnering (Porwal and Hewage, 2013)</td><td colspan="2">● Statement of needs
● Business case development
● Brief development
● Identify project targets
● Develop architecture reference model</td><td colspan="3">● Pre-start up BIM meeting
● Development of concept design
● Sustainability and area analysis
● Start-up BIM meeting
● Prepare developed design
● Prepare technical design
● Conduct BIM model analysis
● Correct BIM model errors</td></tr>
<tr><td>Sustainability contractual factors in the public sector in Jordan identified by the literature (Sourani, 2013) and the interview analysis</td><td colspan="5">● Highlighting sustainability in the project brief as a primary aim
● Integrating sustainability requirements into contract specifications and conditions (including specifying any project-specific sustainability requirements)
● Emphasising the importance of sustainability in tender evaluations and selection procedures
● Requirements and incentives for the supply side to demonstrate a commitment to sustainable development through policy and implementation
● Requiring the supply side to demonstrate the capability of delivering sustainability requirements
● Encouraging tenderers to suggest innovative solutions and approaches that support the client’s overall sustainability objectives</td></tr>
</table>

Work Stages (RIBA, 2013)	Stage 0: Strategic Definition	Stage 1: Preparation and Brief	Stage 2: Concept Design	Stage 3: Developed Design	Stage 4: Technical Design
Key stakeholder involvement for BIM -based projects identified by the literature (Hjelseth, 2010) and the interview analysis	● Public client (MPWH, PS and PM) ● BIM consultants (the designers)		● Public client (MPWH and PM) ● BIM consultants (the designers) ● The contractor BIM Units (the preferred contractor)		
BIM LOD (AIA, 2013; CIC, 2013)	LOD 100		LOD200	LOD 300, LOD 350	
Two-stage tender strategy (RICS, 2014)			Tender stage 1	Tender stage 2 at the end of RIBA stage 4	

8.2.4 Framework Structure

This section is focused on the methodology of building the proposed framework based on Table 8.4. According to Arora and Johnson (2006), a framework is defined as a set of processes created to achieve a set of goals. Four main steps have been identified by Arora and Johnson (2006), which are:

- the project boundaries and confinements to be defined;
- the first step in the process is the first boundary;
- the last step in the process is the last boundary; and
- all major steps between the first and last are to be identified.

Arora and Johnson (2006) believed that creating a sequential process within a framework is to document and describe the process, generate ideas about improvement, determine the best method and train others. RIBA is used for modelling the processes under the proposed framework. The RIBA Plan of Work follows a descriptive approach to describe the way a construction process should be organised and managed (Hughes, 2003). This kind of approach has been adopted by many researchers for mapping the construction process (Edel and Christenson, 1967; Ahuja and Nandakumar, 1985; London et al., 2008). Zanni (2017) argues that this descriptive model can be used as a framework which focuses on the procurement approaches. Therefore, the RIBA Plan of Work (2013) stages is used to model the proposed framework.

This research defines construction procurement as a set of tasks that govern the activities undertaken by the client, consultants and contractors to plan, design, assess, purchase and construct projects to deliver the required end-product to the client (see Section 4.2.1). Therefore, the structure of the proposed framework constitutes three main vertical axes: the procurement tasks, key stakeholders' involvement and responsibilities and additional information with the intention of solving any procurement issues in the public sector in Jordan. All three axes are aligned with the RIBA (2013) stages (see Figure 8.1).

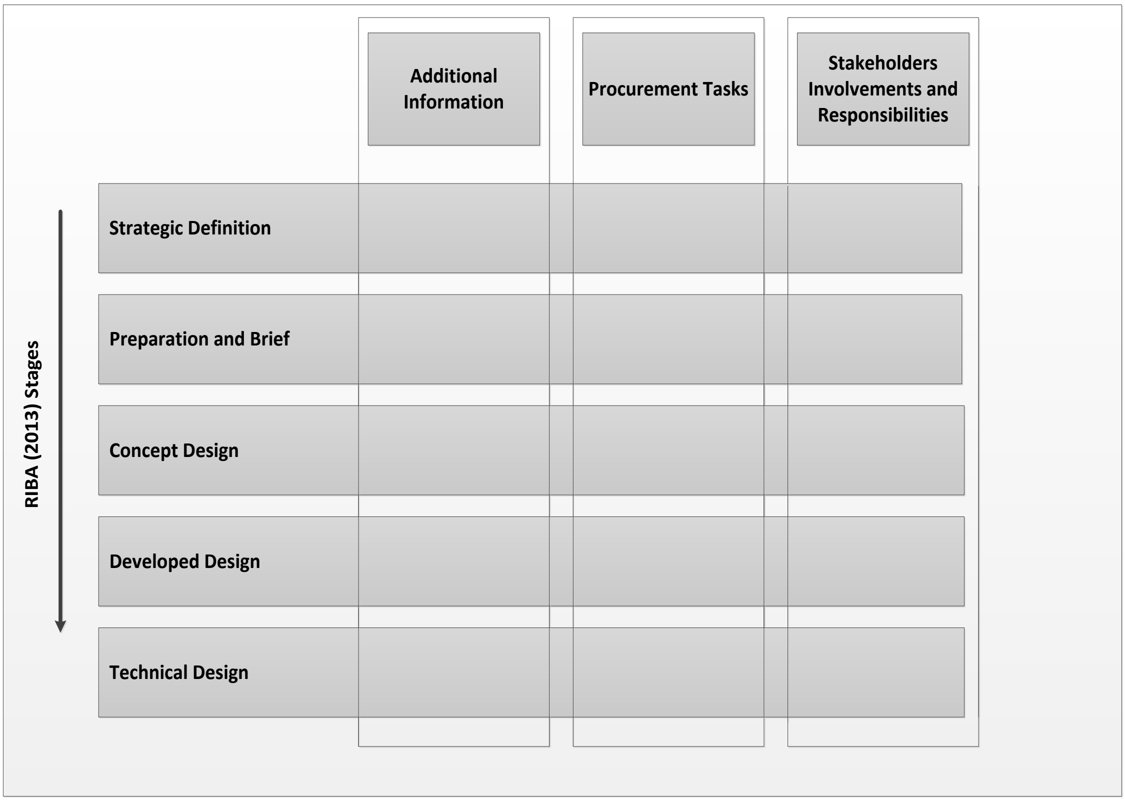


Figure 8.1: The conceptual framework

The tasks axis is based on the current procurement tasks, as stated by the interview participants in Table 7.4. This is because the aim of the framework is to improve the implementation of BIM and enhance sustainability under the currently adopted construction procurement. However, this tasks list has been modified and includes tasks related to BIM and sustainability. This modified list is based on the interview analysis, the RIBA Overlay BIM Plan of Work (RIBA, 2012), the Green Overlay to the RIBA Plan of Work (2011), Gray and Hughes (2001) and Porwal and Hewage (2013). These references were used for their relevance to the scope of this research. As a result, the following tasks were added:

- architecture reference model development;
- pre-start up BIM meeting;
- sustainability and area analysis;
- start-up BIM meeting;
- conduct BIM model analysis; and
- correct BIM model errors.

The tasks axis also includes procuring the project team: the consultants and contractors. As stated in Table 8.4, this research proposed the use of a two-stage tender strategy under the traditional procurement approach to tackle the issue of late contractor involvement. These stages in addition to the consultants' appointment need to comply with the adopted tender procedures followed by the public sector in Jordan. Therefore, the pre-qualification procedures were adopted for the consultants' appointments and the first-stage contractor appointment. The contractor appointment in the second-stage tender is based on negotiation. Table 8.5 represents the procurement tasks in addition to the stakeholders' involvement and responsibilities.

Table 8.5: Procurement tasks and stakeholders' involvement and responsibilities

Framework		
Stage (RIBA, 2013)	**Tasks**	**Stakeholder involvement and responsibilities**
Stage 0: Strategic Definition	● Develop a statement of requirement ● Develop a full business case	● PS ● MPWH/PM
Stage 1: Preparation and Brief	● Develop an outline of the project brief ● Set project targets ● Prepare a 'request for proposal' document ● Prequalification list ● Choose based on the lowest price ● Assigning BIM consultants	● MPWH/PM
	● Architect BIM model development LOD 100	● Architect BIM ● MPWH/PM to approve
Stage 2: Concept Design	● Pre-start-up BIM meeting ● Develop a BIM model LOD 200 ● Sustainability and area analysis	● BIM consultants ● MPWH/PM
	● BIM design model development LOD 200 and early sustainability analysis	● BIM consultant ● MPWH/PM to approve

Stage 3 & Stage 4: Developed Design and Technical Design	● Prepare 'request for proposal' document ● Prequalification list ● Choose based on the lowest price ● Assigning a contractor BIM unit in the pre-contractual agreement basis	● BIM consultants ● MPWH/PM
	● Start-up BIM meeting	● MPWH/PM ● BIM consultants ● Contractor BIM units
	● BIM design model development LOD 300-350 to meet the project brief	● BIM consultants ● Prefer bidder contractor BIM unit to consult, advice and give feedback. ● MPWH/PM to approve
	● Construction award based on the negotiation process	● MPWH/PM

The additional information axis includes information connected to the main procurement tasks in the task axis. The reason for this is to explain and/or describe the main procurement tasks, and to add any additional information related to BIM implementation. This additional information is based on the literature and interview analysis to solve the current procurement issues that affect BIM implementation, and thus hinder sustainability in the public sector in Jordan; these are shown in Table 8.4 and include the following:

- BIM core activities recommended by the RIBA BIM Overlay (2012);
- key tasks recommended by the Green Overlay to the RIBA (2011);
- BIM model LOD;
- procurement sustainability factors;
- tender procedures according to the Jordanian Government Tender Instructions pursuant to Article (16) of the Government Works By-Law No. (71) of 1986;
- extended pre-qualification list; and
- BIM model analysis.

The final proposed framework is presented in Figure 8.2. It includes all three main axes modelled using the RIBA (2013) stages. The tasks should be executed in the sequence that they are presented. Therefore, the links between the tasks are interrelated; task 3 cannot take place before task 2. This applies throughout the framework.

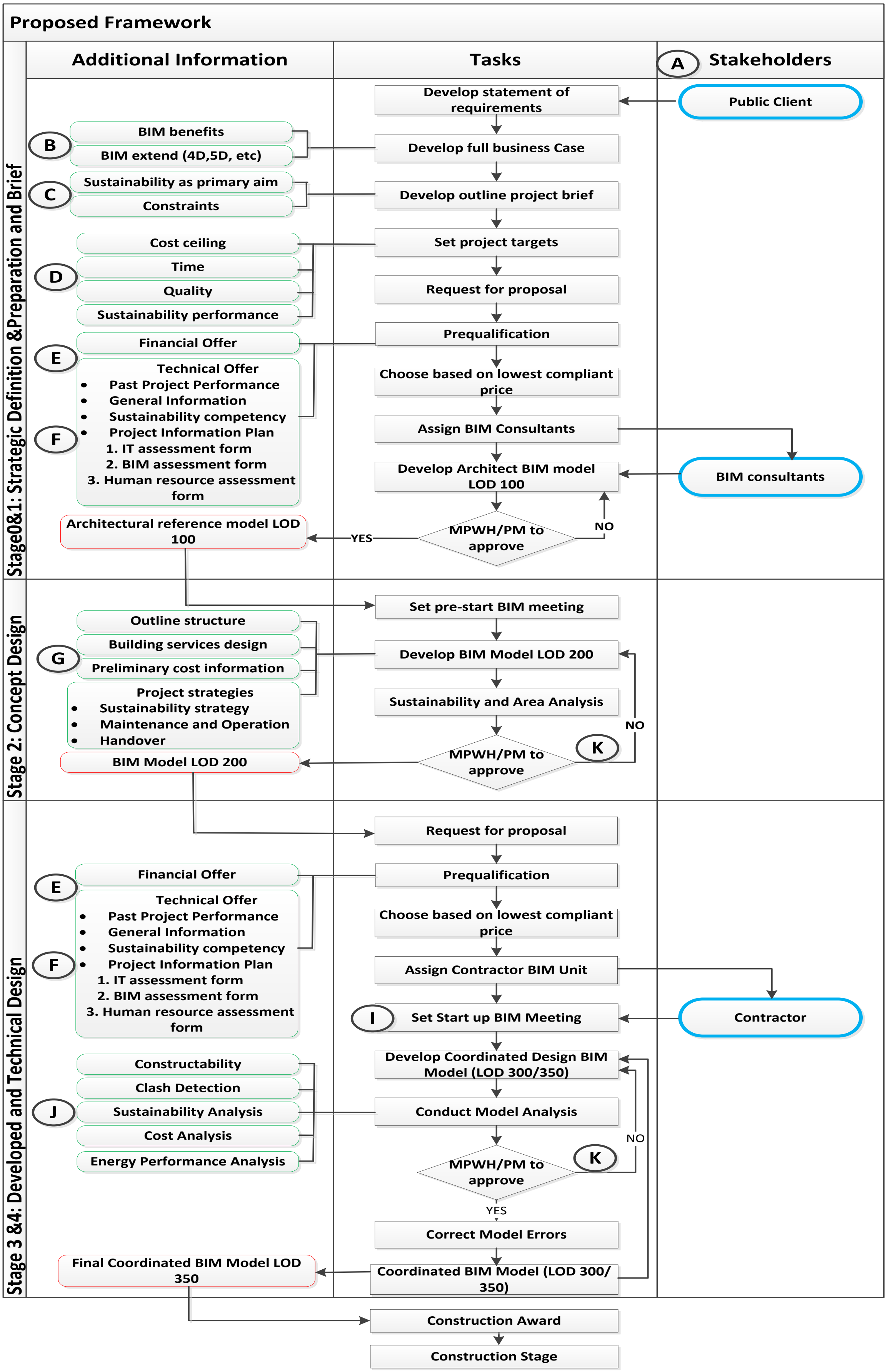


Figure 8.2: The proposed procurement framework for delivering public buildings in Jordan

Table 8.6 illustrates the meaning of the symbols, abbreviations, research methods and provides a description of the references used in the framework.

Table 8.6: Framework key and references

References	**Research methods**	**Description of reference**
A	I and LR	Described in the stakeholder involvement (see Table 7.4.3) (Hjelseth, 2010)
B	LR	Core BIM activities recommended by the BIM Overlay to the RIBA Outline Plan of Work (RIBA, 2012)
C	I and LR	Key tasks recommended by the Green Overlay to the RIBA Outline Plan Work (RIBA, 2011; Sourani, 2013) and sustainability as the primary target in the project brief, as stated in Section 7.7.4.2
D	I and LR	Identified in Section 7.7.3 (Sourani, 2013)
E	I and LR	Financial and technical offers described in Section 7.4.2, and the Government Tender Instructions, pursuant to Article (16) of the Government Works By-law No. (71) of 1986
F	I and LR	Described and stated in Section 7.6.5 (the interview analysis) (BSI, 2013; Porwal, 2013; Sourani, 2013)
G	LR	Information exchange (RIBA, 2013)
I	I and LR	Discussed in Section 7.6.3 (Porwal, 2013)
J	LR	(Porwal and Hewage, 2013)
K	LR	The iterative process of modelling and reappraisal to achieve an integrated and optimal design (Masterman, 2002; Bower, 2003; Hamza and Greenwood 2007; HEEPI, SUST and Thirdwave, 2008)

Key: LR: Literature Review, I: Interviews

Next Process Task: → Relationship: —

Task: ▭ Additional information: ▭ Stakeholders: ⬭

Stakeholders keys

Public Client	**BIM consultants**	**Contractor**
MPWH	BIM manager	Preferred bidder
Project manager (internal of external)	Architect	Awarded contract
Project sponsor (PS)	Other consultants	

8.3 MAIN FRAMEWORK COMPONENTS FOR IMPROVING BIM IMPLEMENTATION AND ENHANCING SUSTAINABILITY OUTCOMES

A large portion of the building sector in Jordan especially the public buildings suffer from sustainability performance issues (FFEM and ANME, 2010). The importance of the building sector is that it accounts for 33% of the final energy consumption in Jordan (UNEP, 2007) and consumes a significant amount of the available water in a country that is considered to be one of the world's most water stressed countries (Kisbi, 2011). Therefore, delivering sustainable buildings becomes a key target (RSSJ and FES, 2013).

BIM was identified as a promising solution in terms of improving sustainability and meeting the global need for sustainable buildings (Kumanayake and Bandara, 2012). Moreover, BIM was also identified as being at the core of sustainability by BIM practitioners in Jordan (see Section 7.3.4). However, BIM is mostly used for basic functions in the Jordanian public sector such as visualisation and clash detection (see Section 7.6.2.5). To achieve effective BIM implementation and enhance building sustainability, the level of integration should be taken into consideration. The time of the participants' involvement and team characteristics are some of the main attributes for enhancing this integration.

8.3.1 Timing of the Contributors' Entry to the Framework

In Chapter 6, the questionnaire respondents verified that the procurement approach is among one of the major barriers to implementing BIM. In Chapter 7, the interview participants claimed that the main procurement attribute that contributes to effective BIM implementation and thus improving the buildings' sustainability in Jordan is the early involvement of the contractor in the design stage. However, they also expressed the view that the public client does not accept contractually bringing the contractors into the design phase because of the culture of procurement in Jordan. On the other hand, it was suggested that the contractors be enrolled on a PCSA basis through a contractor BIM unit. Therefore, the contractor is hired through the means of a two-stage tender process under a traditional procurement approach to enhance team integration, and thus also sustainability performance.

8.3.2 Team Characteristics

In Chapter 7, the interviewees stated that prequalification is part of the current tender procedure in the public sector in Jordan. It is also one of the most popular procedures worldwide (Plebankiewicz, 2009). However, the prequalification procedure in Jordan has been criticised due to its limiting list, which has a direct effect on the effective implementation of BIM and achieving sustainability. Therefore, this framework proposes a pre-qualification list suggested by the interview analysis and the literature review to appoint BIM and sustainability qualified consultants and contractors. This list includes BIM and IT assessment forms, and it assesses the bidders based on their sustainability competency through:

- emphasising the importance of sustainability in the tender evaluations and selection procedures;
- requiring the tenderers to demonstrate a commitment to sustainable development through policy and implementation;
- requiring the tenderers to demonstrate their capability in delivering sustainability requirements; and
- requiring the tenderers to suggest innovative solutions and approaches that support the client's overall sustainability objectives.

8.4 FRAMEWORK VALIDATION

8.4.1 Validation Aim and Objectives

Refinement and examination of the proposed framework suitability for the public building sector in Jordan is the aim of the framework validation phase. Validity and reliability as well as identifying further gaps that can improve the proposed framework were the basis for the validation process objectives. These objectives are:

- to determine if the framework is reliable and valid;
- to verify if the framework can be implemented under the governmental procurement regime in Jordan;
- to identify possible gaps in the framework;
- to examine the appropriateness and practicalities of the RIBA (2013) stages;
- to elicit areas for improvement for the proposed framework.

8.4.2 Validation Process and Respondents' Profile

The framework validation includes two stages (see Figure 8.3). In the first stage, discussions were undertaken with three researchers at the University of Portsmouth that have experience and knowledge in the construction industry in the Middle East and Jordan. The aim of these discussions was to refine the developed framework before the actual validation process. The second stage (the actual validation process) was conducted through validation interviews with experts in the public construction sector in Jordan in order to examine and refine the suitability of the proposed framework for the public building sector in the country. A focus group approach was considered; however, the researcher could not gather all the participants at the same place and time. Therefore, semi-structured interviews were used.

Validation process and tools	Points to validate	Outcomes
Pre-validation discussions: - Interviews' questions refinement - Proposed framework - Participants: three construction management researchers with experience in the Middle East and Jordan construction industry	**Proposed framework refinement:** - Structure and language of the framework - Information flow clarity - Content clarity - Suggestions for improvement	**Outcome:** - The proposed framework is ready for the semi-structured validation interviews
Semi-structured validation interviews: - Participants: seven interviews with a BIM regional manager, a BIM manager, a contract manager, a project manager, a construction manager and a tender manager - Proposed framework - Table 8.6 and 8.7 without responses	**Refine and examine the validity and suitability of the framework** - Clarity of the structure - Information flow clarity - Facilitating public buildings delivery in Jordan - Implementation under existing public procurement systems - The applicability of the RIBA plan of work stages (2013) in Jordan - Facilitating BIM implementation - Best to own the framework - Suggestions for improvement	**Outcome:** - The framework has a clear structure and information flow - The framework facilitates the delivery of public buildings in Jordan - The framework can be implemented under the existing public procurement systems - RIBA plan of work stages (2013) are applicable in Jordan and it was used before - The framework was found to be able to facilitate BIM effectively in the public sector in Jordan. However, some concerns were raised and discussed in Section 8.5.4. - The best entity to execute the framework and to own the BIM models is MPWH

Figure 8.3: Validation process map

The BIM feasibility study (in Phase One of the data collection) identified the BIM practitioners (29 responses) in the public Jordanian construction sector, and they were contacted for interviews. 12 experts responded and were part of the interviews (in Phase Two of the data collection) (see Section 7.1.2). In order to gather wider views on the proposed framework, and to give it more validity and reliability, all the 29 respondents who stated that they had used BIM in delivering public buildings in Jordan were contacted to participate in the validation stage (the final phase of the study). This is because the validation process can involve the respondents who participated in the first place in the research (Patton, 1990; Lincoln and Guba, 1985). 7 out of the 29 respondents agreed and were available to take part in the framework validation process, and four of the seven were also part of the main interviews (in Phase Two of the data collection) (see Table 8.7).

Table 8.7: Validation participants

Company size	Participant	Company	Position	No. of years' experience	Size of the project
S	P1	Public client/ GTD	Tender manager	24	1-50 million JD
M	P2	Public client/ MPWH	Project manager	8	1-150 million JD
S	P3	Consultant	Project manager	22	1-50 million JD
M	P4	Consultant	BIM manager	8	20-100 million JD
S	P5	Construction management	Construction manager	45	5-200 million JD
S	P6	Contractor	BIM regional manager	9	20 million - 4.5 billion JD
M	P7	Contractor	Project manager	13	1-50 million JD

8.4.3 Findings from the Validation Interviews

Semi-structured validation interviews were used for obtaining in-depth data and a statistical analysis to improve the framework. In order to achieve the validation interview aim and objectives, the proposed framework (see Figure 8.1) was sent to the interviewees before asking the questions. Two sets of questions were used: closed-ended ones requiring an answer of yes or no, as shown in Table 8.8, and open-ended questions, as shown in Table 8.9. Seven interviewees responded, and they indicated and agreed that the proposed framework is useful and is a good stepping stone towards integrating BIM under the existing procurement approach to deliver sustainable public buildings in Jordan. A summary of the responses from the respondents in the validation phase from the closed-ended questions are shown in Table 8.8 whereas Tables 8.9 to 8.15 represent the validation responses on the open-ended questions for each of the validation participants.

Table 8.8: Summary of the results of the framework validation

Questions	P 1	P 2	P 3	P 4	P 5	P 6	P 7	Total
Does the framework have a clear structure?	1	1	1	1	1	1	1	7
Does the framework have a clear information flow?	1	1	1	1	1	1	1	7
Does the framework facilitate delivering public buildings in Jordan?	1	1	1	1	1	1	1	7
Does the framework facilitate BIM implementation in the public sector in Jordan?	1	1	1	1	1	1	1	7
Does the framework have the potential to enhance public buildings' sustainability performance?	1	1	0	1	1	0	1	5
Can the framework be implemented under the current public construction procurement systems?	1	1	1	1	0	1	1	6
Does the framework have clear procurement processes?	1	1	1	1	1	1	1	7
Does the framework have the potential to overcome the poorly coordinated design in the public sector?	1	1	0	1	1	1	1	6
Are the RIBA (2013) stages applicable in Jordan?	1	1	1	1	0	1	0	5
Should the project manager have a leading role in implementing the framework?	0	1	0	1	0	0	1	3
Pn (n=1-7) = Participants (BIM regional manager, BIM manager, contract manager, project manager, construction manager and tender manager) Yes= 1 and No= 0								

Table 8.9: Validation questions and results (P1)

Validation Findings						
Is this framework useful to you? Please give your reasons.	**Who should take ownership of this framework?**	**Under what circumstances would you use the framework?**	**How would you compare this framework to current BIM approaches in Jordan?**	**Is there anything missing in the content of the procurement processes, BIM implementation and sustainability considerations?**	**How can this framework be improved?**	**Points to consider.**
Yes, It provides guidance for procuring consultants and contractors for BIM-based building projects.	The GTD.	It can be used to guide the Governmental Tender Department (GTD) on the process of delivering public buildings using BIM.	There is no specific process for BIM implementation. However, in the public sector BIM has been mostly used in the design phase only for visualisation and clash detection.	The procurement process: Consultants (the designers) and contractors are appointed through two approaches: request for proposal or direct award depending on previous performance; this should be included in the framework.	The one-stage tender should be with the contractor organisation and not a specific unit (a contractor BIM unit). However, the existence of such a unit in the contractor organisation can be treated as an essential requirement for them to bid for projects.	The framework can guide the public major stakeholders on the required LODs. Is there a need to change or amend the contract form for BIM implementation?

Table 8.10: Validation questions and results (P2)

Validation Findings						
Is this framework useful to you? Please give your reasons.	**Who should take ownership of this framework?**	**Under what circumstances would you use the framework?**	**How would you compare this framework to current BIM approaches in Jordan?**	**Is there anything missing in the content of the procurement processes, BIM implementation and sustainability considerations?**	**How can this framework be improved?**	**Points to consider.**
Yes, It is a step in the right direction for increasing BIM awareness.	The project manager as the representative of MPWH.	As a design tool to guide the key stakeholders during the design phase.	Limited opportunities are offered from the current BIM approaches as BIM implementation is supposed to generate more accurate project schedules and costs. Many contractors tend to bid low to win the project and then raise VOs to get money back at the end of the construction work. Therefore, involving the contractor in the design phase during the implementation of a BIM-based design model will minimise such issues.	The BIM process: Who manages the various BIM models?	Identify who executes the framework.	BIM should be part of the contract documents. How have interoperability issues been tackled? Consultants (the designers) should be appointed as consultants (or as supervision) in the construction phase. How have ownership and copyright of the model information been tackled?

Table 8.11: Validation questions and results (P3)

Validation Findings						
Is this framework useful to you? Please give your reasons.	**Who should take ownership of this framework?**	**Under what circumstances would you use the framework?**	**How would you compare this framework to current BIM approaches in Jordan?**	**Is there anything missing in the content of the procurement processes, BIM implementation and sustainability considerations?**	**How can this framework be improved?**	**Points to consider.**
Yes, As a design and procurement guidance.	MPWH as all the governmental construction works are delivered through this ministry.	It can be used to simplify the delivery process using BIM.	BIM is considered by most of the public construction sector stakeholders as only software; therefore, there is a lack of an existing plan or guidelines for implementing BIM as processes. This can be seen in the absence of organisational structure and procurement processes for BIM implementation. This framework has a clear and easy to follow tender processes, including the need for a pre-qualification list.	This framework is clear and easy to follow; therefore, I am not quite sure if there is anything missing.	By stating who should execute the framework. By identifying who should manage the BIM information throughout the framework. By identifying the design and construction responsibilities.	Stakeholders' attitudes need to be changed. How risk will be distributed under two stages with the implementation of BIM. The public client needs to be educated on the benefits of BIM on time and cost savings as the two-stage tender strategy offers less competitive prices than single stage strategy which is frequently used in the public sector.

Table 8.12: Validation questions and results (P4)

Validation Findings						
Is this framework useful to you? Please give your reasons.	**Who should take ownership of this framework?**	**Under what circumstances would you use the framework?**	**How would you compare this framework to current BIM approaches in Jordan?**	**Is there anything missing in the content of the procurement processes, BIM implementation and sustainability considerations?**	**How can this framework be improved?**	**Points to consider.**
Yes, This framework is a stepping stone for an integrated BIM implementation in Jordan.	The project manager or the MPWH.	If the public client requests BIM, this framework could be used as a guidance for the project team assembling it.	There is no standard approach for BIM in Jordan. However, for most projects, BIM was used for 3D visualisation and clash detection Contractor BIM units will overcome the current issue of having two separate BIM models in the BIM approaches.	BIM implementation: I would say that there is a need to have an information manager. How to eliminate additional and specific risks to BIM implementation.	How can communication be improved between the different parties? Project objectives and goals need to be identified in the framework.	Currently, the focus in the public sector is on minimising cost when delivering their buildings. However, there is the potential to shift to sustainable buildings due to the recent political and economic issues in the region. Having a framework for implementing BIM to achieve sustainability is a step forward.

Table 8.13: Validation questions and results (P5)

Validation Findings						
Is this framework useful to you? Please give your reasons.	**Who should take ownership of this framework?**	**Under what circumstances would you use the framework?**	**How would you compare this framework to current BIM approaches in Jordan?**	**Is there anything missing in the content of the procurement processes, BIM implementation and sustainability considerations?**	**How can this framework be improved?**	**Other points to consider.**
Yes, It can be used to educate and guide the major stakeholders when implementing BIM.	MPWH.	It can be used to simplify the delivery process when implementing BIM.	Current BIM approaches are segregated in nature, and BIM has mostly been used in the design stage for visualisation. This framework is a structured process that brings more team integration into the design stages.	BIM implementation: Identifying who should manage the BIM information throughout the framework? Sustainability considerations: The facility manager inside the MPWH should be involved or consulted early in the process for sustainability approaches.	Implementing the framework under a more collaborative procurement approach. How construction BIM models fit in the framework	Before considering sustainability, the government needs to ask and enforce it.

Table 8.14: Validation questions and results (P6)

Validation Findings						
Is this framework useful to you? Please give your reasons.	**Who should take ownership of this framework?**	**Under what circumstances would you use the framework?**	**How would you compare this framework to current BIM approaches in Jordan?**	**Is there anything missing in the content of the procurement processes, BIM implementation and sustainability considerations?**	**How can this framework be improved?**	**Points to consider.**
Yes, This framework looks very useful as it describes a structured procurement process for implementing BIM.	MPWH and specifically the Governmental Tender Department (GTD).	BIM is new in Jordan; many professionals have limited experience in 'how to' implement this technology, especially the contractors and sub-contractors; this framework can introduce these professionals through their involvement with the consultants in the design stage.	There is no existing BIM standard in Jordan. Therefore, BIM has been implemented in many different ways with a total segregation between the design and construction.		By including the agreed project objectives and targets in terms or cost, time, quality and sustainability.	Sustainability options cost more. There is a need to change the attitude and awareness in order to implement BIM more effectively. BIM implementation will change the payment mechanism. Graphic and non-graphic information will not be at the same LOD at each stage for the different areas throughout any project.

Table 8.15: Validation questions and results (P7)

Validation Findings						
Is this framework useful to you? Please give your reasons.	**Who should take ownership of this framework?**	**Under what circumstances would you use the framework?**	**How would you compare this framework to current BIM approaches in Jordan?**	**Is there anything missing in the content of the procurement processes, BIM implementation and sustainability considerations?**	**How can this framework be improved?**	**Points to consider.**
Yes, This framework is mapping the timely involvement of the major stakeholders, their responsibilities and obligations; therefore, it can be used as a reference document throughout the process.	MPWH and the project manager.	If the public client requires public buildings using BIM.	We do not have a specific BIM process. However, the public sector started to implement BIM recently; thus, having a structured framework for that is a good step.		Besides implementing BIM effectively, what exactly are you looking to achieve? The project objectives and goals need to be clearly identified and stated.	Limited public projects have been delivered with the two-stage tender process. This is because most of the public projects were delivered using a single-stage tender after the design completion. In order for the framework to work better, pre-start up BIM meetings, start-up BIM design meetings and other BIM-based meetings should be held in the MPWH design department.

8.4.4 Concerns Raised by the Validation Interviewees

The validation interviewees agreed on the need for this framework in order to implement BIM and enhance sustainability performance for the public buildings in Jordan. However, some concerns were raised regarding the framework. These concerns can be identified as key points to consider and key questions raised by the validation interviewees to be able to improve the framework.

- **Who should execute the framework?**

The aim of the framework is to guide the public client in Jordan in applying for BIM when designing public buildings to improve their performance. Therefore, as all the governmental buildings are executed by the Ministry of Public Work and Housing (MPWH), the framework should be executed by the MPWH. Moreover, the validation interviewees agreed that the ownership of the framework should be with the public client. The validation interviewees P1, P2, P3, P4 and P6 expressed the view that the MPWH should own the framework. P5 and P7 were more specific by stating that the Government Tender Department, which is one of the MPWH's departments, should own the framework in order to guide the public consultants and contractors through the tender stages.

- **Besides implementing BIM effectively, what can the framework be used for?**

The framework is important to the building project stakeholders in the public sector in Jordan; it has been designed to inform all the stakeholders about the procurement process for implementing BIM and sustainability. As BIM is mostly used in the public sector in Jordan for visualisation and clash detection, this framework can be used to educate the different stakeholders through their early involvement in the design phase. P5, a validation interviewee, stated that:

> BIM is new in Jordan, many professionals have limited experience in 'how to' implement such technology, especially the contractors and sub-contractors; this framework can introduce such professionals through their involvement with the consultants in the design stage.

- **Governmental initiation and enforcement of sustainability**

There is a lack of enforcement of sustainability by the public client. The validation interviewee P5 stated that "before considering sustainability, the government needs to ask for sustainable outcomes and enforce it". This confirmed the lack of an enforcement body in Jordan, which has been reported by RSSJ and FES (2013). Moreover, the interview participants (see Section 7.7.4.1) also claimed that the government's lack of initiative and funding were among the major barriers to introducing sustainable technology. Therefore, in order for the framework to work, the government needs to step up and start requesting and enforcing sustainability in the delivery of its public buildings.

- **Who should manage the BIM?**

BIM models contain information collected from various stakeholders. This information should be managed and secured over the project lifecycle. Certain protocols and plans such as the CIC BIM protocol (2013) and the BIM Overlay to the RIBA Outline Plan of Work (RIBA, 2012) require the appointment of an information manager (a BIM manager). However, the interview participants in Chapter 7 claimed that because BIM implementation is limited, roles such as a BIM information manager are lacking in Jordan. However, the lead consultant (the architect) could be appointed as a BIM information manager to manage and secure the BIM inputs from various stakeholders (Barnes and Davies, 2015). Moreover, the interviewee participants (see Section 7.5.3) and the validation interviewee P2 recommended that the design consultants be assigned to the role of supervisory consultant in the construction phase to eliminate any conflicts and issues related to the designed stages. Therefore, by assigning the lead design consultant (the architect) as a BIM manager, he/she will be able to manage the design and construction BIM, which will support greater coordination in developing and maintaining an integrated BIM models (Porwal and Hewage, 2013).

- **How can communication between the different parties be improved through the framework?**

Communication is a significant factor in executing complex buildings projects. BIM is an effective communication tool among building stakeholders (Kim, 2014; Azhar et al., 2012) through BIM features such as visualisation (3D) and walkthrough. These features will ensure that the public client is informed, educated, and that their expectations are met.

Moreover, BIM will assist the government in evaluating the options and improving the decision-making process. This leads to a promoting of the building management, saving time and reducing wastage and thus project costs (Eastman, 2011; Hartmann, 2012).

In the framework, BIM pre-start-up and BIM start-up meetings are to enhance communication and collaboration. These meetings were recommended by RIBA (2012) and the interviewees in (see Section 7.6.3) as they stated that to overcome BIM implementation barriers and to achieve effective communication, they are essential to the process. The validation interviewees P1 and P5 reported that to enhance the communication between the stakeholders under this framework, these meetings alongside other progress meetings, should be held in the MPWH design department; moreover, the development of BIM over the project lifecycle should be registered and updated in the MPWH design department servers.

- **How to eliminate additional and specific risks to BIM implementation?**

There are many studies on the risks entailed in BIM implementation, and they can be classified within two main themes: technology and process-related risks. A lack of BIM standards for model integration and managing multidisciplinary teams is one of the significant technology-related risks. Multidisciplinary information integration in a single BIM model needs to have access from multiple users, which in turn makes it requisite that there are BIM protocols to ensure consistency of information and formatting styles (Azhar, 2012). In the absence of a standard protocol, each stakeholder uses his/her own standards, which could lead to inconsistencies and inaccuracies in the BIM model. Weygant (2011) suggested having frequent “model audits” to avoid such issues.

Other technological-related risks, according to Azhar (2012), are interoperability and licensing issues. Interoperability issues are not in the scope of the proposed framework. However, they can be defined as issues related to the data exchange between different applications to avoid data re-entry and to facilitate automation. Common languages such as XML, Schemas and IFC have significantly helped to solve the interoperability issues (Smith and Tardif, 2009). Moreover, identifying BIM requirements and goals during the early stages of a given construction project will enable an efficient exchange of information.

BIM process-related risks include a "lack of determination of ownership of BIM data, and the need to protect it through copyright laws and other legal channels" (Azhar, 2012). Rosenberg (2007) suggested that setting ownership rights and responsibilities in the contract documents are the best solution for preventing copyright disagreement issues. RIBA (2012) suggested the need to define long-term responsibilities, including ownership of the model, early during the 'preparation and brief' stage. For the ownership of the 'Final Coordinated BIM Model LOD 350' in the framework, the public client is the best entity to own the model. This is because the information embedded in this model will be used to deliver the BIM Model LOD 500 (facility management), which includes information that can be used to manage the public buildings effectively and efficiently over the building operation lifecycle. Moreover, as the preferred bidding contractor in the first tender stage might not be the awarded the role of construction contractor in the second stage, a clear statement should be embedded in the PCSA about the ownership of the 'Final Coordinated BIM Model LOD 350'.

Moreover, the responsibility for controlling the data entry and inaccuracies is also among the BIM process-related risks. This is a BIM contractual issue where being responsible for updating the project information model data and maintaining data accuracy over the project lifecycle entails a high risk. Another risk is that the BIM integrated concept blurs responsibility levels to the limit that risk and liability might be enhanced. Azhar (2012) suggested that implementing an integrated and collaborative procurement approach, such as with IPD and DB, is one of the most effective ways to deal with such risks.

- **Is there a need to change the contract form?**

There are two main contract forms that have been adopted by the public sector; the Jordan Engineering Service Contract C1 and C2 (for the consultants), and the Contract Agreement Book for Construction Part 1 and 2. The validation interviewee P6 reported that in order to implement BIM, it should be embedded in the contract for engineering services and contractor appointments. However, implementing BIM will raise additional contractual issues relating to contractual indemnities, project risks, responsibilities and copyright. These issues are not addressed in such standard contracts forms, which could affect the speedy adoption of BIM. Investigating the types of existing construction contract forms is not within the scope of this research. However, international efforts were made by issuing BIM protocols in order to address these issues related to BIM implementation.

The idea of a supplementary protocol outside of the contract means that a gradual approach to BIM adoption could be achieved without the need to redraft contracts. In the UK, the CIC BIM Protocol was issued to meet the requirements of BIM level 2. This protocol can be used as a supplementary legal agreement that can be incorporated into a construction contract and professional service appointments by way of a simple amendment. Moreover, this protocol puts in place specific liabilities, obligations and associated limitations on the use of BIM models.

In the USA, the AIA released its 'Building Information Modelling Protocol Exhibit', which is intended to be attached to the owner–architect and owner–contractor agreements. Another construction contract family is the 'ConsensusDocs', which could be used as an alternative to the standard form of contract. 'ConsensusDocs' covers digital communication, such as emails, drawings and payments with a focus on the BIM models. One of the 'ConsensusDocs' construction contracts is 'ConsensusDOCS 301 BIM Addendum', which was issued in 2010 by ConsensusDocs (Lowe and Muncey, 2010). This BIM addendum tackled one of the main risks specific to BIM-based projects, which is that stakeholders may assume that the contribution of other stakeholders to the BIM model as being accurate. This was achieved by specifying that each stakeholder is responsible for any contribution they make (Lowe and Muncey, 2010).

- **How construction BIM models are generated?**

The final outcome in the proposed framework, as shown in Figure 8.2, is the 'Final Coordinated BIM Design Model LOD 350'. 'ConsensusDOCS 301' was issued as a BIM addendum document that can be used alongside the traditional procurement approach (Lowe and Muncey, 2010). This document makes clear the difference between the two types of BIM models: design and construction models. The full or final BIM design models should comprise all the design models. The BIM construction models consist of data derived from the full or final BIM design model. This document defines the BIM construction models as being equivalent to the shop drawings. Porwal and Hewage (2013) drew a conceptual diagram to explain the design and construction models' generation, as explained in the BIM addendum (see Figure 8.4).

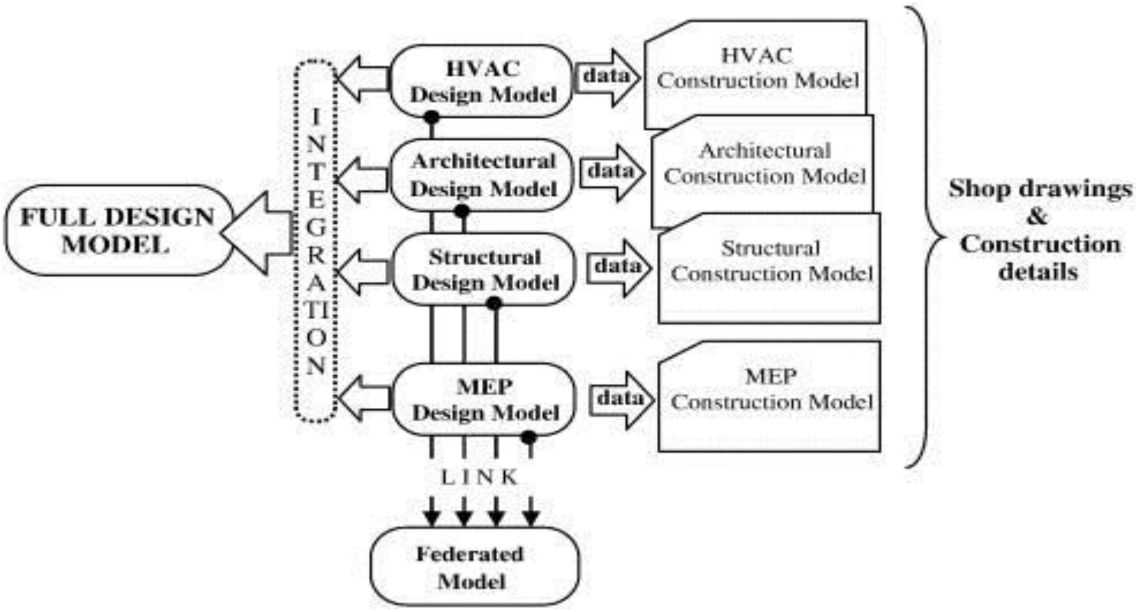


Figure 8.4: Diagrammatic representation of model definitions (Porwal and Hewage, 2013)

The federated model was defined in the BIM addendum as:

> A model consisting of linked, but distinct component models, drawings derived from the models, texts, and other data sources that do not lose their identity or integrity by being linked, so that a change to one component model in a federated model does not create a change in another component model. (Lowe and Muncey, 2010).

- **BIM LOD limitation**

LOD is identified as an important and critical issue as it represents the model information at specific stages, and it is allied with the practical side of BIM implementation (Wu and Issa, 2014). The proposed framework aims to tackle this issue by providing a LOD for each stage and also for the contractor appointment. However, the validation interviewees P4 and P6 stated that despite the need to have guidance on BIM LOD for different stages, as shown in the framework, there is a limitation on the use of the specific BIM LOD during the different stages. P4 further claimed that "during one stage or another, the mechanical design might be LOD 300, the electrical might be LOD 350 and HVAC might be LOD 400". P6 added that "for the 'Final Coordinated BIM Model LOD 350', you might have LOD 300 for the electrical, which we consider to be acceptable for construction as most of the parts are procured; on the other hand, HVAC, for example, needs to be LOD 350-400".

The suggested BIM LOD in the framework are used to guide the public stakeholders in Jordan on what is required during the different stages when implementing BIM, especially with the absence of standardised and structured processes for BIM implementation. However, this framework can be customised for a specific building project by identifying BIM LOD for each package at different stages.

8.5 FRAMEWORK REFINEMENTS

The framework for delivering public buildings in Jordan was developed based on the questionnaires, interviews analysis and the literature review. The framework was revised and refined based on certain key issues and concerns raised by the validation interviewees. These issues are:

- project targets should be identified early in the process;
- facility managers in the MPWH should be consulted and involved, as solo entities early in the development of the project brief to advise on sustainability approaches;
- MPWH contractor and consultant classifications should be part of the selection process;
- in the processes, consultants and contractors are usually appointed either on request for proposal or by a direct award; these need to be clearly shown in the framework;
- design consultants should be assigned as supervision consultants in the construction phase.

The refinement of the framework based on the validation interviews findings

Setting project targets early in the delivery process are necessary to achieve value for money. ‘Setting project targets’ is the fourth step in the framework in ‘RIBA (2013) stages 0&1: ‘the Strategic Definition & Preparation and Brief’. However, the validation interviewees claimed that this is for information purposes only. The public clients including PS and MPWH and represented by PM are involved at the beginning of the project to develop a statement of need and proceed with the project. The validation interviewees stated that there is also a need for a facility manager inside the MPWH to be involved in the process in order to advise on cost effectiveness, value for money and sustainability approaches. It is worth mentioning that the public buildings in Jordan are managed by an internal department in the MPWH called the 'Planning and Project Management Unit' (MPWH, 2018b). Pilanawithana and Sandanayake (2017) studied the role of the facility managers under the RIBA stages (2013), and they found that they have a vital role in briefing the client's requirements during the preparation and brief stage. Therefore, the MPWH facility manager will be added to the process at an early stage whilst developing the outline brief for the project.

The validation interview participants pointed out the need to clearly indicate the different public consultant and contractor grades during the tender process in the framework. The public consultants and contractors are classified into different grades depending on two criteria: their expertise in areas such as buildings, roads and sewerage, and also the maximum size of the projects that they have been allowed to bid for. As the focus of this research is on buildings, the building contractors are classified into grades 1 to 5, and the building consultants are classified into first grade class A, first grade class B, second grade and third grade. These grades will be added to the selection of the consultants and contractors under the framework. Moreover, despite the issues with the limited pre-qualification list for the public consultants and contractors, the validation interviewees wanted to add a direct award as the method for appointing the consultants and contractors since most of the public projects were delivered on the basis of a pre-qualification or direct award. In order to assign the design consultants' team into the supervisory role, a clause in the Jordan Engineering Service Contract C1 and C2 should be added.

8.6 FRAMEWORK IMPLEMENTATION BARRIERS

The stakeholders' mind-sets and attitudes need to be changed to appreciate lifecycle thinking. The framework is suitable for public buildings in Jordan. However, BIM implementation and sustainability decisions might cost more, but operational cost is reduced when a building is environmentally friendly, socially acceptable and economically viable. The lack of enforcement of BIM implementation by the Jordanian public client has led to an absence of a standardised procurement approach towards implementing this technology in delivering buildings (taken form the validation interviews). Therefore, it would not be an easy task to change the normal practices of the major stakeholders to use a defined framework that can provide a thorough guide on the procurement process for implementing BIM to achieve sustainable buildings. Although changing the current practices will always have its advantages and disadvantages, the major stakeholders (the public client, consultants and contractors) have gained BIM experience over the last few years to enhance their decision-making and buildings' performance (taken from the questionnaires and interviews). In spite of this, the BIM competency gap between the public consultants and contractors is still an issue (see Table 6.3 and Section 7.3.5.3), which could affect the implementation of the framework. However, the public contractors have started to train using BIM units inside their companies to fill this gap (see Section 7.6.4).

The public client in Jordan used to procure their buildings using DBB (see Figure 6.11 and Table 7.3), and on the lowest cost that met the minimum specifications (Section 7.4.1). By contrast, despite the advantages of implementing two stages of tender processes under the framework, the competition will be less than under the DBB approach. Therefore, the public client needs to be educated on the benefits of early contractor involvement on BIM implementation and sustainability, including the cost and time savings and constructability (taken from the interviews). Moreover, tendering could be based on an open-book basis to allow the client to understand and monitor the contractor pricing. Therefore, a culture change is needed to move towards a more collaborative culture in place of one that induces conflict. The revised framework is presented below in Figure 8.5.

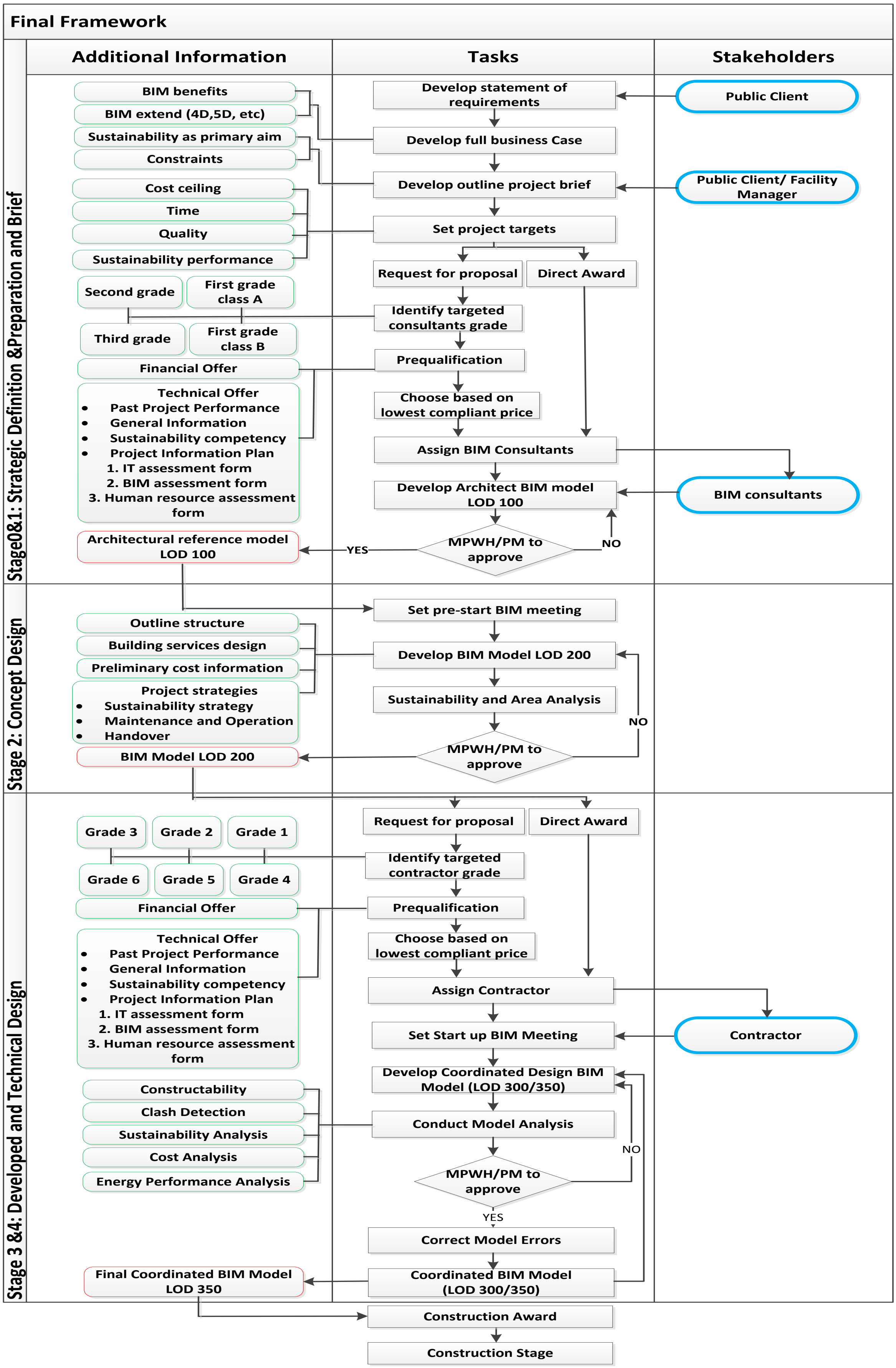


Figure 8.5: The final procurement framework for delivering public buildings in Jordan

8.7 CHAPTER SUMMARY

This chapter concentrates on the framework development, validation and discussion for delivering sustainable public buildings in Jordan. The framework was developed based on a problem-solving approach and under the currently adopted procurement approach in the public sector in Jordan. The procurement issues and suggested improvement measures were taken from the interview analysis and the literature.

The framework was validated through interviews with BIM practitioners in the public sector in Jordan. The framework presents a sequential process that can facilitate BIM implementation and achieve sustainable public buildings in Jordan. The findings from the validation interviews were presented in detail. The framework implementation has certain challenges and benefits for the public sector in Jordan that have been identified. The challenges include the following: changing the norms such as from the one-stage tender to the two-stage tender process, which is considered to be a less competitive approach; there is a lack of contractor BIM competency as few contractors have delivered BIM-based projects; the ownership of the BIM models; and paying more for adopting sustainable options and the BIM models. For the framework benefits, this research did not prove how much cost and time can be saved, or how much improved quality and sustainability performance can be achieved by implementing the framework. However, BIM implementation can doubtlessly save time, cut costs and improve the sustainability of buildings by increasing the integration between the delivery team, automated continuous sustainability performance analysis and easing the decision-making process through features such as visualisation (3D) and walkthrough. All the validation interviewees agreed on the usefulness and suitability of the framework. Nevertheless, they highlighted some points to consider. These points include: the use of the defined MPWH contractor and consultant classifications as part of the tender process; involving the facility manager early as a solo entity in developing the project brief to advise on sustainability approaches; and adding another possibility for selection (the direct award) as an option in the tender process. A summary of the entire research will be presented in the next chapter.

CHAPTER 9: CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

9.1 INTRODUCTION

This chapter will focus on providing the general conclusions and recommendations. The first section presents how the research aim and objectives have been met and achieved. The subsequent section provides key contributions of this research. Subsequent to this, this chapter discusses the research limitations, challenges and recommendations for future research.

9.2 ACHIEVEMENT OF THE RESEARCH AIM AND OBJECTIVES

The aim of the research was to develop a procurement framework to enhance the implementation of BIM in the Jordanian public sector for better sustainable building performance. In pursuing this aim, seven objectives were established. This section summarises how the research objectives have been met and provides the related references to the chapters and sections in the thesis.

9.2.1 Objective 1: To investigate the importance of delivering sustainable public building projects in Jordan (Chapter 2):

In order to justify this research, it was necessary to start by investigating the importance of delivering sustainable public buildings in Jordan. Accordingly, the literature review enabled certain insights into the importance of delivering sustainable buildings worldwide and in Jordan. It was found that globally buildings consume more energy than any other single sector; therefore, it is expected that the greatest cuts can be achieved from this sector. In Jordan, the building sector accounts for 33% of the final energy consumption in a country which imports 96.5% of its energy needs from neighbouring countries. This consumes a considerable portion of the state's annual budget, which is equal to 83% of the total export gains. Moreover, it was found that the building sector consumes a significant amount of the available water in a country that is considered to be one of the world's most water stressed countries.

A Lack of national resources combined with significant population growth and rapid urbanisation due to political, cultural and economic reasons have put pressure on the public buildings in Jordan to be more sustainable. Moreover, the public client is the major client and key driver for the building sector in the country. However, it has been shown that a large portion of public building projects suffers from sustainability performance issues. Therefore, greening this sector becomes a key focus. Finally, it has been evidenced that research on achieving sustainable buildings through project management approaches is still lacking. Far less research has focused on these issues for developing economies, particularly in Jordan.

9.2.2 Objective 2: To investigate the impact of adopting BIM approaches on the design and delivery of sustainable building projects (Chapters 3 and 7):

Research suggests that BIM as a management approach can help overcome many of the issues reported in the public buildings in Jordan, that is time delays, cost overruns and a lack of sustainability performance. Indeed, sustainability enhancement is among the main BIM benefits. The 'Sustainable BIM Triangle' has been introduced in Chapter 3, and it provides evidence that BIM adoption and implementation supports sustainability in two aspects. Firstly, BIM supports sustainability throughout the building lifecycle from planning to demolition by:

- Visualisation including 3D models and walkthrough features; this will ease the stakeholders' decision-making, and thus be more sustainably oriented.
- The ability to exchange data embedded in BIM among the multi-disciplinary users with the help of different sustainability analysis tools and the automation of the design evaluation processes.
- BIM contributes by improving the collaboration and communication between various stakeholders during sustainable design, construction and operations.

Secondly, BIM adoption and implementation supports the analysis and assessment of sustainable building projects. BIM facilitates the acquisition of much needed data for sustainability that is the coordinated dataset of information that has been naturally captured over the project lifecycle in the building information models. Moreover, BIM integration with other performance analysis software significantly simplifies the sustainability analyses performed on the buildings'. Furthermore, BIM can aid in enhancing the efficiency of sustainable assessment standard methods by estimating and interpreting the credentials of the different methods, which could enhance the stakeholders' understanding of this, thus ensuring the achievement of the certification requirements. Finally, the stakeholders can choose more effective strategies through BIM to achieve the required building certification.

The support given from BIM on the design and for delivering sustainable buildings is also illustrated by the key stakeholders in the public sector in Jordan. It was found that BIM has a potential to significantly contribute to delivering public buildings in Jordan. This can be achieved through visualisation and a sustainability analysis.

This research also revealed that despite the well-defined BIM benefits to building sustainability, there are three main barriers to the employment of BIM: business and legal barriers; human and organisational barriers; and technical barriers. The procurement approach, which falls within the business and legal barriers, is considered to be one of the most significant challenges to BIM implementation in the public sector. Thus, when many public clients around the world posed a range of actions to implement BIM, deploying collaborative procurement approaches have been requested. In spite of this, the literature revealed the absence of any preceding research on BIM, and the effect of procurement on BIM implementation in the public sector in Jordan.

9.2.3 Objective 3: To investigate the impact of procurement approaches on the uptake of BIM and delivering sustainable buildings (Chapter 4)

This has been achieved through reviewing the literature on the potential advantages and disadvantages of the main public procurement approaches (DBB, DB, and CM) on the implementation of BIM (see Section 4.3). IPD was also explored as the optimum procurement approach for implementing BIM. The potential contributions of BIM under each of these approaches were also discussed. It was found that the traditional DBB is the most popular procurement approach implemented in the public sector in many countries around the world. Despite the positive impact of BIM on the process of DBB, it has been shown that this procurement approach is the least able to realise the BIM benefits. This is due to many reasons, such as the late contractor involvement and limited BIM adoption during the tender stage. On the other hand, IPD was found to be the closest fit for BIM implementation. This is due to the stakeholders' involvement and integration from the beginning of the process, which creates an effective environment for BIM implementation, and thus the full realisation of BIM benefits. However, IPD in its pure form is too idealistic for the common adoption on construction projects globally due to many legal, financial, cultural and technological issues. Therefore, researchers started to develop innovative procurement approaches that adopt some elements related to the collaborative procurement approaches, and which are a closer fit between aspiration and specific market dynamics to facilitate BIM implementation (see Section 4.4).

Finally, despite the focus on procurement approaches and their effect on BIM implementation to realise the potential benefits, including sustainability enhancement, this thesis has shown that procurement approaches also have a significant impact on achieving sustainable outcomes (see Section 4.5). This is through the level of integration achieved under each different procurement approach, and the more integrated the procurement approach, the better the sustainability outcomes.

9.2.4 Objective 4: To investigate the current BIM status, feasibility, benefits and barriers in the public sector in Jordan (Chapters 5 and 6 and Section 7.3)

Reviewing the literature revealed the absence of any previous research on BIM in the public sector in Jordan (see Chapter 3). Therefore, BIM was still unknown in this context. Consequently, this research conducted a BIM feasibility study and interviews with key stakeholders and BIM practitioners in the public sector in Jordan as an exploratory study (see Chapter 5) to investigate BIM's status, its benefits and barriers, and also whether it is feasible for public building projects in Jordan as a management tool. As a result, this research has shown that BIM is feasible for public buildings in Jordan as a management tool, and it is timely to adopt BIM (see Chapter 6). It was also revealed that BIM has been mainly implemented in the design phase for 3D visualisation and clash detection. Finally, it was found that the current procurement approach and the lack of a comprehensive framework or implementation plan constitute significant barriers to implementing BIM in the public building sector in Jordan (see Chapter 6 and Section 7.3).

9.2.5 Objective 5: To investigate the procurement approaches used in the Jordanian public sector and their effect on the adoption of BIM and the subsequent ability to deliver sustainable building projects (Chapter 5, Section 6.2 and Chapter 7):

The procurement approach has been identified as a significant challenge to implementing BIM as a management tool (see Chapter 4 and Sections 6.2 and 7.3). Therefore, it was necessary to investigate the procurement approaches currently adopted in the public sector in Jordan and their effect on BIM implementation. This research found that the traditional DBB is the most frequently used procurement approach in the public sector in Jordan, and the key tasks and stakeholders' involvement and responsibilities under this approach have been identified (see Section 7.5). This research also confirmed that this approach is the only used one when delivering public buildings using BIM (see Section 7.5.2). The major effect of such an approach on BIM implementation is the consequence of having two BIM fragmented processes (see Section 7.3).

The main reasons for implementing this approach for the majority of public buildings have been explored (see Section 7.4), and the clear message was that changing the traditional procurement approach to a more collaborative one needs a national effort in terms of changing the legislation, the culture of the stakeholders and conducting trainings for the consultants and contractors. The interview participants raised the main issues associated with the current procurement approach that have affected the implementation of BIM (see Section 7.5). Moreover, they suggested some improvement measures to overcome these issues (see Section 7.6). Therefore, for an improved BIM implementation and the ensuing sustainable outcomes, these issues need to be solved.

For sustainability, the management of the current procurement approach was found to be one of the major barriers to achieving sustainable public buildings in Jordan. The main features of this approach that hinder sustainable outcomes are the late contractor involvement and the selection of the contractor based on the lowest price bid. Finally, this research identified the most important procurement factors for addressing the environmental and sustainable issues under the preferred procurement approach in the public building sector (see Section 7.7).

9.2.6 Objective 6: To develop a procurement framework to enhance the implementation of BIM in the Jordanian public sector for better sustainable buildings' performance (Chapter 8)

The literature analysis (see Chapter 4), questionnaire analysis (see Chapter 6) and interview analysis (see Chapter 7) clearly stated that the procurement approach is one of the major challenges for effective BIM implementation in the public sector in Jordan. The interview participants (the BIM practitioners) indicated that changing the entire procurement approach for a more collaborative approach is a challenging task. Therefore, the aim of the framework was to deliver a more effective BIM implementation under the currently adopted procurement approach in the public sector in Jordan with an emphasis on sustainability performance. A problem-solving approach was adopted as the methodology for developing the framework to respond to the issues raised about the current procurement approach that affects BIM implementation in the public sector in Jordan (see Section 8.2.2). The proposed solutions for these issues were based on the interview participants' suggestions and the secondary data (see Section 8.2.3). The framework was structured based on the RIBA (2013) stages, and the main tasks and key stakeholder involvement under the current procurement approach in the public sector in

Jordan were provided by the interview participants. These tasks are considered to be the foundation of the proposed framework. The framework is described in Section 8.2.4.

9.2.7 Objective 7: To refine and validate the developed framework (Chapter 8)

There was a need to validate the procurement framework before it is implemented. Therefore, the validation process aimed to determine the reliability and validity of the proposed framework and to identify further gaps in the proposed framework (see Section 8.4.1). This was achieved by determining the clarity of the structure, information flow and appropriateness and practicalities of the proposed framework, and also whether the framework can be implemented under the government regime in the public sector in Jordan.

The validation process was conducted over two stages (see Section 8.4.2). In the first stage, in the form of a pilot study, there were discussions with the construction management researchers at the University of Portsmouth to refine the developed framework before the actual validation process. In the second stage, the process was carried out through the validation interviews with the experts in the public construction sector in Jordan to refine and examine the suitability of the proposed framework for the public construction sector in Jordan.

It was found that the proposed framework is useful, and that it is a good stepping stone towards integrating BIM under the current procurement approach to be able to deliver sustainable public buildings in Jordan. On the other hand, a few concerns were raised by the validation interviewees (see Section 8.4.4). The refinements to the proposed framework are described in Section 8.5. These refinements were used to further improve the framework.

As discussed above, the objectives of this research were achieved, and the main aim has been realised. This has been achieved through: studying the importance of delivering sustainable public buildings in Jordan; the potential contribution of BIM in being able to deliver sustainable buildings; the impact of the different procurement approaches on BIM implementation and sustainability considerations; designing a procurement framework based on the BIM practitioners' suggestions and the literature; and validating the framework through the help of the researchers and BIM practitioners working in the public sector in Jordan.

9.3 CONTRIBUTION TO KNOWLEDGE

This study is of significance to the construction public sector in Jordan because it deals with existing and future problems. The government has recently started to press for BIM implementation. However, there is a lack of studies to help with this BIM implementation, and thus be able to address these current and future problems of sustainability. This research has made significant contributions in the following areas:

- Filling a gap in the built environment body of research by providing a systematic review of the effect of project management systems, BIM and procurement approaches on the delivery of sustainable buildings.
- Being the first study about BIM in the public sector in Jordan, thus making a significant contribution by providing solid knowledge about BIM adoption and implementation in this context. The knowledge acquired and developed will support policy makers and decision makers in designing strategies and plans for BIM adoption and implementation in Jordan. This knowledge will also pave the way for other researchers to focus on the issues revealed in this study when conducting research on BIM in the public sector in Jordan.
- Enabling insight into the subjective perception of professionals (that is the project managers, BIM managers, tender managers and construction managers) in regard to the relationship between the procurement approaches and effective BIM implementation.
- Providing a systematic procurement framework for BIM uptake in the public sector in Jordan to enhance building sustainability performance. Currently, the procurement approaches adopted by the Jordanian public sector are the main barriers to an effective implementation of BIM and the main cause of BIM being utilised in a fragmented way. Consequently, BIM is used mainly for visualisation and clash detection. The proposed procurement framework will help overcome the procurement barriers faced by the BIM practitioners in the public sector in Jordan and enhance the integration of the key project stakeholders to effectively implement BIM and so improve sustainability performance.

9.4 RESEARCH LIMITATIONS

Due to the time restrictions of a research project and the scope of this study, the following limitations are identified; however, these do not limit the value of the findings established in this study.

- The generalisability of the proposed framework: despite the employment of rigorous scientific methods to develop the proposed framework, it was based on data collection from a single case (the Jordanian public sector).
- The developed framework not being implemented in any particular organisation: the framework, however, has been validated by BIM practitioners in the Jordanian public sector.
- The limitation of the sample size: this research considers the MPWH and GTD as representatives of the public client due to their significant role in procuring the public buildings. Nevertheless, the researcher acknowledges that conducting the study with a larger sample will enable broader generalisations of the research outcomes. Collecting data from other governmental ministries such as the Ministry of Municipal Affairs, the Ministry of Higher Education and the Ministry of Health would be appropriate.
- Many organisational, technical, business and legal barriers for BIM implementation in the Jordanian public sector were identified through the questionnaire and interview analysis. This research provided recommendations to overcome these barriers. However, these barriers need to be investigated more.

9.5 RESEARCH CHALLENGES

This research has been faced with certain challenges. These challenges are:

- The use of the NVIVO software to analyse the main interviews: the researcher was not familiar with the software, and thus it constituted a long learning curve to be able to use the software, arrange the sources and perform the necessary enquiries.
- Transcribing and translating the interviews: the official language in Jordan is Arabic, so transcribing the interview data included: listening to the recorded interviews, typing these records in Arabic, sending it back to the interviewees to check the content, translating the content into English, and then sending the Arabic and English transcripts to two Arabic speaking researchers to check the translations. This process was time consuming.
- The data collected for this research was based on a field study: the researcher had to travel several times from the UK to Jordan. In addition, as the targeted sample for the interviews were at a high managerial level, such as the tender managers, project managers and directors, the researcher had to rearrange a few interviews due to last minute requests for cancellation from the interviewees due to their busy schedules and deadlines.
- The follow up process with the research participants: this was due to some of the participants lacking of access to their email addresses and because of their busy schedules.

Therefore, the researcher had to use different methods such as second and third email reminders in addition to phone calls.

9.6 RECOMMENDATIONS FOR FUTURE RESEARCH

Investigating the BIM theory and procurement approaches in light of this research has paved the way for future research in Jordan. As discussed throughout this research, the procurement approaches have a significant role in the successful implementation of BIM. Therefore, some of the potential areas for future research are as follows:

- As the proposed framework has not been implemented on any organisation, the researcher recommends future research on applying the proposed framework to a case study to measure the actual impact of the framework and to suggest modifications if any are needed based on a longitudinal study.
- The researcher recommends future studies on the applicability of the proposed framework to comparable industries in Jordan and also to the construction industries in other similar countries.
- Future research could also further develop the procurement framework into a detailed process map by researching and reshaping the tasks carried out by the consultants and the contractors for each stage throughout the building lifecycle.
- Taking into consideration the recommendations of the BIM practitioners in the Jordanian public sector, the proposed framework is based on the traditional procurement approach to smoothly introduce BIM to the current procurement environment. However, there is still a need for an in-depth investigation into the adoption of a collaborative based procurement approach, such as IPD in Jordan. This could be achieved by identifying the challenges and constraints of applying these approaches, and how to overcome these challenges and constraints.
- Other organisational, technical, business and legal barriers for BIM implementation in the Jordanian public sector were identified. This research provided recommendations to overcome some of these barriers. However, future studies need to be conducted to investigate these barriers in a thorough and detailed manner.
- This study provided recommendations for overcoming the barriers to delivering sustainable public buildings in Jordan. However, these barriers need to be investigated further.

REFERENCES

7 Group & Reed, B. (2009). *The integrative design guide to green building: Redefining the practice of sustainability*. Hoboken, NJ: Wiley.

ACIF & APCC. (2015). *Building and construction procurement guide: Project team integration and building information modelling*. Retrieved from https://www.acif.com.au/documents/item/724.

Adeyemi, A., Martin, D., & Kazim, R. (2014). Elimination of waste and inefficient facilities in existing buildings for sustainability in developing nations. *International Journal of Architecture and Urban Development, 4* (1), 5-16.

AGC. (2006). *The contractor guide to BIM. The Associated General Contractors of America (AGC)*. Retrieved from https://www.engr.psu.edu/ae/thesis/portfolios/2008/tjs288/Research/AGC_GuideToBIM

Ahmad, A. (2013). *The use of refurbishment, flexibility, standardisation and BIM to support the design of a change-ready healthcare facility*. PhD Thesis. Loughborough University.

Ahmed, S. M. (2014, December). *Barriers to BIM/4D implementation in Qatar*. Paper presented at the International Conference on Smart, Sustainable and Healthy Cities. Abu Dhabi, United Arab Emirates.

Ahn, Y. H., Kwak, Y. H., & Suk, S. J. (2016). Contractors' transformation strategies for adopting Building Information Modeling. *Journal of Management in Engineering, 32*(1), 1–13. https://doi.org/http://dx.doi.org/10.1061/(ASCE)ME.1943-5479.0000390.

Ahuja, H. N., & Nandakumar, V. (1985). Simulation model to forecast project completion time. *Journal of Construction Engineering and Management, 111*(4), 325–342.

AIA California Council. (2007). *Integrated project delivery, a working definition.* Retrieved from http://aiacc.org/wp-content/uploads/2010/07/A-Working-Definition-V2-final.pdf.

AIA. (2008). *Building Information Modeling protocol exhibit*. Document E202.The American Institute of Architects: U.S.

AIA. (2013). *AIA G202-2013 Project Building Information Modeling protocol.* Retrieved from http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab099086.pdf.

Ajayi, S. O., Oyedele, L. O., Ceranic, B., Gallanagh, M., & Kadiri, K. O. (2015). Life cycle environmental performance of material specification: a BIM-enhanced comparative assessment*. International Journal of Sustainable Building Technology and Urban Development,* 6 (1), 14-24. http://dx.doi.org/10.1080/2093761X.2015.1006708.

Aje, I. (2012). The impact of contractors' prequalification on construction project delivery in Nigeria. *Engineering, Construction and Architectural Management, 19*(2), 159-172. https://doi.org/10.1108/09699981211206098.

Akbarnezhad, A., Ong, K. C. G., & Chandra, L. R. (2014). Economic and environmental assessment of deconstruction strategies using Building Information Modeling. *Automation in Construction, 37*, 131–144.

Al Assaf, A. (2017). *Enhancing transparency and accountability in the public construction sector in Jordan.* Integrity and Anti-corruption Commission. Retrieved from http://www.jiacc.gov.jo/documents/9db9c9fe-1706-4113-a13b-63ffb46202cb.pdf.

Al Awad, O. (2015). *The uptake of advanced IT with specific emphasis on BIM by SMEs in the Jordanian Construction Industry*. PhD Thesis. The University of Salford.

Al Emam, D. (2015, June 02). Construction sector vital for Jordan's economy, security. *The Jordan Times.* Retrieved from http://www.jordantimes.com/news/local/construction-sector-vital-jordan%E2%80%99s-economy-security-%E2%80%94-pm.

Al Khalil, M. I. (2002). Selecting the appropriate project delivery method using AHP. *International Journal of Project Management, 2*0(6), 464-469.

Al-Hazim, N., Salem, Z. A., & Ahmad, H. (2017). Delay and cost overrun in infrastructure projects in Jordan. *Procedia Engineering, 182*, 18-24.

Ali, H., & Al Nsairat, S. (2009). Developing a green building assessment tool for developing countries: Case of Jordan. *Journal of Building and Environment, 44*(2009), 1053-1064.

Al-Kilani, M., (2015). *Sustainable development in Jordan.* United Nations. Retrieved from https://sustainabledevelopment.un.org/content/documents/15286Al-Kilani,%20Jordan%20MDG-SDG%2020150527%20in%20absentia.pdf.

Alkilani, S., & Jupp, J. (2012). Paving the road for sustainable construction in developing countries: a study of the Jordanian construction industry. *Australasian Journal of Construction Economics and Building, 1*(1), 84-93.

Alsubeh, M. A. (2013). A strategic framework for sustainable construction in Jordan. *Journal of Civil and Environmental Research, 3*, 102-107.

Al-Zoabi, A. (2001). Sustainable development in Jordan. *Local Environment, 6*(2), 169-180. DOI: 10.1080/13549830120052809.

Anton, L.A., & Diaz, J. (2014). Integration of lifecycle assessment in a BIM environment. *Procedia Engineering, 85*, 26-32. http://dx.doi.org/10.1016/j.proeng.2014.10.525.

Aranda-Mena, G., Crawford, J., Chevez, A., & Froese, T. (2009). Building Information Modelling demystified: Does it make business sense to adopt BIM? *International Journal of Managing Projects in Buisness, 2*(3), 419–434.

Arayici, Y., Coates, P., Koskela, L. J., Kagioglou, M., Usher, C., & O'Reilly, K. (2011). BIM adoption and implementation for architectural practices. *Structural Survey, 29* (1), 7-25.

Arayici, Y., Coates, S. P., Koskela, L. J., Kagioglou, M., Usher, C., & O'Reilly, K. (2009, October). *BIM implementation for an architectural practice*. Paper presented at the 26th International Conference on IT in construction. Istanbul Technical University, Turkey.

Arora, V., & Johnson, J. (2006). A model for building a standardised hand-off protocol. *The Joint Commission Journal on Quality and Patient Safety, 32* (11).

Ashcraft, H. W. (2010). *Negotiating an integrated project delivery agreement.* San Francisco: Hanson Bridgett.

Asl, M. R., Zarrinmehr, S., Bergin, M., & Yan, W. (2015). BPOpt: A framework for BIM-based performance optimization. *Energy and Buildings, 10*8, 401-412. http://dx.doi.org/10.1016/j.enbuild.2015.09.011.

Autodesk. (2003). *Building Information Modelling for sustainable design: Autodesk building solutions.* (White Paper). Retrieved from http://images.autodesk.com/latin_am_main/files/bim_for_sustainable_design_oct08.pdf.

Autodesk. (2003). *Building Information Modelling in practice: Autodesk building solutions.* (White Paper). Retrieved from http://www.1stpricing.com/pdf/AutoCAD_BIM_in_Practice.pdf.

Autodesk. (2005). *Building Information Modeling for sustainable design*. (White Paper). Retrieved from http://www.autodesk.com.

Autodesk. (2008). *Building Information Modeling for sustainable design*. (White paper). Retrieved from http://images.autodesk.com/adsk/files/bim_for_sustainable_design_oct08.pdf.

Autodesk. (2012). *Autodesk ecotect analysis*. Sustainable building design software.

Awad, A. (2016). *Implementing the sustainable development goals.* Socialwatch. Retrieved from http://www.socialwatch.org/node/17228.

Awwad, R. A. (2013). *Surveying BIM in the Lebanese Construction Industry*. Slovakia: International Association for Automation and Robotics in Construction.

Azhar, S. (2011). Building Information Modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. *Leadership and Management in Engineering, 11*(3), 241-252.

Azhar, S., & Brown, J. (2009). BIM for sustainability analyses. *International Journal of Construction Education and Research, 5* (4), 276–292.

Azhar, S., Carlton, W. A., Olsen, D., & Ahmad, I. (2011). Building Information Modeling for sustainable design and LEED ® rating analysis. *Automation in Construction, 20*(2), 217–224. http://doi.org/10.1016/j.autcon.2010.09.019.

Azhar, S., Hein, M., & Sketo, B. (2008, April). *Building information modeling (BIM): benefits, risks and challenges*. Paper presented at the Proceedings of the 44th ASC Annual Conference. Auburn, Alabama.

Azhar, S., Khalfan, M., & Maqsood, T. (2012). Building Information Modeling (BIM): Now and beyond. *Journal of Construction Economics and Building, 12* (4) 15-28.

Baker, M. A., & Foy, A. (2008). Business and Management Research (2nd ed.). United Kingdom, Argyll: Westburn Publishers Ltd.

Baker, S. (2006). *Sustainable development*. London: Routledge.

Balgheeth, Y. (2016). *Enhancing existing health and safety processes in public sector construction projects within Saudi Arabia using building information modelling approaches*. PhD Thesis. University of Salford, Salford.

Bani Ismail, L. (2012). *An evaluation of the implementation of Total Quality Management (TQM) within the construction sector in the United Kingdom and Jordan*. PhD Thesis. University of Huddersfield.

Barlish, K., & Sullivan, K. (2012). How to measure the benefits of BIM: A case study approach. *Automation in Construction, 24*, 149–159.

Barnes, P., & Davies, N. (2015). *BIM in principle and practice* (2nd ed.). London: ICE Publishing.

Basbagill, J., Flager, F., Lepech, M., & Fischer, M. (2013). Application of life-cycle assessment to early stage building design for reduced embodied environmental impacts. *Building and Environment, 60,* 81–92.

Becerik-Gerber, B., & Kensek, K. (2010). Building Information Modeling in architecture, engineering, and construction: Emerging research directions and trends. *Journal of Professional Issues in Engineering Education and Practice, 136*(3). https://doi.org/10.1061/(ASCE)EI.1943-5541.0000023.

Bendassolli, P. F. (2013). Theory building in qualitative research: reconsidering the problem of induction*. In Forum: Qualitative Social Research* Sozialforschung*, 14*(1).

Bernstein, H., Jones, S., & Russo, M. (2010). *Green BIM: How Building Information Modeling is contributing to green design and construction.* Bedford, MA: McGraw-Hill Construction.

Bernstein, P. G., & Pittman, J. H. (2004). *Barriers to the adoption of Building Information Modeling in the building industry.* (White Paper). Retrieved from http://academics.triton.edu/faculty/fheitzman/Barriers%20to%20the%20Adoption%20of%20BIM%20in%20the%20Building%20Industry.pdf.

Bieker, T., Dyllick, T., Gminder, C. U., & Hockerts K. (2001, September). *Towards a sustainability balanced scorecard linking environmental and social sustainability to business strategy*. Paper presented at the Proceedings of the 2001 Business Strategy and the Environment Conference. The University of Leeds, UK.

BIM Forum (2013). *Level of development specification*. Retrieved from https://bimforum.org/wp-content/uploads/2013/08/2013-LOD-Specification.pdf.

Blaikie, N. (2007). Approaches to social enquiry. Cambridge: Polity.

Blaikie, N. (2010). *Designing social research*. (2nd eds.). USA, Cambridge: Polity Press.

Boktor, J., Hanna, A., & Menassa, C. (2014). State of practice of Building Information Modeling in the mechanical construction industry. *J. Manage. Eng., 10*(1061),78–85.

Bolpagni, M. (2013). *The implementation of BIM within the public procurement: A model-based approach for the construction industry.* VTT Technology, Finland, 130.

Bonenberg, W., & Wei, X. (2015). Green BIM in sustainable infrastructure. *Procedia Manufacturing, 3*, 1654–1659.

Bordass, B., Cohen, R., Standeven, M., & Leaman, A. (2001). Assessing building performance in use 3: energy performance of the probe buildings. *Building Research and Information, 29*(2), 114-128.

Bosche, F., Ahmed, M., Turkan, Y., Haas, C.T., & Haas, R. (2015). The value of integrating Scan-to-BIM and Scan-vs-BIM techniques for construction monitoring using laser scanning and BIM: the case of cylindrical MEP components. *Automation in Construction, 49,* 201-213. http://dx.doi.org/10.1016/j.autcon.2014.05.014.

Bossink, B. A. G. (2007). The interorganizational innovation processes of sustainable building: A Dutch case of joint building innovation in sustainability. *Journal of Building and Environment, 42*, 4086–4092.

Bourdeau, L., Halliday, S., Huovila, P., & Richter, C. (1997, June). *Sustainable development and the future of construction.* Paper presented at the Proceeding of the 2nd International Conference on Buildings and the Environment. Paris: CSTB-CIB.

Bower, D. (2003). *Management of procurement.* London: Thomas Telford.

Brammer, S., & Walker, H. (2011). Sustainable procurement in the public sector: An international comparative study. *International Journal of Operations & Production Management 31*(4), 452–476.

Brandon, P. S. (1999). Sustainability in management and organization: the key issues? *Building Research and Information*, 27(6), 390–396.

Brewer, G., & Gajendran, T. (2012). Attitudes, behaviours and the transmission of cultural traits: Impacts on ICT/BIM use in a project team. *Construction Innovation: Information, Process, Management, 12*(2), 198–215.

Bryman, A. (2004). *Social research methods* (2nd ed.). Oxford: Oxford University Press.

Bryman, A. (2008). *Social research methods*. New York: Oxford University Press.

Bryman, A., & Bell, E. (2007). *Business and research methods* (2nd ed.). Oxford: Oxford University Press.

Bryman, A., & Bell, E. (2011). *Business research methods* (3rd ed.). London: Oxford University Press.

BSI. (2013). *PAS 1192-2:2013 - Specification for information management for the capital/delivery phase of construction projects using building information modelling (RPRT).* British Standard Institution (BSI). Retrieved from http://shop.bsigroup.com/Navigate-by/PAS/PAS-1192-22013/.

BSI. (2013b). *PAS 1192-2:2013 - Specification for information management for the capital/delivery phase of construction projects using building information modelling (RPRT).* British Standard Institution (BSI). Retrieved from http://shop.bsigroup.com/Navigate-by/PAS/PAS-1192-22013/.

Building Information Modeling Task Group (BIMTG). (2014). *A digital tool for Building Information Modeling*. Retrieved from https://sbri.innovateuk.org/competition-display-page/-/asset_publisher/E809e7RZ5ZTz/content/a-digital-tool-for-building-information-modelling/1524978.

BuildingSMART. (2011). *BIM in the Middle East*. BuildingSmart: UAE.

BuildingSMART. (2012). *National Building Information Modelling initiative: volume 1 – strategy.* Sydney: Building Smart Australasia,

Burgan, B. A., & Sansom, M. R. (2006). Sustainable steel construction. *Journal of Constructional Steel Research, 62*, 1178-1183.

Bynum, P., Issa, R., & Olbina, S. (2013). Building Information Modeling in support of sustainable design and construction. *Journal of Construction Engineering and Management, 139(*1), 24-34.

Cabinet Office. (2012). *Government construction strategy: Final report to government by the Procurement/Lean Client Task Group*. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/61157/Procurement-and-Lean-Client-Group-Final-Report-v2.pdf.

Cambridge University Press*.* (2018). Cambridge online dictionary, Cambridge Dictionary online. Retrieved from https://dictionary.cambridge.org/dictionary/english/.

Cao, D., Wang, G., Li, H., Skitmore, M., Huang, T., & Zhang, W. (2015). Practices and effectiveness of building information modelling in construction projects in China. *Automation in Construction, 49*, 113–122.

Carbon Trust. (2008). *Low carbon refurbishment of buildings. A guide to achieving carbon savings from refurbishment of non-domestic buildings* Work. UK, London: The Carbon Trust.

Carter, N. (2007). *The politics of the environment: ideas, activism, policy* (2nd ed.). Cambridge: Cambridge University Press.

Carter, S., M., & Little, M. (2007). Justifying knowledge, justifying method, taking action: Epistemologies, methodologies, and methods in qualitative research. *Qualitative Health Research*, *17*(10), 1316-1328.

Cefrio. (2011). *Improving efficiency and productivity in the construction sector through the use of information technology*. French Centre for Automation of Organizations. Quebec, Canada: Cefrio.

Chan, C. T. W. (2007). Fuzzy procurement selection model for construction projects. *Construction Management and Economics, 25*, (6), 611-618.

Chang, R. D., Zuo, J., Soebarto, V., Zhao, Z. Y., Zillante, G., & Gan, X.L. (2017). Discovering the transition pathways toward sustainability for construction enterprises: importance- performance analysis. *Journal of Construction Engineering and Management, 143* (6). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001295.

Chartered Institute of Building. (2010). Code of practice for project management for construction and development. US, New Jersey, Hoboken: Wiley-Blackwell.

Cheng, J. C. P., & Lu, Q. (2015). A review of the efforts and roles of the public sector for BIM adoption worldwide. *Journal of Information Technology in Construction (ITcon), 20,* 442–478.

Cheng, J. C., & Ma, L.Y. (2013). A BIM-based system for demolition and renovation waste estimation and planning. *Journal of Waste Management, 33* (6), 1539–1551.

Chew, M. Y. L., Tan, S. S., and Kang, K. H. (2004). Building maintainability-Review of state of the art. *Journal of Architectural Engineering*, 10(3), 80–87.

Chong, H., Lee, C., & Wang, X. (2017). A mixed review of the adoption of Building Information Modelling (BIM) for sustainability. *Journal of Cleaner Production, 142*, 4114-4126

CIB. (2004). *50 years of international cooperation to build a better world.* Rotterdam: CIB.

CIBSE (2006). *Guide A: Environmental design*. UK, London: The Chartered Institution of Building Services Engineers (CIBSE),.

CIC. (2013). *Building Information Model (BIM) protocol. Standard protocol for use in projects using Building Information Models*. Construction Industry Council (CIC). Retrieved from http://www.bimtaskgroup.org/bim-protocol/.

CIFE. (2007). *CIFE technical reports*. Retrieved from http://cife.stanford.edu/Publications/index.html.

Ciriaci, F. (2000, month date). New government sworn*. The Jordan Times, 25*(7481), 1-4.

Cleves, J. A., & Dal Gallo, L. (2012, April). *Integrated project delivery: The game changer.* Paper presented at the American Bar Association Meeting: Advanced Project Delivery: Improving the Odds of Success.

Clough, R. H., Sears, G. A., & Sears, S. K. (2008). Construction project management: A practical guide to field construction management. New Jersey: Wiley.

COBIM. (2012). *Common BIM requirements 2012*. Retrieved from: https://buildingsmart.fi/en/common-bim-requirements-2012/.

Cohen, J. (2010). *Integrated project delivery: Case studies.* AIA California Council 2010. Sacramento, USA.

Cole, R. J. (2005). Building environmental assessment methods: Redefining intentions and roles. *Building Research and Information, 33*(5), 455–467.

Computer Integrated Construction Research Program. (2010). *BIM project execution planning guide – version 2.0.* The Pennsylvania State University, University Park, USA.

Cook, C. (2004, March/April 17). *Scaling the building information mountain*. CAD User AEC Magazine.

Crawford, L., & Pollack, J. (2004). Hard and soft projects: a framework for analysis [electronic version. *International Journal of Project Management, 22,* 645 -653.

Crawley, D., & Aho, I. (1999). Building environmental assessment methods: applications and development trends. *Building Research and Information, 27*(4-5), 300–308.

CRC Construction Innovation. (2007). *Adopting BIM for facilities management: solutions for managing the Sydney Opera House.* Cooperative Research Center for Construction Innovation, Brisbane, Australia. Retrieved from http://eprints.qut.edu.au/27582/.

CRC for Construction Innovation. (2007). *Business Drivers for BIM*. Commonwealth of Australia, Brisbane. Retrieved from https://eprints.qut.edu.au/26834/1/2634.pdf.

Creswell, J. W. (1994). *Research design*. Thousand Oaks, California: Sage Publications.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approach* (2nd ed.). Thousand Oaks, California: Sage Publications.

Creswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five traditions* (2nd ed.). London: Sage Publications.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approach* (3rd ed.). Thousand Oaks, California: Sage Publications.

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches*. Thousand Oaks, California: Sage Publications.

Crosbie, T., Dawood, N., & Dawood, S. (2011). Improving the energy performance of the built environment: The potential of virtual collaborative life cycle tools. *Automation in Construction,* *20*(2):205–216. Retrieved from http://www.scopus.com/inward/record. url?eid=2-s2.0 79551687730&partnerID=40&md5=d4f2d9466b0c97918eaceaa52f6d0cb4.

Crotty, M. (1998). The foundations of social research: Meaning and perspective in the research process. London ; Thousand Oaks, Calif.: Sage Publications.

Crotty, R., (2012). *The impact of Building Information Modelling: Transforming construction*. New York: Routledge.

CURT (Construction Users Roundtable). (2010). *BIM implementation: An Owner's guide to getting started*. US, Cincinnati: CURT.

CW Staff. (2014). *Dubai to make BIM software mandatory for major projects*. Retrieved from http://arabianindustry.com/.

Dainty, A. R. J. (1998*). A grounded theory of the determinants of woman`s under-achievement in large construction companies*. Loughborough University.

Dalgliesh, C. D., Bowen, P. A., & Hill, R. C. (1997). Environmental sustainability in the delivery of affordable housing in South Africa. *Engineering, Construction and Architectural Management, 4*(1), 23-39.

Daly, H. (1993). Sustainable growth: an impossibility theorem. In H. Daly, & K. Townsend Eds.), *Valuing the earth: Economics, ecology ethics*. Cambridge: MIT Press.

Davies, R., & Harty, C. (2013). Measurement and exploration of individual beliefs about the consequences of building information modelling use*. Construction Management and Economics, 31*(11), 1110-1127.

Davis, M. (2005). *Scientific papers and presentations.* United Kingdom, London: Elsevier Ltd.

Dawson, C. (2002). *Practical research methods: a user-friendly guide to mastering research techniques and projects.* Oxford: How to Books Limited.

Dedrick, J., Gurbaxani, V., & Kraemer, K. L. (2003). Information technology and economic performance: A critical review of the empirical evidence. *Journal of ACM Computing Surveys, 35*(1), 1–28.

Denholm, C., & Evans, T. (2007). *Supervising doctorates down under: Keys to effective supervision*. Australia: Acer Press.

Denscombe, M. (2007). *The good research guide: For small scale social research projects* (3rd ed.). UK, Maidenhead: Open University Press, Mc Graw-Hill Education.

Denzin, N, & Lincoln, Y. (1998). *Collecting and interpreting qualitative materials.* CA: Sage, Thousand Oaks.

DETR [Department of Environment, Transport and the Regions]. (1999). *A better quality of life: a strategy for sustainable development for the United Kingdom.* London: DETR.

DETR [Department of Environment, Transport and the Regions]. (2000). *Building a better quality of life: a strategy for more sustainable construction.* Retrieved from http://webarchive.nationalarchives.gov.uk/20090609014547/http://www.berr.gov.uk/files/file13547.pdf.

Dictionary online. (2018). Retrieved from http://www.dictionary.com/

Dillon, J., & Wals, A. E. J. (2006). On the danger of blurring methods, methodologies and ideologies in environmental education research. *Environmental Education Research, 12*(3-4), 549-558.

Ding, G. K. C. (2008). Sustainable construction: The role of environmental assessment tools. *Journal of Environmental Management, 86*(3), 451–464.

Dlakwa, M., & Culpin, M. (1990). Reasons for overrun in public sector construction projects. *Nigeria, Butterworth-Heinemann Ltd. 8*(4); 237- 241.

Dong, B., O'Neill, Z., & Li, Z. (2014). A BIM-enabled information infrastructure for building energy Fault Detection and Diagnostics. *Automation in Construction, 44*, 197–211.

Donovan, N. (2017). *Two stage tenders what is two stage tendering?* Retrieved from https://www.lexology.com/library/detail.aspx?g=2e5ada34-30a9-4e9e-987a-6c8c270cb5a3.

Doroudiani, S., and Omidian, H. (2010). Environmental, health and safety concerns of decorative mouldings made of expanded polystyrene in buildings. *Building and Environment*, 45(3), 647–654.

Dossick, C. S., & Neff, G. (2010). Organizational divisions in BIM enabled commercial construction. *Journal of Construction Engineering and Management, 136*(4), 459–467. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000109.

DTI (Department of Trade and Industry). (n.d). Tool and techniques for process improvement. Retrieved from http://www.businessballs.com/dtiresources/TQM_process_improvement_tools.pdf.

Du Plessis, C. (2001). Sustainability and sustainable construction: the African context. *Building Research and Information*, 29(5), 374–380.

Duke, P., Higgs, S., & McMahon, W. R. (2010). *Integrated project delivery: The value proposition. An owner's guide for launching a healthcare capital Project via IPD*. Retrieved from http://www.waterallianceafrica.org/portals/KLMK/Skins/KLMK_Rev/images/KLMKIPDWhitePaperFinal2010.pdf.

Dwairi, S., Mahdjoubi, L., Odeh, M., & Kossmann, M. (2016). Development of OntEIR framework to support BIM clients in construction. *International Journal of 3-D Information Modeling, 5* (1). 45-66. Retrieved from http://www.igi-lobal.com/gateway/article/171613.

Earley, M. (2015). *BIM Level 2 Standards for Business*. Retrieved from http://www.bim-manager.net/.

Easterby-Smith, M., Golden-Biddle, K., & Locke, K. (2008). Working with pluralism: Determining quality in qualitative research. *Organizational Research Methods, 11*(3): 419-429.

Easterby-Smith, M., Thorpe, R., & Jackson, P. (2012). *Management research* (4th ed.). London: Sage Publications.

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2008). BIM handbook: a guide to Building Information Modelling for owners, managers, designers, engineers, and contractors. Hoboken, N.J: Wiley Publishing.

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). *BIM handbook: A guide to Building Information Modeling for owners, managers, designers, engineers and contractors* (2nd ed.). New York: John Wiley and Sons.

Eckblad, S., Ashcraft, H., Audsley, P., Blieman, D., Bedrick, J., & Brewia, C. (2007). *Integrated project delivery: A working definition*. AIA California Council, Sacramento, California.

Edel, D. H., & Christenson, R. J. (1967). *Introduction to creative design.* Englewood Cliffs, N.J: Prentice-Hall.

Edwards, B. (1999). *Sustainable architecture: European directives and building design* (2nd ed.). Oxford: Butterworth-Heinemann Ltd.

Eere. (n.d). *The social benefits of sustainable design*. Retrieved from https://www1.eere.energy.gov/femp/pdfs/buscase_section3.pdf.

Egan, J. (1998). *Rethinking construction: report of the construction task force on the scope for improving the quality and efficiency of UK construction*. London: Department of the Environment, Transport and the Region

Emmitt, S., and Ruikar, K. (2013). *Collaborative design management*. UK, London: Routledge.

Enache-Pommer, E., & Horman, M. (2009). Key processes in the building delivery of green hospitals. *Building a Sustainable Future*, 636–645.

Enkvist, P. A., Naucler, T., & Rosander, J. (2007). A cost curve for greenhouse gas reduction. *McKinsey Q. 1,*35–45.

Eriksson, P. E., & Westerberg, M. (2011). Effects of cooperative procurement procedures on construction project performance: A conceptual framework. *International Journal of Project Management, 29*(2), 197-208.

Etikan, I., Musa, S. A., & Allkassim, R. S. (2015). Comparison of convenience and purposive sampling. *American Journal of Theoretical and Applied Sciences, 5*(1), 1-4.

European Construction Technology Platform (ECTP). (2008). *Vision and strategic research agenda focus area processes and ICT*. Retrieved from http://www.ectp.org.

Evans, R., Haryott, R., Haste, N., & Jones, A. (1998). *The long-term costs of owning and using buildings.* London: Royal Academy of Engineering.

Farrell, P. (2011). *Writing a built environment dissertation: Practical guidance and examples.* Oxford, UK: WileyBlackwell.

Fellows, R. F., & Liu, A. M. (2015). *Research methods for construction*. London: John Wiley & Sons.

FFEM and ANME. (2010). *Introducing thermal and energy requirements standards in Tunisia.* French Fund for Global Environment and National Agency for Energy Management (ANME). Retrieved from: http://www.ffem.fr/jahia/webdav/site/ffem/shared/ELEMENTS_COMMUNS/U_ADMINISTRATEUR/5PUBLICATIONS/Changement_climatique/Plaquette_Tunisie_ReglThermique_GB.pdf

Fitzgerald, B., & Howcroft, D. (1998). Towards dissolution of the IS research debate: From polarisation to polarity. *Journal of Information Technology, 13*, 313-326.

Forcada, N., Gangolells, M., Casals M., & Macarulla, M. (2017). Factors affecting rework costs in construction. *Journal of Construction Engineering and Management, 143*(8).

Foulkes, J. (2012). *Design and build procurement in the context of BIM and the government construction strategy*. Retrieved from https://www.fgould.com/uk-europe/articles/design-and-build-procurement-context-bim-and-gover/.

Fox, S., & Hietanen, J. (2007). Inter-organizational use of building information models: Potential for automational, informational and transformational effects. *Construction Management and Economics*, 25(3), 289-296.

Francom, T., Asmar, M., & Ariaratnam, S. (2014, May). *Using alternative project delivery methods to enhance the cost performance of trenchless construction projects*. Paper presented at the Construction Research Congress, 1219-1228.

Gamage, I. S. W. (2011). *A waste minimisation framework for the procurement of design and build construction projects*. PhD Thesis. Loughborough University.

Garner, J. (2014). *Tendering strategies RICS guidance note*. London, UK: Royal Institution of Chartered Surveyors (RICS).

Gee, J. P. (2005) *An Introduction to Discourse Analysis: Theory and Method*. New York: Routledge.

Gerber, D. J., Lin, S. H. E., Pan, B. P., & Solmaz, A. S. (2012, March). Design optioneering: Multi-disciplinary design optimization through parameterization, domain integration and automation of a genetic algorithm' in L Nikolovska and R Attar (eds). *SimAUD 2012*, Orlando, Florida, USA, pp. 23-30

Gerges, M., Ahiakwo, O., Jaeger, M., & Asaad, A. (2016). Building Information Modeling and its application in the state of Kuwait. I*nternational Journal of Civil, Environmental, Structural, Construction and Architectural Engineering, 10*(1), 81-86.

Gerges, M., Austin, S., Mayouf, M., Ahiakwo, O., Jaeger, M., & Saad, A. (2017). An investigation into the implementation of Building Information Modeling in the Middle East. *Journal of Information Technology in Construction (ITcon), 22*(2), 1–15. Retrieved from http://www.itcon.org/2017/1.

Gerges, M., Austin, S., Mayouf, M., Ahiakwo, O., Jaeger, M., Saad, A., & Gohary, T. E. (2017). An investigation into the implementation of Building Information Modeling in the Middle East. *Journal of Information Technology in Construction (ITcon), 22*, 1-15. Retrieved from http://www.itcon.org/2017/1.

Gerring, J. (2007). Is There a (Viable) Crucial-Case Method? *Comparative Political Studies*, *40*(3), 231-253.

Ghassemi, R., & Becerik-Gerber, B. (2011). Transitioning to integrated project delivery: Potential barriers and lessons learned. *Lean Construction Journal,* 32–52.

Ghazal, M. (2016, January 30). Population stands at around 9.5 million, including 2.9 million guests. *The Jordan Times*. Retrieved from http://www.jordantimes.com/news/local/population-stands-around-95-million-including-29-million-guests.

Gibbs, D. J., Emmitt, S., Lord, W., & Ruikar, K. (2015). BIM and construction contracts: CPC 2013's approach*. Proceedings of the ICE: Management, Procurement & Law, 168*(6), 285-293. DOI: 10.1680/jmapl.14.00045.

Giddings, B., Hopwood, B., & O'Brien, G. (2002). Environment, economy and society: Fitting them together into sustainable development. *Sustainable Development, 10* (4), 187-196.

Giedion, S. (1967). *Space, time and architecture: the growth of a new tradition*. Harvard University Press.

Giel, B., Issa, R., & Olbina, S. (2010, August). *Return on investment analysis of Building Information Modeling in construction*. Paper presented at the Proceedings of the International Conference on Computing in Civil and Building Engineering, UK. Retrieved from http://www.engineering.nottingham.ac.uk/icccbe/proc eedings/pdf/pf77.pdf.

Glen, W. (1994). Use value of historical space structures in relation to adaptability for housing. *International Journal for Housing Science and Its Applications*, 18(1), 63-68

Goedert, J. D., & Meadati, P. (2008). Integrating construction process documentation into Building Information Modeling. *Journal of Construction Engineering and Management, 134*(7), 509–516. https://doi.org/10.1061/(ASCE)0733-9364(2008)134:7(509).

Goodrum, P., Smith, A., Slaughter, B., & Kari, F. (2008). Case study and statistical analysis of utility conflicts on construction roadway projects and best practices in their avoidance. *Journal of Urban Planning and Development, 134* (2), 63–70.

Government Construction Strategy. (GCS). (2016). Government construction strategy (2016-20). Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/510354/Government_Construction_Strategy_2016-20.pdf.

Graphisoft. (2003). *The Graphisoft virtual building: Bridging the Building Information Model from concept into reality*. (Graphisoft White paper). Graphisoft, Budapest.

Gray, C., & Hughes, W. (2001). *Building design management*. Oxford: Butterworth-Heinemann.

Green, J., & Thorogood, N. (2004). *Qualitative methods for health research*. London: Sage Publications.

Grifa, M. A. (2006*). The construction industry in Libya, with particular reference to operations in Tripoli.* PhD Thesis. Newcastle University.

Grilo, A., & Jardim-Goncalves, R. (2011). Challenging electronic procurement in AEC sector: A BIM-based integrated perspective. *Automation in Construction, 20*(2), 107–114. Retrieved from https://www.sciencedirect.com/science/article/pii/S0926580510001378.

Grilo, A., Jardim-Goncalves, R. (2010). Building Information Modeling and collaborative working environments. *Automation in Construction, 19*(5), 521-664.

Gu, N., & London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction, 19*(8), 988–999.

Guba, E. G. (1990). The alternative paradigm dialog. In E. G. Guba (Ed.), *The paradigm dialog* (pp. 17-30). Newbury Park, CA: Sage Publications.

Haapio, A., & Viitaniemi, P. (2008). A critical review of building environmental assessment tools. *Environmental Impact Assessment Review, 28*(7), 469–482.

Hadaddin, K. (2014). *The construction industry in Jordan.* Retrieved from http://www.appconsultores.org.pt/fotos/editor2/sem_jordania_17_03_2009_construction_industry.ppt.

Häkkinen, T., & Kiviniemi, A. (2008, September) *Sustainable building and BIM*. Paper presented at the Proceedings of the SB08 Conference Melbourne. Melbourne, 21-25.

Hall, M., & Purchase, D. (2006). Building or bodging? Attitudes to sustainability in UK public sector housing construction development. *Sustainable Development, 1*4, 205-218. https://doi.org/10.1002/sd.265.

Halliday, S. (2008). *Sustainable construction*. Oxford: Butterworth-Heinemann.

Halsnaes, K. (2002). *Climate change & sustainable development: prospects for developing countries.* London: Earthscan publications Ltd.

Hammond, G. P., and Jones, C. I. (2008). Embodied energy and carbon in construction materials. *Proceedings of the Institution of Civil Engineers-Energy*, 161(2), 87–98.

Hamza N., & Greenwood D. (2007, September). *The impact of procurement methods on delivering environmentally sensitive buildings*. Paper presented at the Proceedings of 23rd Annual ARCOM Conference. Belfast, UK: Association of Researchers in Construction Management, 723-732.

Hamza, N., & Greenwood, D. (2009). Energy conservation regulations: Impacts on design and procurement of low energy buildings. *Journal of Building and Environment, 44* (5), 929-936.

Hanf, K., & Jansen, A. (1998). *Governance and environment in Western Europe: Politics, policy and administration.* Harlow: Longman.

Hannele, K., Reijo, M., Tarja, M., Sami, P., Jenni, K., & Teija, R. (2012). Expanding uses of Building Information Modeling in life-cycle construction projects. *Work, 41*, 114-119.

Hardin, B. (2009). *BIM and construction management: Proven tools, methods, and workflows.* Indianapolis, Indiana, US: Wiley Publishing.

Hardin, B., & McCool D. (2015). *BIM and construction management: Proven tools, methods, and workflows* (2nd Edition.). US, New Jersey, Hoboken: John Wiley & Sons.

Hartmann, T., Van Meerveld, H., Vossebeld, N., & Adriaanse, A. (2012). Aligning building information model tools and construction management methods. *Automation in construction, 22,* 605-613.

Hawken, P., Lovins, E., & Lovins, H. (1999). *Natural capitalism: Creating the next industrial revolution*. United states, Washington, DC: Little Brown and Company.

Hay, C. (2002). *Political analysis. A critical introduction.* Basingstoke: Palgrave.

HEEPI, SUST & Thirdwave. (2008). *High performance buildings: The business case for universities and colleges.* Retrieved from http://www.sustainabilityexchange.ac.uk/files/hpb_business_case.pdf.

Hergunsel, M. F. (2011). *Benefits of building information modelling for construction managers and BIM scheduling*. Master thesis. Worcester Polytechnic Institute, Worcester, MA.

Hill, R., & Bowen, P. (1997). Sustainable construction: principles and a framework. *Journal of Construction Management and Economics, 15*(3), 223-239. https://doi.org/10.1080/014461997372971.

Hjelseth, E. (2009, July). *Exchange of relevant information in BIM-objects defined by the Life cycle Information Model (LIM*). Paper presented at the CIB-IDS, Finland, Espoo.

HM Government. (2012). *Building Information Modeling, industrial strategy: Government and industry in partnership* (Government Report). London.

Holmberg, J. (Ed.). (1992). *Making development sustainable: Redefining institutions, policy, and economics*. Washington, DC: Island Press.

Holness, G. V. R. (2008). Building Information Modeling Gaining Momentum. *|| ASHRAE Journal, 50*(6), 28-40.

Holzer, D. (2007, September). *Are you talking to me? Why BIM alone is not the answer.* Paper presented at the Proceedings of the Fourth International Conference of the Association of Architecture Schools of Australasia.

Holzer, D. (2009). *Sense-making across collaborating disciplines in the early stages of architectural design*. PhD Thesis. RMIT University.

Holzer, D. (2015). BIM for procurement: Procuring for BIM. In R. H. Crawford, & A. Stephan, (Eds.). *Living and learning: Research for a better built environment: 49th International Conference of the Architectural Science Association 2015*, pp.237–246. The Architectural Science Association and The University of Melbourne.

Hooper, M., & Ekholm, A. (2010, November). *A pilot study: towards BIM integration. An analysis of design information exchange & coordination*. Paper presented at the Proceedings of the CIB W78 2010: 27th International Conference. Cairo, Egypt.

Hopwood, B., Mellor, M., & O'Brien, G. (2005) Sustainable development: Mapping different approaches. *Sustainable Development, 13*(1), 38-52.

Horman, M. Riley, D., Lapinski, A., Korkmaz, S., Pulaski, M., Magent, C. Luo, Yupeng Harding, N., Dahl, P. (2006). Delivering green buildings: Process improvements for sustainable construction. *Journal of Green Building, 1*(1), 123-140. https://doi.org/10.3992/jgb.1.1.123.

Howard, R., & Bjork, B. C. (2008). Building Information Modelling: Experts´ views on standardisation and industry deployment. *Advanced Engineering Informatics, 22*(2), 271-280.

Howell, I., & Batcheler, B. (2005). *Building Information Modelling two years later huge potential, some success and several limitations*. Newforma white paper.

Hughes, W., Champion, R. and Murdoch, J. (2015) Construction Contracts. 5th ed. Oxon: Routledge.

Hughes, W., Murdoch, J.R., 2001. *Roles in Construction Projects: Analysis and Terminology*. Birmingham: Construction Industry Publications.

Huovila, P., & Koskela, L. (1998, August). *Contribution of the principles of lean construction to meet the challenges of sustainable development*. Paper presented at the Proceedings of International Group for Lean Construction (IGLC). Sao Paulo, Brazil.

Hyde, K. F. (2000). Recognising deductive processes in qualitative research. *Qualitative Market Research: An International Journal, 3*(2), 82-89.

Ibrahim, M., Krawczyk, R., & Schipporiet, G. (2004). *A web-based approach to transferring architectural information to the construction site based on the BIM object concept*. Presented in the proceeding of Culture, Technology and Architecture, South Korea conference.

ICAEN (Institut Català d'Energi). (2004). *Sustainable building: Design manual, volume 2*. New Delhi: The Energy and Resources Institute.

Ilozor B., & Kelly D. (2012). Building Information Modeling and integrated project delivery in the commercial construction industry: A conceptual study. *Journal of Engineering, Project, and Production, 2*(1), 23–36. Retrieved from http://www.ppml.url.tw/EPPM_Journal/volumns/02_01_January_2012/ID_013_2_1_23_36.pdf.

International Institute for Sustainable Development. (1992). *Business strategy for sustainable development, leadership and accountability for the '90s.* Winnipeg: International Institute for Sustainable Development.

Jänicke, M., & Weidner, H. (1997). Germany. In M. Jänicke, & H. Weidner, (Eds.), *National environmental policies: A comparative study of capacity-building*. Berlin: Springer-Verlag.

Janicke, M., & Weidner, H. (1997). National environmental policies: A comparative study of capacity building. Berlin: Springer-Verlag.

Jauhiainen J. (2011). BIM maturity: The second generation. *SOLIBRI magazine*. Helsinki, FINLAND: Solibri, Inc.

Jennings, D., & Wattam, S. (1998). *Decision making: an integrated approach* (2nd ed.). Washington, D.C*:* Financial Times Pitman Publishing.

Jin Lin, S., Ali, A., & Alias, A. (2015). Analytic hierarchy process decision-making framework for procurement strategy selection in building maintenance work. *Journal of Performance of Constructed Facilities, 29*(2), 1-13. https://doi.org/10.1061/(ASCE)CF.1943-5509.0000529.

Jordan Construction Contractors Association (JCCA). (2015). *Annual Report 2015*. Amman, Jordan. Retrieved from http://www.jcca.org.jo/DataFiles/Annual_Report/Final%20Anual%20Report%202015..pdf.

Jordan Construction Contractors Association (JCCA). (2016). *Annual Report 2016*. Amman, Jordan. Retrieved from http://www.jcca.org.jo/DataFiles/Annual_Report/Final%20Anual%20Report%202016..pdf

Jordan Times. (2015). Gov't preparing 10-year plan for construction sector growth. *The Jordan Times.* Retrieved from http://www.jordantimes.com/news/local/gov%E2%80%99t-preparing-10-year-plan-construction-sector-growth%E2%80%99.

Jordan Times. (2017a). JD 1.5b worth of construction projects ongoing: Halaseh. *The Jordan Times.* Retrieved from http://www.jordantimes.com/news/locl/jd15b-worth-construction-projects-ongoing-%E2%80%94-halaseh.

Jordan Times. (2017b). 2030 sustainable development agenda top priority for Jordan. *The Jordan Times*. Retrieved from http://www.jordantimes.com/news/local/2030-sustainable-development-agenda-top-priority-jordan%E2%80%99.

Jung, Y, & Gibson, G.E. (1999). Planning for computer integrated construction. *Journal of Computing in Civil Engineering, ASCE, 13*(4), 217–225.

Jung, Y., & Joo, M. (2011). Building information modelling (BIM) framework for practical implementation. *Automation in Construction, 20*(2), 126–133.

Kapogiannis, G., Gaterell, M., & Oulasoglou, E. (2015). Identifying Uncertainties Toward Sustainable Projects. *Procedia Engineering, 118*, 1077-1085.

Kassem, M., Iqbal, N., Kelly, G., Lockley, S., & Dawood., N. (2014). Building information modelling: protocols for collaborative design processes. *Journal of Information Technology in Construction (ITcon), 19*, 126-149.

Kent, D. C., & Becerik-Gerber, B. (2010). Understanding construction industry experience and attitudes toward integrated project delivery. *Journal of Construction Engineering and Management, 136*(8), 815-825.

Khaddaj, M., & Srour, I. (2016). Using BIM to retrofit existing buildings. *Procedia Engineering, 145,* 1526-1533. http://dx.doi.org/10.1016/j.proeng.2016.04.192.

Khosrowshahi, F., & Arayici, Y. (2012). Roadmap for implementation of BIM in the UK construction industry. *Engineering, Construction and Architectural Management, 19*(6), 610-635. https://doi.org/10.1108/09699981211277531.

Kibert, C. J. (2005). *Sustainable construction: green building design and delivery*. Hoboken, New Jersey: John Wiley and Sons, Inc.

Kibert, C. J. (2007). The next generation of sustainable construction. *Building Research and Information, 35*(6), 595-601.

Kibert, C. J. (2008). *Sustainable construction: Green building design and delivery* (2nd ed.). New Jersey: John Wiley & Sons.

Kibert, C. J., Sendzimir, J., & Guy, B. (2000). Construction ecology and metabolism: natural system analogues for a sustainable built environment. *Construction Management and Economics*, 18(8), 903–916.

Kim, H., & Anderson, K. (2012). Energy modelling system using Building Information Modelling open standards. *Journal of Computing in Civil Engineering, 27*(3), 203–211. https://doi.org/10.1061/(ASCE)CP.1943-5487.0000215.

Kim, J. I., Kim, J. H., Fischer, M., & Orr, R. (2015). BIM-based decision-support method for master planning of sustainable large-scale developments. *Automation in Construction, 58*, 95-108. http://dx.doi.org/10.1016/j.autcon.2015.07.003.

Kim, K. P. (2014). *Conceptual Building Information Modelling framework for whole-house refurbishment based on LCC and LCA*. PhD Thesis. Aston University.

Kisbi, Y. (2011). Construction in Jordan melds old and new methods for energy efficiency. *Washington Times*. Retrieved from http://www.washingtonenergysummit.com/2011/twt/images/TWT_Energy_Section.pdf.

Kiviniemi, A., Tarandi, V., Karlshoj, J., Bell, H., & Karud, O.J. (2008). *Review of the development and implementation of IFC compatible BIM*. A technical report for ERAbuild. Retrieved from https://www.sintef.no/globalassets/upload/byggforsk/bygninger/erabuild-bim-final-report-january-2008.pdf.

Kneifel, J. (2010). Life-cycle carbon and cost analysis of energy efficiency measures in new commercial buildings. *Energy and Buildings*, 42(3), 333–340.

Knight, A., & Ruddock, L. (2008). *Advanced research methods in the built environment.* United Kingdom: Wiley-Blackwell.

Knight, D., & Addis, B. (2011, November). *Embodied carbon dioxide as a design tool: a case study*. Paper presented at the Proceedings of the Institution of Civil Engineers, Telford, 171–176.

Konchar, M., & Sanvido, V. (1998). Comparison of U.S. project delivery system. *Journal of Construction Engineering and Management, 124*(6), 435 – 444.

Koolwijk, J. S. J., & Vrijhoef, R. (2005, June). *Procurement strategies for dynamic control of construction projects and supply chain.* Paper presented at the Proceeding of the 11th Joint CIB International Symposium. Advancing Facilities Management and Construction through Innovation, Helsinki, Finland, 184–185.

Koppinen, T., & Lahdenperä, P. (2004). The current and future performance of road project delivery methods. *VTT Publications*. Retrieved from https://www.vtt.fi/inf/pdf/publications/2004/P549.pdf

Korkmaz, S., Messner, J., Riley, D. R., & Magent, C. (2010). High performance green building design process modeling and integrated use of visualization tools. *Journal of Architectural Engineering, 16*(1), 37–45.

Korkmaz, S., Swarup, L., & Riley, D. (2013). Delivering sustainable, high-performance buildings: influence of project delivery methods on integration and project outcomes. *American Society of Civil Engineers.* DOI: 10.1061/(ASCE)ME.1943-5479.0000114.

Krygiel, E., & Nies, B. (2008). *Green BIM: successful sustainable design with building information modeling.* Indianapolis: Wiley Publishing.

Ku, K., and Mills, T. (2010). *Research needs for building information modeling for construction safety*. US, Boston: Associated Schools of Construction.

Kumanayake R. P., & Bandara R. M. P. S. (2012, August). *Building Information Modelling (BIM): How it improves building performance.* Paper presented at the International Symposium on Ensuring National Security through Reconciliation & Sustainable Development. Colombo, Sri Lanka, 357–365.

Kumar, S. S., & Cheng, J. C. P. (2015). A BIM-based automated site layout planning framework for congested construction sites. *Automation in Construction, 59*, 24-37. http://dx.doi.org/10.1016/j.autcon.2015.07.008.

Kylili, A., Fokaides, P.A., Vaiciunas, J., & Seduikyte, L., (2015). Integration of building information modelling (BIM) and life cycle assessment (LCA) for sustainable constructions. *Journal of Sustainable Architecture and Civil Engineering, 4* (13), 28-38. http://dx.doi.org/10.5755/j01.sace.13.4.12862.

Kymell, W. (2008). *Building Information Modeling. Planning and managing construction projects with 4D CAD and simulations*. McGrawHill. New York.

Labuschagne, C., & Brent, A. C. (2005). Sustainable project life cycle management: The need to integrate life cycles in the manufacturing sector. *International Journal of Project Management, 23,* 159–168.

LACCD. (2016). *BIM Standard.* Los Angeles, USA: Los Angeles Community College District.

Lahdenperä, P. (2001). Design-Build procedures. Introduction, illustration and comparison of U.S. modes. *Espoo: VTT Publications, 452*. Retrieved from http://www.vtt.fi/inf/pdf/publications/2001/P452.pdf.

Laishram, B. (2011, December). *Building Information Modeling in PPP projects: Perspectives and hurdles.* Paper presented at the International Conference on Structural Engineering, Construction & Management. Kandy, Sri Lanka

Lancaster, F.D., & Tobin, J. (2010, May). *Integrated project delivery: Next generation BIM for structural engineering*. Paper presented in the Structural Congress conference, ASCE. https://doi.org/10.1061/41130(369)254.

Langdon, D. (2012). *Getting the most out of BIM a guide for clients.* Retrieved from https://issuu.com/jojowasmydog/docs/davis_langdon_-_bim_guide_for_clients_-_apri_l2012.

Rawlinson, S. (2006). *Procurement: construction management.* Retrieved from http://www.Building.co.uk.

Lapinski, A., Horman, M., & Riley, D. (2006). Lean processes for sustainable project delivery. *Journal of Construction Engineering and Management, 132*(10).

Latham, M. (1994). *Constructing the team: Final report of the government/industry review of procurement and contractual arrangements in the UK construction industry.* London: HMSO.

Lee, S., Kim, K., & Yu, J. (2014). BIM and ontology-based approach for building cost estimation. *Automation in Construction, 41*, 96-105.

Lee, S., Yu, J., & Jeong, D. (2015). BIM acceptance model in construction organizations. *Journal of Management Engineering, 10*(1061).

Lekka-Kowalik, A. (2010). Why science cannot be value-free. Understanding the rationality and responsibility of science. *Science and Engineering, Ethics, 16*, 33-41.

Lim, Y. W. (2015). Building Information Modeling for indoor environmental performance analysis. *American Journal of Environmental Sciences, 11* (2), 55-61.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Newbury Park, CA: Sage Publications.

Liu, R., & Issa, R. R. A. (2012). 3D visualization of sub-surface pipelines in connection with the building utilities: Integrating GIS and BIM for facility management. *Computing in Civil Engineering*, 341–348.

Liu, Z., Osmani, M., Demian, P., & Baldwin A. N. (2011, October). *The potential use of BIM to aid construction waste minimalisation*. Paper presented at the Proceedings of the CIB W78-W102 2011: International Conference. Sophia Antipolis, France.

Locke, E. A. (2007). The case for inductive theory building. *Journal of Management, 33*(6), 867-890.

Lomborg, B. (2001). *The sceptical environmentalist: Measuring the real state of the world.* Cambridge: Cambridge University Press.

London, K., Singh, V., Taylor, C., Gu, N., & Brankovic, L. (2008, September). *Building Information Modelling project decision support framework*. Paper presented at the Proceedings of the Twenty-Fourth Annual Conference Association of Researchers in Construction Management (ARCOM). Cardiff, UK, 665-673.

Loosemore, M. (2013). *Innovation, strategy and risk in construction: Turning serendipity into capability.* London: Routledge. http://dx.doi.org/10.4324/9780203809150.

Lopez, R., Love, P. E. D., Edwards, D.J., & Davis, P. R. (2010). Design error classification, causation, and prevention in construction engineering. *Journal of Performance of Constructed Facilities, 24*(4), 399–408.

Love, P. E. D., & Smith, J. (2003). Benchmarking, benchaction, and benchlearning: Rework mitigation in projects. *Journal of Management in Engineering*, 147–159.

Love, P. E. D., Davis, P., Baccarini, D., Wilson, G., & Lopez, R. (2008, March). *Procurement selection in the public sector: A tale of two states.* Paper presented at the Clients Driving Innovation. Third International Conference of the Cooperative Research Centre (CRC) for Construction Innovation. Gold Coast, Australia, 1-11.

Love, P. E. D., Edwards, D., Irani, Z., & Sharif, A. (2012). Participatory action research approach to public sector procurement selection. *J. Constr. Eng. Manage, 138*(3), 311–322.

Love, P. E. D., Edwards, D.J., Smith, J., & Walker, D. H. T. (2009) Divergence or congruence? A path model of rework for building and civil engineering projects. *Journal of Performance of Constructed Facilities, 23*(6), 480–488.

Love, P. E. D., Skitmore, M., & Earl, G. (1998). Selecting a suitable procurement method for a building project. *Construction Management and Economics, 16*(2), 221-233.

Lowe, H., & Muncey, M. (2010). ConsensusDOCS 301 BIM Addendum. Construction Lawyer. *Associated GeneralContractors of America*. Retrieved from https://www.agc.org/.

Lu W., Fung A., Peng Y., Liang C., & Rowlinson S. (2014). Cost benefit analysis of Building Information Modeling implementation in building projects through demystification of time-effort distribution curves. *Building and Environment, 82*(2014), 317-327. doi:10.1016/j.buildenv.2014.08.030.

Lu, Y., Li, Y., Skibniewski, M., Wu, Z., Wang, R., & Le, Y. (2015). Information and communication technology applications in architecture, engineering, and construction organizations: A 15-year review. *Journal of Management Engineering, 31*(1). https://doi.org/10.1061/(ASCE)ME.1943-5479.0000319.

Lu, Y., Wu, Z., Chang, R., & Li, Y. (2017). Building Information Modeling (BIM) for green buildings: A critical review and future directions. *Automation in Construction, 83*, 134-148. DOI: 10.1016/j.autcon.2017.08.024.

Macozoma, D. S. (2002). *Understanding the concept of flexibility in design for deconstruction. Design for Deconstruction and Materials Reuse*. University of Karlsruhe Karlsruhe, Germany: CIB Publication, 272.

Magent, C., Korkmaz, S., Klotz, L., & Riley, D. (2009). A design process evaluation method for sustainable buildings. *Journal of Architectural Engineering and Design Management, 5*(1–2), 62–74.

Mah, D., Manrique, J.D., Yu, H., Al-Hussein, M., & Nasseri, R. (2011). House construction CO2 footprint quantification: a BIM approach. *Construction Innovation, 11*(2), 161–178.

Manning, R., & Messner, J. (2008). Case studies in BIM implementation for the programming of healthcare facilities. *Journal of Information Technology in Construction (ITcon), 13*, 246–257.

Mante, J., Ndekugri, I., Ankrah, N., & Hammond, F. (2012, September*). The influence of procurement methods on dispute resolution mechanism choice in construction*. Paper presented at the 28th Annual ARCOM Conference. Edinburgh, UK, Association of Researchers in Construction Management, 979-988.

Maricopa. (2011). *A primer on construction delivery methods*. Retrieved from http://www.gc.maricopa.edu/adminsvcs/oct_05/insert.pdf.

Mark, L. (2013). *Architects 'liable for energy performance'.* Retrieved from https://www.architectsjournal.co.uk/architects-liable-for-energy-performance/8646999.article.

Markeset, T., & Kumar, U. (2003). Integration of RAMS and risk analysis in product design and development work processes: a case study. *Journal of Quality in Maintenance Engineering*, 9(4), 393–410.

Marshall, C., & Rossman, G. B. (2010). *Designing qualitative research* (5th ed.). UK, London: Sage Publication Inc.

Martin, C., & Guerin, D. (2006). Using research to inform design solutions. *Journal of Facilities Management, 4*(3), 167-180. https://doi.org/10.1108/14725960610673751.

Martin, H. (2012). *BIM anatomy: An investigation into implementation prerequisites*. Lund University Faculty of Engineering.

Masterman, J. W. E. (2002) *Introduction to building procurement systems* (2nd ed.). London: Spon Press.

Masurier, J. L., Wilkinson, S., & Shestakova, Y. (2006, April). *An analysis of the alliancing procurement method for reconstruction following an earthquake*. Paper presented at the Proceedings of the 8th U.S. National Conference on Earthquake Engineering, 1.

Matarneh, R., & Hamed, S. (2017). Exploring the adoption of Building Information Modeling (BIM) in the Jordanian Construction Industry. *Journal of Architectural Engineering Technology, 6*(189). Doi: 10.4172/2168-9717.1000189.

Matthews, J., Love, P., Heinemann, S., Chandler, R., Rumsey, C., & Olatunj, O. (2015). Real time progress management: Re-engineering processes for cloud-based BIM in construction. *Automation in Construction, 58*, 38-47. http://dx.doi.org/10.1016/j.autcon.2015.07.004.

McCuen, T. L., Suemann, P. C., & Krogulecki, M. J. (2012). Evaluating award-winning BIM projects using the national building information model standard capability maturity model. *Journal of Management in Engineering, 28*(2), 224–230. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000062.

Mcgough, D., Ahmed, A., & Austin, S. (2013). Integration of BIM in higher education: Case study of the adoption of BIM into Coventry University's Department of Civil Engineering, Architecture and Building. *Proceedings of Sustainable Building and Construction Conference,* (SB13), 394–403.

McGraw-Hill. (2010a). *Green BIM: How Building Information Modeling is contributing to green design and construction*. Bedford, MA: McGraw-Hill Construction.

McGraw-Hill. (2010b). *SmartMarket report: The business value of BIM in Europe.* Bedford, MA: McGraw-Hill Construction.

McGraw-Hill. (2014). *SmartMarket report: The business value of BIM for construction in major global markets*. Massachusetts, Bradford: McGraw-Hill Construction.

McPartland, R. (2016). *What is the Common Data Environment (CDE)? National Building Specification (NBS).* Retrieved from https://www.thenbs.com/knowledge/what-is-the-common-data-environment-cde.

Meadowcroft, J. (2007). National sustainable development strategies: features, challenges and reflexivity. *European Environment, 17*, 152-163. https://doi.org/10.1002/eet.450.

Meadowcroft, J., (2000). Sustainable development: A new(ish) idea for a new century. *Political Studies, 48*(2), 370-387.

Menezes, A., Cripps, A., Bouchlaghem, D., & Buswell, R. (2012). Predicted vs. actual energy performance of non-domestic buildings: using post-occupancy evaluation data to reduce the performance gap. *Applied Energy, 97*, 355-364. Retrieved from https://dspace.lboro.ac.uk/2134/9937.

Middle East Construction News. (2011). *Jordan's BIM masterplan in ME Construction News.* Retrieved from http://meconstructionnews.com/1552/the-tech-revolution.

Miettinen R., & Paavola S. (2014). Beyond the BIM utopia: Approaches to the development and implementation of Building Information Modeling. *Automation in Construction, 43,* 84–91. http://doi.org/10.1016/j.autcon.2014.03.009.

Migliaccio, G., Gibson, G., & O'Connor, J. (2009). Procurement of Design-Build services: Two-phase selection for highway projects*. Journal of Management Engineering, 25*, (1), 29–39.

Mihindu, S., & Arayici Y. (2008, July). *Digital construction through BIM systems will drive the re-engineering of construction business practices*. Paper presented at the Proceedings of Visualisation, International Conference. London, 29–34.

Miller, R., Strombom, D., Iammarino, M., & Black, B. (2009). *The commercial real estate revolution: Nine transforming keys to lowering costs, cutting waste, and driving change in a broken industry.* United States, New Jersey. John Wiley & Sons.

MillsOakley. (2015). *IPD and BIM: A new dimension to collaboration*. Retrieved from http://www.millsoakley.com.au/ipd-and-bim-a-new-dimension-to-collaboration/.

Minchin, R., Jr., Li, X., Issa, R., & Vargas, G. (2013). Comparison of cost and time performance of Design-Build and Design-Bid-Build delivery systems in Florida. *J. Constr. Eng. Manage., 139*(10).

Ministry of Energy and Mineral Resources-Jordan (MEMR). (2012). *Annual Report*. Retrieved from http://eis.memr.gov.jo/publication/2016-04-03-07-59-21/annual-report/81-annual-report-2012.

Ministry of Public Work and Housing (MPWH). (1987). *Government works by-law No. (71) of 1987 Jordan*. Retrieved from http://mpwh.gov.jo/English/Pages/bylaw2.aspx.

MMRAE. (1991). *National environment strategy for Jordan*. Amman: Al-Iman Press.

MMRAE. (1995). *Environment Protection Law, Number (12)*. Amman: GCEP.

MMRAE. (1999). *Jordan national agenda 21.* Unpublished report. Amman: GCEP.

Mohemad, R., Hamdan, A. R., Othman, Z. A., & Noor, N. M. M. (2011, June). *Modelling ontology for supporting construction tender evaluation process*. Paper presented at the International Conference on Semantic Technology and Information Retrieval. Putrajaya, Malaysia, 285-288. Retrieved from http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5995803.

Molenaar, K. R., Songer, A. D., & Barash, M. (1999). Public-sector design/build evolution and performance. *Journal of Management in Engineering, 15*(2), 54–62.

Molenaar, K., Sobin, N., Gransberg, D., McCuen, T., Korkmaz, S., & Horman, M. (2009). *Sustainable, high performance projects and project delivery methods: A state-of practice report.* White Paper for the Design-Build Institute of America and the Charles Pankow Foundation.

Moore, D.R., & Dainty, A. R. J., (2000). Work-Group communication problems within UK design and build projects: An investigative framework. *Journal of Construction Procurement,* 44-55.

Morledge, R., Smith, A., & Kashiwagi, D. T. (2006). *Building procurement*. London: Blackwell publishing ltd.

Morrell, P. (2010). *Low carbon construction innovation and growth team: Final report.* London: Department for Business Innovation and Skills (BIS). Retrieved from http://www.carbonaction2050.com/sites/carbonaction2050.com/files/document-attachment/IGT%20Low%20Carbon%20Construction.pdf.

Mostafa, A. S. (2016). *Developing the construction procurement methods in the UAE to implement Building Information Modelling (BIM*). MSc Dissertation. The British University in Dubai (BUiD), Dubai. Retrieved from http://bspace.buid.ac.ae/handle/1234/952.

MP. (1993). *Economic and Social Development Plan 1993–1997*. Amman: Jordan Press Foundation.

MPWH. (2018a). *Construction laws*. Retrieved from http://www.mpwh.gov.jo/English/Pages/laws.aspx.

MPWH. (2018b). *Ministry directorate*. Retrieved from http://mpwh.gov.jo/English/Pages/Department.aspx.

Mulvihill, P.R., & Jacobs, P. (1998). Using scoping as a design process. *Environmental Impact Assessment Review, 18*(4), 351-369.

Muriro, A. (2015). *Design and build procurement method in practice: key challenges and practice-based enablers*. PhD Thesis. University of Salford.

MWI. (2016). *National Water Strategy of Jordan, 2016 – 2025.* Retrieved from http://www.mwi.gov.jo/sites/enus/Hot%20Issues/Strategic%20Documents%20of%20%20The%20Water%20Sector/National%20Water%20Strategy(%202016-2025) 25.2.2016.pdf.

Nanajkar, A., & Gao, Z. (2014, September). BIM implementation practices at India's AEC firms. Paper presented at the International Conference on Construction and Real Estate Management 2014 (pp. 134–139). https://doi.org/10.1061/9780784413777.016.

Naoum, S. G. (2007). *Dissertation research and writing for construction students* (2nd ed.). Oxford, UK: Elsevier Butterworth-Heinemann.

Naoum, S. G. (2011). *Procurement and management of construction*. MSc Lecture notes (unpublished material). School of Built Environment and Architecture. London South Bank University, pp. 1-15.

NASA., & S. A. F. E. (2001). *Report on sustainable design, design for maintainability and total building commissioning.* National Aeronautics and Space Administration (NASA).

Nassar, L. (2017). *Implementing the 2030 agenda for sustainable development in Jordan: where are we now?* WANA Institute. Retrieved from http://wanainstitute.org/en/blog/implementing-2030-agenda-sustainable-development-jordan-where-are-we-now.

National Institute of Building Sciences. (2007). *United States national building information modeling standard version 1- part 1: Overview, principles, and methodologies.* Washington: National Institute of Building Sciences. Retrieved from http://www.facilityinformationcouncil.org/bim/publications.php.

National Research Council. (2009). *Advancing the competitiveness and efficiency of the U.S. Construction Industry*. Washington, DC: National Academies Press.

NBIMS. (2012). *Frequently asked questions about the national BIM standard-United States.* Retrieved from https://www.nationalbimstandard.org/faqs.

NBS. (2011). *NBS National BIM report 2011*. UK: National Building Specification (NBS). Retrieved from https://www.thenbs.com/knowledge/nbs-national-bim-report-2011

NBS. (2013). *National BIM report 2013*. UK: National Building Specification (NBS). Retrieved from https://www.thenbs.com/knowledge/nbs-international-bim-report-2013.

NBS. (2015). *National BIM report 2015.* UK: National Building Specification (NBS). Retrieved from https://www.thenbs.com/knowledge/nbs-national-bim-report-2015.

NBS. (2016). *National BIM report 2016*. UK: National Building Specification (NBS). Retrieved from https://www.thenbs.com/knowledge/national-bim-report-2016.

NBS. (2016). *NBS international BIM report*. RIBA Enterprises. Retrieved from https://www.thenbs.com/knowledge/nbs-international-bim-report-2016

Neumayer, E. (1999). The ISEW: Not an index of sustainable economic welfare. *Social Indicators Research, 48*, 77-101.

Newsham, G. R., Mancini, S., & Birt, B. J. (2009). Do LEED-certified buildings save energy? Yes, but … . *Energy and Buildings, 41*(8), 897–905.

NHBC. (2013). *Zero carbon strategies for tomorrow's new homes*. Milton Keynes, UK: NHBC Foundation.

Nikou Goftar, V., El Asmar, M., & Bingham, E. (2014). A Meta-analysis of literature comparing project performance between Design-Build (DB) and Design-Bid-Build (DBB) delivery systems. *Construction Research Congress 2014*, 1389-1398

Nofera, W., and Korkmaz, S. (2010, November). *Design Process Integration for Sustainable, High performance Buildings*. Paper presented in the proceedings of The Engineering Project Organizations Conference, 4-6, Lake Tahoe, CA.

Ofori, G. (1998). Sustainable construction: Principles and a framework for attainment—comment. *Construction Management and Economics, 16*, 141-145. http://dx.doi.org/10.1080/014461998372448.

Olatunji, O. A. (2011). A preliminary review on the legal implications of BIM and model ownership. *Journal of Information Technology in Construction (ITcon), 16*, 687–696.

Omran, A., Alnor, M. A., & Gebril, A. O. (2012). An Evaluation of the critical success factors for construction projects in Libya. *Journal of Economic Behaviour, 2*(1), 17-25.

Onwuegbuzie, A., & Leech, N. (2005) On becoming a pragmatic researcher: The importance of combining quantitative and qualitative research methodologies. *International Journal of Social Research Methodology, 8*(5), pp. 375-387.

Operational Energy Use-wikicommon language (n.d). Retrieved from http://www.sccommonlanguage.eu/index.php?title=Operational_Energy_Use.

Oppenheim, A. N. (2000). *Questionnaire design, interviewing and attitude measurement*. Bloomsbury Publishing.

Page, P., Carr, J., Chadwick, D., & Porter, K. (2012). *An introduction to clinical research.* Oxford University Press.

Pandey, R. P., & Shahbodaghlou, F. (2015, September). *Measuring contribution of Building Information Modeling (BIM) to the construction sustainability goals*. Paper presented at the 51st ASC Annual International Conference Proceedings. Texas, 2015.

Parasonis, J., Keizikas, A., & Kalibatiene, D. (2012). The relationship between the shape of a building and its energy performance. *Architectural Engineering and Design Management, 8*(4), 246–256.

Park, M., Ji, S., Lee, H., & Kim, W. (2009). Strategies for Design-Build in korea using system dynamics modelling. *Journal of Construction Engineering and Management, 135*(11), 1125–1137.

Patton, M. Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). Newbury Park, CA: Sage Publications, Inc.

Patton, M. Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). Newbury Park, California: Sage Publications.

Pcholakis. (2010). *LEAN construction project delivery methods: Job order contracting, IPD, 5D BIM.* Retrieved from https://buildinginformationmanagement.wordpress.com/tag/matoc/.

Pearce, A.R., Han Ahn, Y., & Global, H. (2012). *Sustainable buildings and infrastructure: Path to the future.* London and New York: Routledge, Taylor & Francis Group.

Pearce, D. (2006). Is the construction sector sustainable? Definitions and reflections. *Journal of Building Research and Information, 34*(3), 201-207.

Penttila, H. (2006). Describing the changes in architectural information technology to understand design complexity and free-form architectural expression. *IT in Construction, 11*, 395-408

Petra News. (2000). In letter of designation, king urges new premier to protect national unity*. The Jordan Times*, *25*(7481), 1-4.

Pilanawithana, N., & Sandanayake, Y.G. (2017). Positioning the facilities manager's role throughout the building lifecycle. *Journal of Facilities Management, 15*(4), 376-392. https://doi.org/10.1108/JFM-06-2016-0024.

Pishdad-Bozorgi, P., & de la Garza, J. (2012). *Comparative analysis of Design-Bid-Build and Design-Build from the standpoint of claims*. Paper presented at Construction Research Congress conference, 21-30. Indiana, United States. American Society of Civil Engineers.

Plebankiewicz, E. (2009). Contractor prequalification model using fuzzy sets. *Journal of Civil Engineering and Management 15*(4): 377–385. http://dx.doi.org/10.3846/1392-3730.2009.15.377-385.

Pollack, J. (2007). The changing paradigms of project management*. International Journal of Project Management, 25*(3), 266.

Popic, Z., & Moselhi, O. (2014). Project delivery systems selection for capital projects using the analytical hierarchy process and the analytical network process. *Construction Research Congress, 2014*, 1339-1348

Porwal, A., & Hewage, K. N. (2013). Building Information Modeling (BIM) partnering framework for public construction projects. *Automation in Construction, 31*, 204–214. https://doi.org/10.1016/j.autcon.2012.12.004.

Preuss, L. (2009). Addressing sustainable development through public procurement: the case of local government. *Supply Chain Management: An International Journal 14*(3), 213–223.

Prins, M., & Owen, R. (2010). Integrated design and delivery solutions. *Archit. Eng. Des. Manage., 6*(4), 227–231.

Public Project Authority (PPA). (2010). *Report on the implementation of buildings and infrastructures projects.* Public Project Authorities, Management of Follow-up and Information, Tripoli.

Ramey, H.L., & Grubb, S. (2009). Moderism, postmodernism and (evidence-based) practice. *Contemporary Family Therapy, 31*, 75-86.

Raskin, J. (2008) The evolution of constructivism. *Journal of Constructivist Psychology*, 21(1), 1-24.

Redclift, M. (2005). Sustainable development (1987-2005): An oxymoron comes of age. *Sustainable Development, 13*(4), 212-227.

Redmond, A., Hore, A., Alshawi, M., & West, R. (2012). Exploring how information exchanges can be enhanced through Cloud BIM, Alan Redmond, Alan. *Automation in Construction, 24*, 175– 183.

Reed, M., Fraser, E., & Dougill, A. (2006). An adaptive learning process for developing and applying sustainability indicators with local communities. *Ecological Economics, 59*(4), 406 – 418.

Renner, M. (2003*). Analysing qualitative data*: *Program development evaluation*. University of Wisconsin-Extension.

RIBA Gulf Chapter. (n.d). *RIBA Gulf Chapter*. Retrieved from https://www.architecture.com/my-local-riba/riba-gulf-chapter.

RIBA. (2011). *Green Overlay to the RIBA Plan of Work (2011)*. RIBA. London, UK.

RIBA. (2012). *BIM Overlay to the RIBA Plan of Work (2012)*. RIBA. London, UK.

RIBA. (2013). *RIBA Plan of Work (2013)*. RIBA. London, UK.

Riege, A. M. (2003). Validity and reliability tests in case study research: A literature review with “hands-on” applications for each research phase. *Qualitative Market Research: An international journal, 6(*2), 75-86.

Riley, D., Magent, M., & Horman, M. (2004). *Sustainable metrics: A design process model for high performance buildings. Proceedings of 16th CIB World Congress, International Council for Research and Innovation in Building and Construction (CIB)*. Rotterdam, Netherlands.

Roaf, S., Crichton, D., & Nicol, F. (2009) *Adapting building and cities for climate change: A 21st century survival guide* (2nd ed.). Oxford: Architectural Press.

Robichaud, L. B., & Anantatmula, V. (2011). Greening project management practices for sustainable construction. *Journal of Management Engineering.* https://doi.org/10.1061/(ASCE)ME.1943-5479.0000030.

Roginski, D. (2011). *Quantity take-off process for bidding stage using BIM tools in Danish Construction Industry*. Master Thesis. Technical University of Denmark. Retrieved from http://www.bim.byg.dtu.dk/upload/subsites/bim/04%20uddannelse/eksamensprojekter/master%20thesis%20%20quantity%20takeoff%20process%20for%20bidding%20stage%20using%20bim%20tools%20in%20danish%20construction%20industry.%20daniel%20roginski%20s091.pdf.

Root, D., & Hancock, M. (1996). Familiarity and procurement preference-putting the brake on the adoption of new procurement methods: Economic management of innovation. *Productivity and Quality in Construction, 11*, 523-534.

Rosenburg, T. L. (2007). *Building Information Modeling.* Retrieved from https://s3.amazonaws.com/academia.edu.documents/7868726/building%20information%20modeling%20%20rosenberg.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1532253857&Signature=M6ez%2FwcpBXjcNlgiCm%2FoHV3EKj0%3D&response-content-disposition=inline%3B%20filename%3DBuilding_Information_Modeling.pdf.

Rosmayati, M., Abdul Razak, H., Zulaiha, A., & Noor, M. M. N. (2010). Decision Support Systems (DSS) in construction tendering processes. *International Journal of Computer Science, 7*(2), 35-45.

Rowlinson, S. (1987). *Design Build: Its development and present status* (Occasional Paper). The Chartered Institute of Building (CIOB), London.

RSSJ and FES. (2013). *Green building development in Jordan*. Amman, Jordan: The Royal Scientific Society of Jordan and the Friedrich-Ebert-Stiftung.

Rwelamila, P., & Edries, R. (2007). Project procurement competence and knowledge base of civil engineering consultants: An empirical study. *Journal of, Management in Engineering, 3*(4), 182-192.

Sackey, E., Tuuli, M., & Dainty, A. (2015). Sociotechnical systems approach to BIM implementation in a multidisciplinary construction context. *Journal of Management Engineering, 31*(1). https://doi.org/10.1061/(ASCE)ME.1943-5479.0000303.

Sacks, R., Koskela, L., Dave, B. A., and Owen, R. (2010). Interaction of lean and building information modeling in construction. *Journal of Construction Engineering Management*, 136(9), 968–980. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000203.

Salmon, J. (2012). *Wicked IPD procurement programs: IPD & BIM solutions unleashed.* Retrieved from https://www.augi.com/articles/detail/wicked-ipd-procurement-programs-ipd-bim-solutions-unleashed.

Sassi, P. (2006). *Strategies for sustainable architecture.* London: Routledge.

Saunders, M., Lewis, P., & Thornhill, A. (2012). *Research methods for business students* (6th ed.). New York: Prentice Hall.

Saunders, M., Lewis, P., Thornhill, A., & Wilson, J. (2009). *Business research methods.* London: Prentice Hall.

Saxon, R. G. (2013). *Growth through BIM.* Construction Industry Council, London.

Schlueter, A., & Thesseling, F. (2009). Building information model based energy/exergy performance assessment in early design stages. *Automation in Construction, 18*(2), 153-63.

Scotland, J. (2012). Exploring the philosophical underpinnings of research: Relating ontology and epistemology to the methodology and methods of the scientific, interpretive, and critical research paradigms. *English Language Teaching, 5*(9), 9.

Sebastian, R. (2011, October). *BIM in Different Methods of Project Delivery*. Paper presented at the ICT for a Low Carbon Economy, Building Data Models, Proceedings of the 2nd Workshop organised by the EEB Data Models Community CIB Conference W078-W012, Sophia Antipolis, France. http://2011-cibw078-w102.cstb.fr/papers/Paper-134.pdf

Sebastian, R. (2011b). Changing roles of the clients, architects and contractors through BIM. *Engineering, Construction and Architectural Management, 18*(2), 176-187. https://doi.org/10.1108/09699981111111148.

Seng, N. W., & Yusof, A. M. (2006, September). *The success factors of design and build procurement method: a literature visit*. Paper presented at the Proceedings of the 6th Asia-Pacific Structural Engineering and Construction Conference, 1-11.

Serpell, A., & Alarcon, L.F. (1998). Construction process improvement methodology for construction projects. *International Journal of Project Management 16*(4), 215 – 221.

Sev, A. (2009). How can the construction industry contribute to sustainable development? *A Conceptual Framework. Sustainable Development, 17*(3), 161-173. https://doi.org/10.1002/sd.373.

Sexton, M. (2003, April). *A supple approach to exposing and challenging assumptions and PhD path dependencies in research*. Paper presented at the 3rd international postgraduate research conference. Lisbon. Retrieved from http://www.research.scpm.salford.ac.uk/bf2003/sexton_keynote.pdf.

Sheth, B. A. Z. (2011). *A refurbishment framework with an emphasis on energy consumption of existing healthcare facilities.* PhD Thesis. Loughborough University.

Shoubi, M. V., Bagchi, A., & Barough, A. S. (2015). Reducing the operational energy demand in buildings using building information modeling tools and sustainability approaches. *Ain Shams Engineering Journal, 6*(1), 41-55. https://doi.org/10.1016/j.asej.2014.09.006.

Shrestha, P., O'Connor, J., & Gibson, G. (2012). Performance Comparison of Large Design-Build and Design-Bid-Build Highway Projects. *Journal of Construction Engineering Management, 138*(1), 1–13.

Shrivastava, S., & Chini, A. (2012). Using Building Information Modeling to assess the initial embodied energy of a building. *International Journal of Construction Management, 12*(1), 51–63. https://doi.org/10.1080/15623599.2012.10773184.

Silverman, D. (1998). Qualitative Research Meanings or Practices?. *Information Systems Journal.* 8(1), 3 – 20.

Silverman, D. (2004). *Qualitative research: theory, method and practice*. New Delhi: Sage Publication.

Simonian, L., & Korman, T. (2010). *Legal considerations in the United States associated with Building Information Modeling.* COBRA 2010 CIB W113 Law & Dispute Resolution. Paris.

Sinha, A., Gupta, R., Kutnar, A. (2013). Sustainable Development and Green Buildings. *Drvna Industrija*, 64(1), 45–53.

Sive, T., & Hays, M. (2009). Integrated project delivery: Reality and promise. *Society for Marketing Professional Services Foundation*. Retrieved from http://www.tedsive.com/docs/Sive_White_Paper_IPD.pdf.

Skinner, M. (2010). *Research: The essential guide.* British Film Institute, London. Retrieved from https://www.scribd.com/document/35577412/Film-Research-the-.

Slaughter, E. S. (2001). Design strategies to increase building flexibility. *Building Research and Information*, 29(3), 208–217.

Smith, D. K., & Tardif, M. (2009). *Building Information Modeling: A strategic implementation guide for architects, engineers, constructors, and real estate managers*. New Jersey: John Wiley & Sons.

Smith, P. (2014). BIM implementation: Global strategies. *Procedia Engineering, 85,* 482–492.

Soltani, S. (2016) The Contributions of Building Information Modelling to sustainable construction. *World Journal of Engineering and Technology, 4*, 193-199. http://dx.doi.org/10.4236/wjet.2016.42018.

Son, H., Kim, C., Chong, W. K., & Chou, J. S. (2011). Implementing sustainable development in the construction industry: Constructors' perspectives in the US and Korea*. Sustainable Development, 19*(5), 337-347. DOI: 10.1002/sd.442.

Sourani, A., & Sohail, M. (2013). Enabling sustainable construction in UK public procurement. Proceedings of the ICE. *Management, Procurement and Law, 166*(6), 297 – 312.

Steel, J., Drogemuller, R., & Toth, B. (2012). Model interoperability in building information modelling. *Journal of Software and Systems Modeling, 11*(1), 99–109.

Steurer, R., Martinuzzi A. (2005). Towards a new pattern of strategy formation in the public sector: first experiences with national strategies for sustainable development in Europe. *Environment and Planning C: Politics and Space, 23*(3), 455–472. https://doi.org/10.1068/c0403j.

Stiles, W. B. (1993). Quality control in qualitative research. *Clinical Psychology Review, 13*, 593-618.

Straker, D. (1995). *A tool book for quality improvement and problem solving.* London: Prentice Hall.

Strauss, A., & Corbin, J. M. (1990). *Basics of qualitative research: Grounded theory procedures and techniques.* Thousand Oaks, CA, US: Sage Publications, Inc.

Stumpf, A., Kim, H., & Jenicek, E. (2009). Early design energy analysis using BIMs (building information models). *Building a Sustainable Future,* 426-436. Doi:10.1061/41020(339)44

Succar, B. (2009). Building information modelling framework: a research and delivery foundation for industry stakeholders. *Automation in Construction, 18*(3), 357–375.

Succar, B., & Kassem, M. (2015). Macro-BIM adoption: Conceptual structures. *Automation in Construction, 57*, 64-79. Retrieved from http://bit.ly/BIMpaperA8.

Succar, B., Sher, W., & Williams, A. (2012). Measuring BIM performance: Five metrics. *Architectural Engineering and Design Management, 8*(2), 120-142.

Suermann, P. C., and Issa, R. A. (2009). Evaluation industry perceptions of building information modelling (BIM) impact on construction. *Journal of Information Technology in Construction*, 14, 574–594.

Sulankivi, K., Kähkönen, K., Mäkelä, T., Kiviniemi, M. (2010, May). *4D-BIM for construction safety planning*. Paper presented in proceedings of the CIB World Congress, Manchester.

Sun, M., & Meng, X. (2009) Taxonomy for change causes and effects in construction projects, *International Journal of Project Management, 27*(6), 560–572.

Swanson, D., Pinter, L., Bregha, F., Volkery, A., & Jacob, K. (2004). *National strategies for sustainable development: Challenges, approaches and innovations in strategic and coordinated action.* Winnipeg, Eschborn: IISD and GTZ.

Swarup, L., Korkmaz, S., & Riley, D. (2011). Project delivery metrics for sustainable, high-performance buildings. *Journal of Construction Engineering and Management, 137*(12), 1043–1051.

Sweis, G. J., Rateb, S., Malek, A. R., Ruba, A. H., & Samer, E. D. (2013). Cost overruns in public construction projects: The case of Jordan. *Journal of American Science, 9*(7), 134-141. Retrieved from http://www.jofamericanscience.org.

Swetnam, D., & Swetnam, R. (2007). *Writing your dissertation*. Oxford: Spring Hill House.

Tahmasebi, M. M., Banihashemi, S., & Hassanabadi, M. S. (2011). Assessment of the variation impacts of window on energy consumption and carbon footprint. *Procedia Engineering, 21,* 820-828. http://dx.doi.org/10.1016/j.proeng.2011.11.2083.

Talebi, S. (2014, October). *Rethinking the project development process through use of BIM.* Paper presented at the Second BIM international conference challenges to overcome.

Tashakkori, A., & Teddlie, C. (1998). *Handbook of mixed methods in social & behavioural research.* Thousand Oaks, CA: Sage Publications, 273 – 296.

Tashakkori, A., & Teddlie, C. (2003). Major issues and controversies in the use of mixed methods in the social and behavioral sciences. In C. Tashakkori, A. Teddlie (Eds.), *Handbook of mixed methods in social & behavioral research.* Thousand Oaks, CA. Sage

Taylor, J. E., & Bernstein, P. G. (2009). Paradigm trajectories of building information modeling practice in project networks. *J. Manage. Eng.*, *2*(69), 69–76.

Teddlie, C., & Yu, F. (2007). Mixed methods sampling: A typology with examples. *Journal of Mixed Methods Researc*h, (1), 77-100.

Tewfik, M., & Ali, M. (2014). Public green buildings in Jordan. *European International Journal of Science and Technology, 3*(7), 2304-9693.

The Hashemite Kingdom of Jordan. (1986). *Pub. Law Number (71) of 1986.* Retrieved from http://webcache.googleusercontent.com/search?q=cache:http://www.gtd.gov.jo/usersfile/upload_files/5171192471331932480.doc&gws_rd=cr&ei=MN0BWZmbH4uegAbA_q84.

Thompson, E. K. (1977). *Recycling buildings: renovations, remodellings, restorations, and reuses; Architectural record*. US, New York: McGraw-Hill, Inc.

Thwala, W. D., & Mathonsi, M. D. (2012). Selection of procurement systems in the South African construction industry: An exploratory study. *Acta Commercii, Independent Research Journal in the Management Science, 12*(1), 13-26

Toukan, Z. (2018). *Jordan implementing the 2017-2019 PIM-PIP action plan*. Retrieved from https://www.menatransitionfund.org/sites/mena_trans_fund/files/documents/JO%20WB%20PIM-PPP%20Reform%20Proposal%20REVISED%20Restructured_0.docx.

TPA. (2016). *E/A design division BIM standard.* The Port Authority of NY & NJ Engineering Department, New York, United States.

Trochim, W. M., & Donnelly, J. P. (2006). *The research methods knowledge base* (3rd ed.). Cincinnati, OH: Atomic Dog.

Tuchman, G., Denzin, N. K., & Lincoln, Y. S. (Eds.) (1994). *Handbook of qualitative research,* (pp. 306-323). Thousand Oaks, CA, US: Sage Publications.

Tuohy, P.G., & Murphy, G.B. (2015). Closing the gap in building performance: Learning from BIM benchmark industries. *Architectural Science Review, 58*(1). 47-56. http://dx.doi.org/10.1080/00038628.2014.975780.

Turina, N., Radujkovic. M., & Pusic, D. C. (2008, September). *Design and Build in comparison with the traditional procurement and possibility of its application in the Croatian construction industry.* Paper presented at the 8th International Conference: Organization, Technology and Management in Construction. Umag, Hrvatska. Retrieved from https://bib.irb.hr/datoteka/362416.65Turina_Radujkovic_Car-Pusic.pdf.

Turner, A. E. (1990). *Building procurement.* London: Macmillan Building and Surveying Series.

UK Parliament. (2008). Climate Change Act: *Section 1(1).* Retrieved from https://www.legislation.gov.uk/ukpga/2008/27/part/1/crossheading/the-target-for-2050.

UKSDS (The UK Sustainable Development Strategy). (2005). *Securing the future: Delivering UK sustainable development strategy*. Retrieved from https://www.gov.uk/government/publications/securing-the-future-delivering-uk-sustainable-development-strategy.

UNCED. (1992). *United Nations Conference on Environment and Development*: *Agenda 21*. New York: United Nations Organization.

UNCHS. (1996). *An urbanising world: Global report on human settlements 1996*. Oxford: Oxford University Press.

UNDESA. (2002). *Guidance in preparing a national sustainable development strategy: Managing sustainable development in a new millennium* (Background Paper No. 13). ACCRA, GHANA: Department of Economic and Social Affairs.

UNEP. (2007). *Buildings and climate change: Status, challenges and opportunities*. United Nations Environmental Program (UNEP), Division of Technology, Industry and Economics (DTIE). Paris, France.

UNESCO. (2012). *Education for sustainable development.* United Nations Educational. Retrieved from http://unesdoc.unesco.org/images/0021/002163/216383e.pdf.

UN-Habitat. (2008). *Urban indicators*. United Nations (UN). Retrieved from https://unhabitat.org/urban-knowledge/guo/.

United Nations. (2015). *Jordan's way to sustainable development.* Retrieved from: https://sustainabledevelopment.un.org/content/documents/16289Jordan.pdf.

United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development*. Retrieved from https://sustainabledevelopment.un.org/post2015/transformingourworld.

Volk, R., Stengel, J., & Schultmann, F. (2014). Building Information Modeling (BIM) for existing buildings: Literature review and future needs. *Automation in Construction, 38*, 109–127.

Wacker, J. G. (1998). A definition of theory: Research guidelines for different theory-building research methods in operations management. *Journal of Operation Management, 16*, 361-385.

Wang, N., Chang, Y., & Nunn, C. (2010). Lifecycle assessment for sustainable design options of a commercial building in Shanghai. *Journal of Building and Environment, 45*, 1415-1421.

Wang, N., Wei, K., & Sun, H. (2014). Whole life project management approach to sustainability. *Journal of Management in Engineering, 30*(2), 246–255. Doi: 10.1061/(ASCE)ME.1943-5479.0000185

Watson, A. (2010, June). *BIM: A driver for change.* Paper presented at the Proceedings of the International Conference on Computing in Civil and Building Engineering W Tizani, (Editor). University of Nottingham, Retrieved from http://www.engineering.nottingham.ac.uk/icccbe/proceedings/pdf/pf69.pdf.

WCED (World Commission on the Environment and Development). (1987). *Our Common Future: The Brundtland Report*. Oxford: Oxford University Press.

Welle, B., Rogers, Z., & Fischer, M. (2012). BIM-centric daylight profiler for simulation (BDP4SIM): A methodology for automated product model decomposition and recomposition for climate-based daylighting simulation. *Building and Environment, 58*, 114–134. https://doi.org/10.1016/j.buildenv.2012.06.021.

Western Australian Council of Social Service (WACOSS). (2000). *Model of Social Sustainability, WACOSS*, Perth. Available at < http://www.wacoss.org.au >.

Weygant, R. S. (2011). *BIM content development: Standards, strategies, and best practices*. New Jersey, Hoboken: John Wiley & Sons.

Wickersham, J. (2009). *Legal and business implications of Building Information Modeling (BIM) and integrated project delivery (IPD).* Harvard University.

Willmott, D. (2010). *The impacts of construction and the built environment.* Retrieved from https://www.willmottdixon.co.uk/asset/9462/download.

Wisdom, J., & Creswell, J.W. (2013). *Mixed methods: Integrating quantitative and qualitative data collection and analysis while studying patient-centered medical home models.* Rockville, MD: Agency for Healthcare Research and Quality. AHRQ Publication No. 13-0028-EF.

Withers, L. (2014). *Government 'will miss key 2016 BIM target'*. Retrieved from https://www.building.co.uk/news/government-will-miss-key-2016-bim-target/5066460.article.

Won, J., Lee, G., & Lee, C. (2009, May). *Comparative analysis of BIM adoption in the Korean Construction Industry and other countries*. Paper presented at the Proceedings of 3rd International Conference on Construction Engineering and Management (ICCEM) and 6th International Conference on Construction Project Management (ICCPM). Jeju, South Korea.

Won, J., Lee, G., Dossick, C., & Messner, J. (2013). Where to focus for successful adoption of Building Information Modeling with an organization. *Journal of Construction, Engineering and Management. 139*(11). https://doi.org/10.1061/(ASCE)CO.1943-7862.0000731.

Wong, A. K., Wong, F. K., & Nadeem, A. (2009, January). *Comparative roles of major stakeholders for the implementation of BIM in various countries.* Paper presented at the International Conference on Changing Roles: New Roles, New Challenges. The Netherlands. Noordwijk Aan Zee.

Wong, A. K., Wong, F. K., & Nadeem, A. (2011). Government roles in implementing building information modelling systems: Comparison between Hong Kong and the United States. *Construction Innovation, 11*(1), 61-76.

Wong, K. D., & Fan, Q. (2013). Building Information Modelling (BIM) for sustainable building design. *Facilities, 31*(3/4), 138–157. https://doi.org/10.1108/02632771311299412.

Wood, G., and Newborough, M. (2003). Dynamic energy-consumption indicators for domestic appliances: environment, behaviour and design. *Energy and Buildings*, 35(8), 821–841.

World Bank. (2016). *How does the World Bank classify countries?* Retrieved from https://datahelpdesk.worldbank.org/knowledgebase/articles/ 378834-how-does-the-world-bank-classify-countries.

Wu, W., & Issa, R. R. (2014). BIM execution planning in green building projects: LEED as a use case. *Journal of Management in Engineering, 31*(1), A4014007. http://dx.doi.org/10.1061/(ASCE)ME.1943-5479.0000314#sthash.N9eiV7VR.dpuf.

Yan, H., & Demian, P. (2008, October). *Benefits and barriers of Building Information Modelling.* Paper presented at the Proceedings of the 12th International Conference on Computing in Civil and Building Engineering (ICCCBE XII) & 2008 International Conference on Information Technology in Construction (INCITE 2008). Tsinghua University, Beijing, China.

Yazan, A. A. (2010). *Climate change and the built environment: an evaluation of sustainable refurbishment options for higher education buildings in the UK.* PhD. Thesis. University of Birmingham.

Yin, R. K. (2003) *Case study research. Design and methods* (3rd ed.). Thousand Oaks, CA: Sage.

Yin, R. K. (2009). *Case study research: Design and methods* (4th ed.). Thousand Oaks, CA: Sage.

Young, N. W., Jones, S. A., & Bernstein, H. M. (2008). *Building Information Modeling (BIM): Transforming design and construction to achieve greater industry productivity*. New York: McGraw-Hill Construction.

Zanni, M. A. (2017). *Communication of sustainability information and assessment within BIM-enabled collaborative environment.* PhD Thesis. Loughborough University.

Zero Carbon Hub. (2014). *Closing the gap between design and as-built performance: evidence review report.* Technical Report. Zero Carbon Hub.

Zhang, J. P., & Hu, Z. Z. (2011). BIM- and 4D- based integrated solution of analysis and management for conflicts and structural safety problems during construction: 1. Principles and methodologies. *Automation in Construction, 20*(2), 155-66.

Zhang, J., Long, Y., Lv, S., & Xiang, Y. (2016). BIM-enabled modular and industrialized construction in China. *Procedia Engineering 145*, 1456-1461. http://dx.doi.org/10.1016/ j.proeng.2016.04.183.

Zhang, S., Lee, J., Venugopal, M., Teizer, J., and Eastman, C. (2012, May). *A framework for automatic safety checking of building information models*. Paper presented in the Construction Research Congress 2012, ASCE, Reston, VA, 574–581.

Zuo, J., & Zhao, Z. Y. (2014). Green building research-current status and future agenda: A review. *Renewable and Sustainable Energy Reviews, 30*, 271-281.

Zuppa, D., Issa, R., & Suermann, P.C. (2009). BIM's impact on the success measures of construction projects. *Journal of Computing in Civil Engineering*, 503- 512.

APPENDIX A: RESEARCH ETHICS

FORM UPR16

Research Ethics Review Checklist

Please include this completed form as an appendix to your thesis (see the Research Degrees Operational Handbook for more information

UNIVERSITY OF PORTSMOUTH

Postgraduate Research Student (PGRS) Information		**Student ID:**	670975
PGRS Name:	MOHAMMAD ALHUSBAN		
Department:	SCES	**First Supervisor:**	Dr. Salam Al-Bizri
Start Date: (or progression date for Prof Doc students)		**10/2014**	

Study Mode and Route:	Part-time ☐ Full-time ☒	MPhil ☐ PhD ☒	MD ☐ Professional Doctorate ☐			

Title of Thesis:	CONCEPTUAL PROCUREMENT FRAMEWORK FOR BUILIDNG INFORMATION MODELLING UPTAKE TO ENHANCE THE BUILDINGS' SUSTAINABILITY PERFORMANCE IN THE JORDANIAN PUBLIC SECTOR
Thesis Word Count: (excluding ancillary data)	73657

If you are unsure about any of the following, please contact the local representative on your Faculty Ethics Committee for advice. Please note that it is your responsibility to follow the University's Ethics Policy and any relevant University, academic or professional guidelines in the conduct of your study

Although the Ethics Committee may have given your study a favourable opinion, the final responsibility for the ethical conduct of this work lies with the researcher(s).

UKRIO Finished Research Checklist:
(If you would like to know more about the checklist, please see your Faculty or Departmental Ethics Committee rep or see the online version of the full checklist at: http://www.ukrio.org/what-we-do/code-of-practice-for-research/)

a) Have all of your research and findings been reported accurately, honestly and within a reasonable time frame?	YES ☒ NO ☐
b) Have all contributions to knowledge been acknowledged?	YES ☒ NO ☐
c) Have you complied with all agreements relating to intellectual property, publication and authorship?	YES ☒ NO ☐
d) Has your research data been retained in a secure and accessible form and will it remain so for the required duration?	YES ☒ NO ☐
e) Does your research comply with all legal, ethical, and contractual requirements?	YES ☒ NO ☐

Candidate Statement:

I have considered the ethical dimensions of the above named research project, and have successfully obtained the necessary ethical approval(s)

Ethical review number(s) from Faculty Ethics Committee (or from NRES/SCREC):	MA2

If you have *not* submitted your work for ethical review, and/or you have answered 'No' to one or more of questions a) to e), please explain below why this is so:

Signed *(PGRS)*:		**Date:** 18-09-2018

University of Portsmouth — Faculty of Technology

Technology Faculty Ethics Committee

ethics-tech@port.ac.uk

Date 03/01/17

Mohammad Alhusban

School of Civil Engineering and Surveying

Dear Mohammad,

Study Title:	A MODEL OF A PROCUREMENT APPROACH FOR EFFECTIVE IMPLEMENTATION OF BUILDING INFORMATION MODELLING
Ethics Committee reference:	MA2

The Ethics Committee reviewed the above application by an email discussion forum between the dates of 28/11/16 and 9/12/16.

Ethical opinion

The members of the Committee present gave a favourable ethical opinion of the updated submission of the above project on the basis of the change of research location described in the revised application form and notice of substantial amendment.

Conditions of the favourable opinion

Nil

Recommendations:

Nil

The favourable opinion of the EC does not grant permission or approval to undertake the research. Management permission or approval must be obtained from any host organisation, including University of Portsmouth, prior to the start of the study.

Summary of discussion at the meeting

The updated application was given a favourable opinion by the three reviewers.

Documents reviewed

The documents reviewed at the meeting were:

Faculty of Technology

Document	*Version*	*Date*
Revised Application Form	2	11/16
Notice of Substantial Amendment	1	11/16

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements set out by the University of Portsmouth

After ethical review

Reporting requirements

The attached document acts as a reminder that research should be conducted with integrity and gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Notification of serious breaches of the protocol
- Progress reports
- Notifying the end of the study

Feedback

You are invited to give your view of the service that you have received from the Faculty Ethics Committee. If you wish to make your views known please contact the administrator ethics-tech@port.ac.uk

Please quote this number on all correspondence: MA2

Yours sincerely and wishing you every success in your research

J Williams

John Williams

Chair Technology FEC

Email: ethics-tech@port.ac.uk

PARTICIPANT INFORMATION SHEET (INTERVIEWS)

Title of Project**: A Model of a Procurement approach for effective implementation of Building Information Modelling**

Name and Contact Details of Researcher(s): Mohammad Alhusban,

Email: mohammad.alhusban@port.ac.uk

Name and Contact Details of Supervisor: Salam Al-Bizri,

Email: salam.al-bizri@port.ac.uk

Ethics Committee Reference Number: MA2

Date and version: November 2016 (version 3.0)

Invitation

I am a second year PhD student in construction management field with background in civil engineering. This research is a part of my PhD degree requirements.

I would like to invite you to take part in my research study. Joining the study is entirely up to you, before you decide I would like you to understand why the research is being done and what it would involve for you. I will go through this information sheet with you, to help you decide whether or not you would like to take part and answer any questions you may have. I would suggest this should take about 60 minutes. Please feel free to talk to others about the study if you wish. Do ask if anything is unclear.

Study Summary

In Jordan and most developing countries, the construction industry faces problems such as chronic resource shortages, general situation of socio-economic stress, institutional weaknesses and a general inability to deal with the key issues. There is also evidence that the problems have become greater in extent and severity in recent years. Building Information Modelling (BIM) has emerged as a potential solution to these problems and to improve the performance of the construction industry. Construction procurement approaches currently applied in Jordan predate the use of lifecycle BIM for the delivery of construction projects. To date, little has been done to align the various procurement approaches used in delivering buildings with the novel opportunities offered via BIM. Participation in the research would require you to attend an interview with the researcher and take approximately 1 hour of your time.

What is the purpose of the study?

This study seeks to explore the current procurement practices to deliver public buildings. The study will also investigate whether these practices are fit for BIM implementation needs and its ability to assess to deliver high performance sustainable buildings. The primary reason behind conducting the research is to gain the Doctoral of Philosophy degree.

Why have I been invited?

You have been invited to take part because you have identified yourself of having experience in delivering a public buildings and BIM implementation.

Do I have to take part?

No, taking part in this research is entirely voluntary. It is up to you to decide if you want to volunteer for the study. I will describe the study in this information sheet. If you agree to take part, I will then ask you to sign the attached consent form, dated November 2016, version number, 3.0.

What will happen to me if I take part?

You will be interviewed for no more than one hour. If the interview has not been completed in this time, the interview can be extended by mutual agreement or arrangements for continuation at a later date will be made. By mutual consent additional interviews may take place to discuss specific areas of managing delivery process. The interview will look at particular areas of the delivery process but will allow scope for open answers and discussion of particular areas of interest in more depth.

Expenses and payments

There will be no expenses or payments on your part

Anything else I will have to do?

No

What data will be collected and / or measurements taken?

The researcher will tape record the entire interview if the participant agreed, then transcribe the text word for word. The transcribed text then becomes the data that are analysed.

What are the possible disadvantages, burdens and risks of taking part?

There are no known risks or disadvantages of taking part, as we strive to protect your confidentiality, unless you explicitly agree that the name of your company can be mentioned in publications arising from the research. If you are taking part in the face-to-face interview, we will send you the transcript of the interview before the analysis to allow you to ensure that you have not been misrepresented.

What are the possible advantages or benefits of taking part?

In taking part, you will be able to reflect on the current way of working. If you take part in an interview with us, we will provide you with the final research results which could have an impact on changing for better.

Will my taking part in the study be kept confidential?

Yes. All of the information you give will be anonymised so that those reading reports from the research will not know who has contributed to it, unless you explicitly agree that the name of your company may be made public. Nobody other than the researchers will have access to the data, which will be saved securely on password-protected computers and stored securely for 10 years in accordance with the Data Protection Act 1998.

The data, when made anonymous, may be presented to others at academic conferences, or published as a project report, academic dissertation or in academic journals or book. It could also be made available to any commissioner or funder of the research. Anonymous data, which does not identify you, may be used in future research studies approved by an appropriate research ethics committee.

The raw data, which would identify you, will not be passed to anyone outside the study team without your express written permission. The exception to this will be any regulatory authority which may have the legal right to access the data for the purposes of conducting an audit or enquiry, in exceptional cases. These agencies treat your personal data in confidence.

What will happen if I don't want to carry on with the study?

As a volunteer you can stop any participation in the interview at any time, or withdraw from the study at any time before, without giving a reason if you do not wish to. If you do withdraw from a study after some data have been collected you will be asked if you are content for the data collected thus far to be retained and included in the study. If you prefer, the data collected can be destroyed and not included in the study. Once the research has been completed, and the data analysed, it will not be possible for you to withdraw your data from the study.

What if there is a problem?

If you have a query, concern or complaint about any aspect of this study, in the first instance you should contact the researcher(s) if appropriate. If the researcher is a student, there will also be an academic member of staff listed as the supervisor whom you can contact. If there is a complaint and there is a supervisor listed, please contact the Supervisor with details of the complaint. The contact details for both the researcher and any supervisor are detailed on page 1.

If your concern or complaint is not resolved by the researcher or their supervisor, you should contact the Head of Department:

The Head of Department
School of Civil Engineering and Surveying
University of Portsmouth
Portland Building
Portland Street
Portsmouth
PO1 3AH

DR DOMINIC FOX
023 9284 2420
dominic.fox@port.ac.uk

If the complaint remains unresolved, please contact:

The University Complaints Officer

023 9284 3642 complaintsadvice@port.ac.uk

Who is funding the research?

This research is funded by the Middle East University, None of the researchers or study staff will receive any financial reward by conducting this study, other than their normal salary / bursary as an employee / student of the University.

Who has reviewed the study?

Research involving human participants is reviewed by an ethics committee to ensure that the dignity and well-being of participants is respected. This study has been reviewed by the Technology Faculty Ethics Committee and been given favourable ethical opinion.

Thank you

Thank you for taking time to read this information sheet and for considering volunteering for this research. If you do agree to participate your consent will be sought; please see the accompanying consent form. You will then be given a copy of this information sheet and your signed consent form, to keep.

CONSENT FORM

DR DOMINIC FOX
Head of School
Portland Building
Portland Street
Portsmouth
PO1 3AH

School of Civil Engineering and Surveying
Email: dominic.fox@port.ac.uk
Telephone: +44 (0)23 9284 2420

Title of Project: **A Model of a Procurement approach for effective implementation of Building Information Modelling**

Name and Contact Details of Researcher(s): Mohammad Alhusban,

Email: mohammad.alhusban@port.ac.uk

Name and Contact Details of Supervisor: Salam Al-Bizri,

Email: salam.al-bizri@port.ac.uk

Ethics Committee Reference Number: MA2

Date and version: November 2016 (version 3.0)

Please initial box

1. I confirm that I have read and understood the information sheet dated November 2016 (version 3.0) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. ☐

3. (If appropriate) I understand that the results of this study may be published and / or presented at meetings or academic conferences, and may be provided to research commissioners or funders. I give my permission for my anonymous data, which does not identify me, to be disseminated in this way. ☐

4. (If appropriate) I agree to the data I contribute being retained for any future research that has been approved by a Research Ethics Committee. ☐

5. I consent for my interview to be audio / video recorded. The recording will be transcribed and analysed for the purposes of the research (add further details about destruction or subsequent storage of recordings and / or transcripts). ☐

6. I consent to verbatim quotes being used in publications; I will not be named but I understand that there is a risk that I could be identified. ☐

7. I understand that the information collected about me will be used to support other research in the future, and may be shared anonymously with other researchers. ☐

8. I agree to be named as a participant and referred to accordingly. ☐

9. I would like to receive further information about the results of the study. ☐

10. I agree to take part in the above study. ☐

Name of Participant: ***Date:*** ***Signature:***

Name of Person taking Consent: ***Date:*** ***Signature:***

Note*: When completed, one copy to be given to the participant, one copy to be retained in the study file*

APPENDIX B: INVITATION LETTER

Study Title: A Model of a Procurement approach for effective implementation of Building Information Modelling

Dear Sir/Ma,

This is Mohammad Alhusban, a research student from School of Civil Engineering and Surveying, University of Portsmouth, UK. I am writing to invite you to participate in my research project. The research aim is to investigate whether procurement approaches influence the ability to use Building Information Modelling (BIM) techniques to deliver sustainable buildings in the Jordanian public construction industry.

The aim of the questionnaire survey is to investigate the feasibility of BIM implementation in the Jordanian public sector. Targeted respondents are public client, public consultants and public contractors. This questionnaire should take about 10 minutes to complete.

I would be very happy to answer any questions you may have and can be contacted on the e-mail address: mohammad.alhusban@port.ac.uk

I look forward to hear from you in due course. Thanking you in anticipation

Thank you,

Mohammad Alhusban

APPENDIX C: BIM FEASIBILITY STUDY QUESTIONNAIRE (MS WORD VERSION):

1. How long is your experience in construction?

    - Less than 5 years
    - 6-10 years
    - 11-20 years
    - More than 20 years

2. What type of company do you represent?

    - Public Client
    - Consultants
    - Contractors
    - Other

3. What size of company do you represent?

    - Micro 1-9 employees
    - Small 10-49 employees
    - Medium 50-249 employees
    - Large 250 and above

4. Does your company adopt and/ or use BIM? If yes, please go to question 5

    - No using
    - Yes, we have just adopted and started using BIM.
    - Yes, mainly for small-size projects.
    - Yes, we use BIM for every project.
    - No, but we plan to adopt it.

5. How open are you to adopting BIM?

    - We liked BIM and, we are willing to continue using it
    - We didn’t like BIM, and we think of stopping using it
    - Undecided

6. What is the stage of BIM utilization in your company?

    - Not using
    - Just adopt and use BIM for pilot projects
    - Adopted and used BIM for visualization Stage
    - Technical analysis and predication Stage

- Fully Integrated Stage
- Other, Please specify:

7. For what type of buildings does your company use BIM?

- Commercial/Retail
- Residential
- Education
- Healthcare
- Industrial
- Other, Please specify:

8. On a scale of 1 to 5 how will you rank the level of BIM awareness of you clients? Please use the scale in the following table.

- 1 Low
- 2
- 3
- 4
- 5 high

9. Who should drive the adoption of BIM?

- Government
- construction professional organizations as Jordanian Engineering Association
- Large construction companies
- Clients
- Joint responsibility between (government and the industry)
- Other, Please specify:

10. From literature review, the following are some of the documented benefits of adopting BIM. On a scale of 1-5. How will you rank them with 5 being the most beneficial and 1 being the least beneficial to the Jordanian public construction industry?

BIM benefits	1	2	3	4	5
• Improved decision-making process (better visualization and "what if "scenarios)					
• Reduced project time and cost					
• Improved quality					
• Improved construction process and efficiency					
• Improved safety					
• Reduced claims or litigation (risks)					
• Better design/multi design alternatives					
• Predictive analysis of performance					
• Improved operations and maintenance (facility					

management)					
• Improve collaboration in design and construction					
• Assist producing sustainable buildings					

11. What other benefits, not listed in question 9 do you think BIM has for the Jordanian public construction industry?

    - 1.
    - 2.
    - 3.

12. From literature review, the following are some of the documented challenges to adopt BIM. On a scale of 1-5. How will you rank them with 5 being the most related challenge and 1 being the least related challenge to the Jordanian public construction industry?

BIM barriers	1	2	3	4	5
• Culture change					
• Lack of legal framework (model ownership, legal contract)					
• Additional resources/ expenses					
• Lack of interoperability					
• Lack of BIM skills/ education and training					
• Lack of Standards					
• Attitude and awareness (resistance to change from 2D drafting practices)					
• Increase risk and liability					
• Procurement approach					
• Complexity (long hours to develop a BIM model)					
• Organisational challenges among construction professionals					

13. Do you think BIM adoption in the Jordanian public construction industry is timely?

    - Too early: the industry not ready yet
    - Early: possibly in the coming future
    - Timely: now is the time to adopt BIM since we need it
    - Late: there is still the possibility to adopt this technology
    - Too late: we are too behind

14. Could you please give any reasons for your answer to question 13 above?

    - 1.
    - 2.
    - 3.

15. With your experience in public sector and with projects that you have worked in the previous five years/ or are currently working on, which of the following procurement types are most adopted?

    - Design-bid-build
    - Design and build
    - Construction management
    - Integrated Project Delivery
    - Other, Please specify

16. Please provide your contact details below if you would like to participate in the next stage of the study:

    - Phone number:
    - Email Address:

APPENDIX D: BIM FEASIBILITY STUDY QUESTIONNAIRE (ONLINE VERSION):

University of Portsmouth

Building Information Modeling (BIM) Feasibility Study

1. How long is your experience in construction?

- ◯ Less than 5 years
- ◯ 6-10 years
- ◯ 11-20 years
- ◯ More than 20 years

2. What type of company do you represent?

- ◯ Public Client
- ◯ Private Client
- ◯ Contractor
- ◯ Consultant

3. What size of company do you represent?

- ◯ Micro 1-9 employees
- ◯ Small 10-49 employees
- ◯ Medium 50-249 employees
- ◯ Large 250 and above

4. Does your company adopt and/ or use BIM? If yes, please go to question 5

- ◯ Not use
- ◯ Yes, we just adopted and started using BIM
- ◯ Yes, mainly for small size projects
- ◯ Yes, we use BIM for every project
- ◯ No, but we plan to adopt

5. How open are you to adopting BIM?

- ◯ We liked BIM and we are willing to continue using it
- ◯ We didn't like BIM and we think of stopping using it
- ◯ Undecided

6. What is the stage of BIM utilization in your company?

- ◯ Not use
- ◯ Just adopt and use BIM for pilot projects
- ◯ Visualization Stage
- ◯ Technical Analyze and Predication Stage- Whole life cycle cost calculation, CO2 performance
- ◯ Fully Integrated Stage – Project schedule & cost and bill of material for procurement generated from BIM
- ◯ Other (please specify)

7. For what type of buildings does your company use BIM?

- ☐ Commercial/ Retail
- ☐ Residential
- ☐ Education
- ☐ Healthcare
- ☐ Industrial
- ☐ Other (please specify)

8. On scale 1 to 5 how will you rank the level of BIM awareness/desire amongst your clients? Please use the scale in the following table?

- ◯ 1 low
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 high

9. Who should drive the adoption of BIM ?

- ◯ Government
- ◯ Construction associations as Jordanian Engineering association and contractor association
- ◯ Large construction companies
- ◯ Clients
- ◯ Joint responsibility between government and the industry
- ◯ Other (please specify)

10. From literature review, the following are some of the documented benefits of adopting BIM. On a scale of 1-5. How will you rank them with 5 being the most beneficial and 1 being the least beneficial to the Jordanian construction industry

	1 least beneficial	2	3	4	5 most beneficial
Improved decision-making process (better visualization and "what if "scenarios)	○	○	○	○	○
Reduced project time and cost	○	○	○	○	○
Improved quality	○	○	○	○	○
Improved construction process and efficiency	○	○	○	○	○
Improved safety	○	○	○	○	○
Reduced claims or litigation (risks)	○	○	○	○	○
Better design/multi design alternatives	○	○	○	○	○
Predictive analysis of performance	○	○	○	○	○
Improved operations and maintenance (facility management)	○	○	○	○	○
Improve collaboration in design and construction	○	○	○	○	○
Assist producing sustainable buildings	○	○	○	○	○

11. What other benefits, not listed in question 9 do you think BIM has for the Jordanian construction industry?

12. From literature review, the following are some of the documented challenges to adopt BIM. On scale of 1-5. How will you rank them with 5 being the most related challenge and 1 being the least related challenge to the Jordanian construction industry?

	Least related challenge 1	2	3	4	Most related challenge 5
Culture change	○	○	○	○	○
Lack of legal framework (model ownership, legal contract)	○	○	○	○	○
Additional resources/ expenses	○	○	○	○	○
Lack of interoperability	○	○	○	○	○
Lack of standards	○	○	○	○	○
Attitude and awareness (resistance to change from 2D drafting practices)	○	○	○	○	○
Increase risk and liability	○	○	○	○	○
Current public policy procurement policy	○	○	○	○	○
Complexity (long hours to develop a BIM model)	○	○	○	○	○
Organizational challenges among construction professionals	○	○	○	○	○
Lack of comprehensive framework or implementation plan	○	○	○	○	○

13. Do you think BIM adoption in the Jordanian construction industry is timely?

- ◯ Too early, the industry is not ready yet
- ◯ Early, possible in the coming future
- ◯ Timely, it is the appropriate time to adopt BIM, we need it
- ◯ Late, but still there is possible to catch up with the technology adoption
- ◯ Too late, we are too behind

14. Could you please give any reasons for your answer to question 14 above?

15. What types of procurement route are preferred when implementing BIM for projects?

- ☐ Design-bid-build
- ☐ Design and build
- ☐ Construction Management
- ☐ Design-Build-Operate
- ☐ Design-Build-Finance-Operate
- ☐ Integrated Project Delivery
- ☐ Project Alliancing

Other (please specify)

16. Please write your contact details if you would like to participate in the next stage of the study:

Done

APPENDIX E: INTERVIEW INVITATION LETTER

REQUEST FOR PARTICIPATION IN RESEARCH STUDY

University of Portsmouth

School of Civil Engineering and Surveying
Researcher(s): Mohammad Alhusban,
Email: mohammad.alhusban@port.ac.uk
Supervisor: Salam Al-Bizri,
Email: salam.al-bizri@port.ac.uk

Study Title: A Model of a Procurement approach for effective implementation of Building Information Modelling

REC Ref No: MA2

Dear Sir/Ma,

This is Mohammad Alhusban, a research student from School of Civil Engineering and Surveying, University of Portsmouth, UK. I am writing to invite you to participate in my research project. The research aim is to investigate whether procurement approaches influence the ability to use Building Information Modelling (BIM) techniques to deliver sustainable buildings in the Jordanian public construction industry.

For this study, I need to collect first-hand information about the construction procurement process that adopted by your organisation. Considering your experience and presence in the construction industry, I believe that your feedback is very important for my research. I would be grateful if you would give me 45-60 minutes of your busy schedule to conduct an interview.

I would be very happy to answer any questions you may have and can be contacted on the e-mail address above.

I look forward to hear from you in due course. Thanking you in anticipation

Thank you,

Mohammad Alhusban

APPENDIX F: INTERVIEW QUESTIONS

- Background information:
  A. What is your title and what are your responsibilities in the company/ department?
  B. How many years of experience do you have in delivering public construction building projects?
  C. What are the construction project sizes (in term of values) you have been working on?
- Does your company/department adopt and/ or use BIM? If yes, what is the stage of BIM utilisation?
- What do you see as the main benefits of BIM in the Jordanian public construction industry?
- Do you think BIM will enhance public buildings' performance? If yes, how?
- What are the barriers to adopt BIM in the Jordanian public construction industry?
- What do you think is the most critical step/action to implement BIM in delivering public buildings in Jordan? And why?
- Do you think procurement approaches adopted affect the implementation of BIM on public construction buildings projects? And why?
- If yes, in your opinion what types of procurement approaches should be adopted to effectively implement BIM for public building projects?
- What types of construction procurement approaches are used? And why? Can you please give a percentage of usage for each approach?

	Procurement approach	Percentage
1	Design-Bid-Build	
2	Design and Build	
3	Construction Management	
4	Integrated Project Delivery	
5	Other (Please specify)	

- A. Can you describe the process of tender under the preferred procurement approach?
  B. Is it single or two-stage tender?

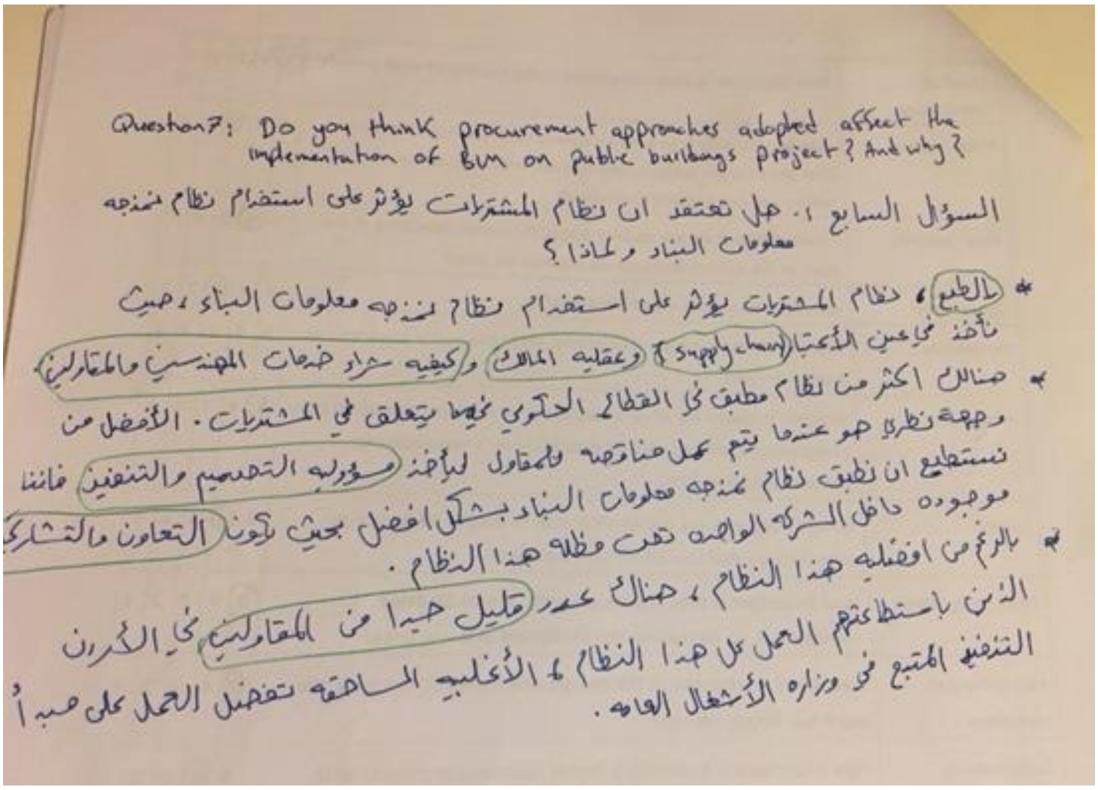
- Can you please provide the key procurement tasks and key participants involvement under the adopted procurement approach at the following stages:

Work Stages (RIBA,2013)	**Procurement Tasks**	**key participants**
Stage 0: Strategic Definition		
Stage 1: Preparation and Brief		
Stage 2: Concept Design		
Stage 3: Developed Design		
Stage 4: Technical Design		
Stage 5: Construction		
Stage 6: Handover and Close Out		
Stage 7: In Use		

- What are the key issues under the adopted procurement approach that affect BIM implementation?
- What measures would you suggest to overcome these issues?
- What are the main barriers for delivering sustainable buildings in the public construction industry? And why?
- How environment and sustainability issues have been addressed in the preferred procurement approach? Can you please rank the following procurement sustainability factors from 1 to 5, where 1 is the least important and 5 is the most important?

    - Highlighting sustainability in the project brief as a primary aim,
    - Integrating sustainability requirements into contract specifications and conditions,
    - Emphasising the importance of sustainability in tender evaluation and selection procedures,
    - Requirement/ incentive for the supply side to demonstrate commitment to sustainable development through policy and implementation,
    - Requiring the supply side to demonstrate capability of delivering sustainability requirements,
    - Encouraging tenderers to suggest innovative solutions and approaches that support the public client overall sustainability objectives,
    - Ensuring that payment mechanisms take account of whether sustainability requirements are delivered,
    - Having sufficient room for significant innovation through the process,
    - Others.
- During the delivery of the buildings, how is the buildings performance evaluated? What metrics have been used?
- Post-completion:
    A. How is building performance assessed? What metrics have been used? For example: schedule growth, cost growth and quality?
    B. In general, what are the results of these evaluations?
    C. Does the performance of the building meet the intended design? If not, what measures have been taken to address this gap?
- Any comments that you wish to highlight

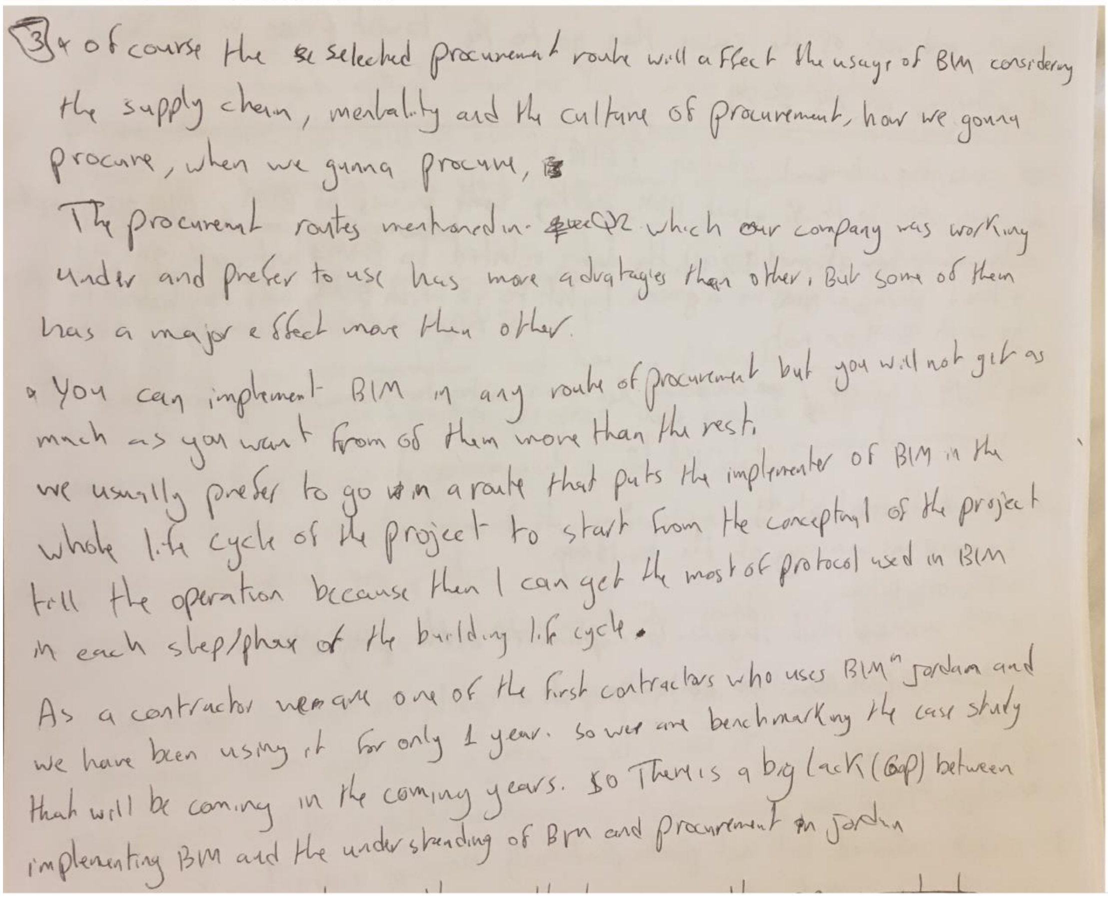
APPENDIX G: INTERVIEWS TRANSCRIPT STAGES SAMPLE



Question7: Do you think procurement approaches adopted affect the implementation of BIM on public buildings project? And why?

السؤال السابع :- هل تعتقد ان نظام المشتريات يؤثر على استخدام نظام نمذجه معلومات البناء ولماذا؟

* بالطبع، نظام المشتريات يؤثر على استخدام نظام نمذجه معلومات البناء، حيث نأخذ بعين الأعتبار (سلسلة التوريد Supply chain) وعقليه المالك وكيفيه شراء خدمات المهندسين والمقاولين.
* هنالك اكثر من نظام مطبق في القطاع الحكومي فيما يتعلق في المشتريات. الأفضل من وجهة نظري هو عندما يتم عمل مناقصه للمقاول ليأخذ مسؤوليه التصميم والتنفيذ فاننا نستطيع ان نطبق نظام نمذجه معلومات البناء بشكل افضل بحيث تكون التعاون والتشارك موجوده داخل الشركه الواحده تحت مظله هذا النظام.
* بالرغم من افضليه هذا النظام، هنالك عدد قليل جدا من المقاولين في الأردن الذين باستطاعتهم العمل على هذا النظام، الأغلبيه الساحقه تفضل العمل على مبدأ التنفيذ المتبع في وزاره الأشغال العامه.



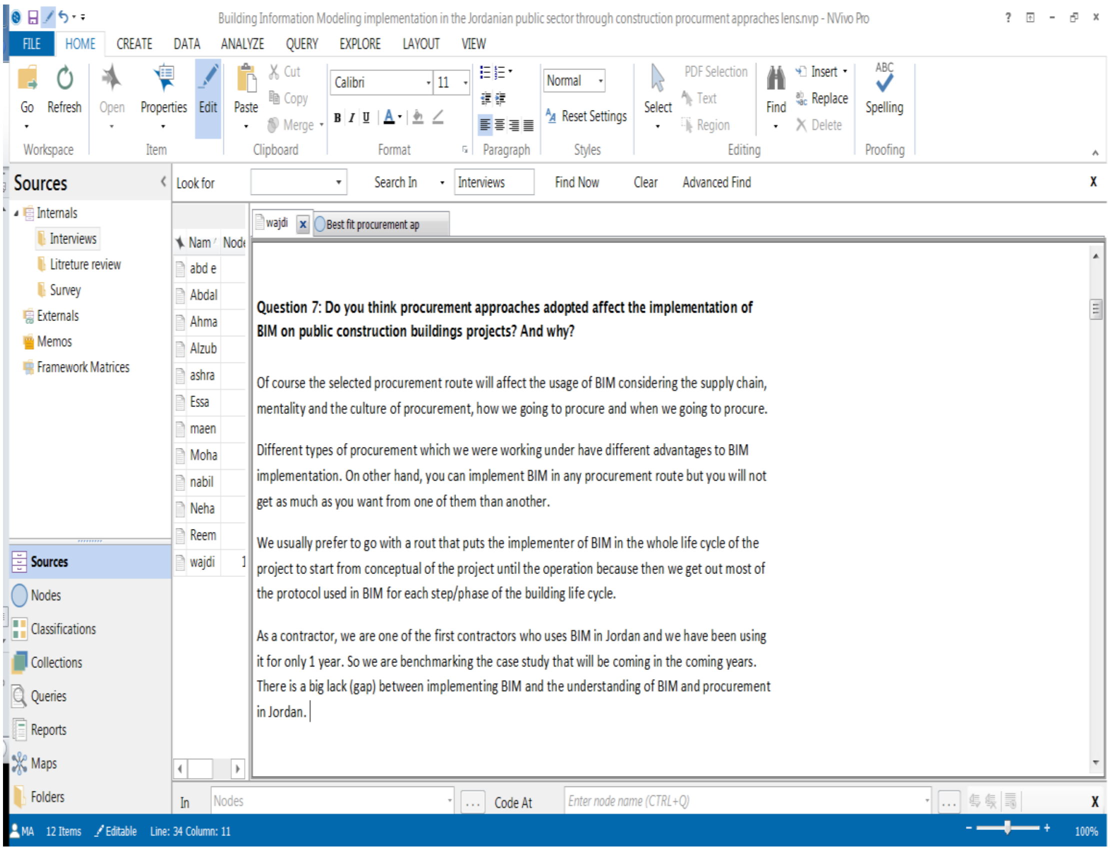
3 * of course the selected procurement route will affect the usage of BIM considering the supply chain, mentality and the culture of procurement, how we gonna procure, when we gonna procure,

The procurement routes mentioned in Q2 which our company was working under and prefer to use has more advantages than other. But some of them has a major effect more than other.

* You can implement BIM in any route of procurement but you will not get as much as you want from of them more than the rest.

we usually prefer to go in a route that puts the implementer of BIM in the whole life cycle of the project to start from the conceptual of the project till the operation because then I can get the most of protocol used in BIM in each step/phase of the building life cycle.

As a contractor we are one of the first contractors who uses BIM in Jordan and we have been using it for only 1 year. So we are benchmarking the case study that will be coming in the coming years. So There is a big lack (Gap) between implementing BIM and the understanding of BIM and procurement in Jordan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Question 7: Do you think procurement approaches adopted affect the implementation of BIM on public construction buildings projects? And why?
Of course the selected procurement route will affect the usage of BIM considering the supply chain, mentality and the culture of procurement, how we going to procure and when we going to procure.
Different types of procurement which we were working under have different advantages to BIM implementation. On other hand, you can implement BIM in any procurement route but you will not get as much as you want from one of them than another.
We usually prefer to go with a rout that puts the implementer of BIM in the whole life cycle of the project to start from conceptual of the project until the operation because then we get out most of the protocol used in BIM for each step/phase of the building life cycle.
As a contractor, we are one of the first contractors who uses BIM in Jordan and we have been using it for only 1 year. So we are benchmarking the case study that will be coming in the coming years. There is a big lack (gap) between implementing BIM and the understanding of BIM and procurement in Jordan.
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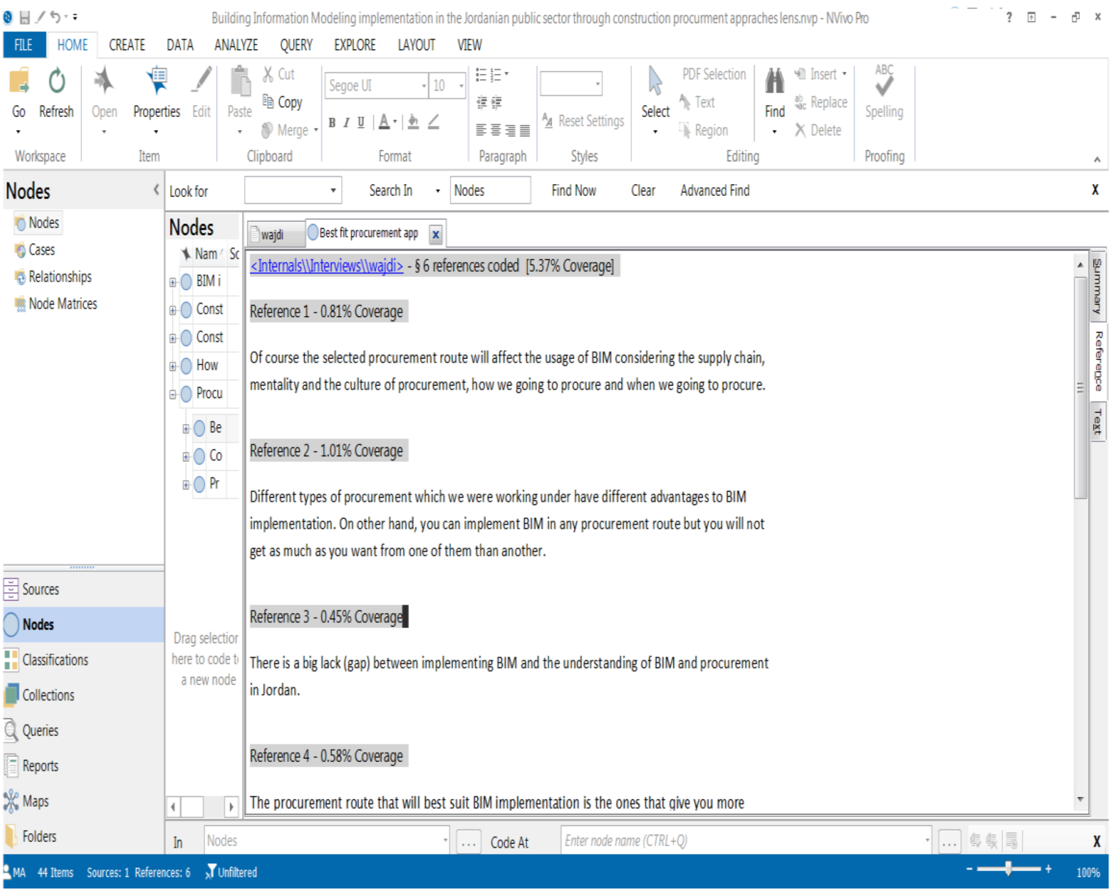
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Reference 1 - 0.81% Coverage
Of course the selected procurement route will affect the usage of BIM considering the supply chain, mentality and the culture of procurement, how we going to procure and when we going to procure.
Reference 2 - 1.01% Coverage
Different types of procurement which we were working under have different advantages to BIM implementation. On other hand, you can implement BIM in any procurement route but you will not get as much as you want from one of them than another.
Reference 3 - 0.45% Coverage
There is a big lack (gap) between implementing BIM and the understanding of BIM and procurement in Jordan.
Reference 4 - 0.58% Coverage
The procurement route that will best suit BIM implementation is the ones that give you more
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APPENDIX H: BIM ASSESSMENT FORM

CPIx - BIM ASSESSMENT FORM

(Based on working documentation provided by Skanska)

1 - Standard Information

Company BIM Representative Name		Interviewee/Person Completing the Form	
Telephone No	Mobile No	E Mail Address	Web Site URL

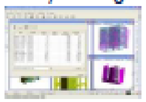
2 - BIM Gateway Questions

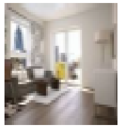
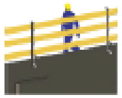
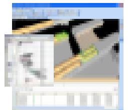
If the answer to any of the following questions is 'No', contact, Project Team Leader, 'name', 'telephone number', 'email address'

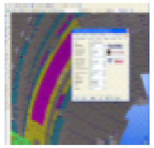
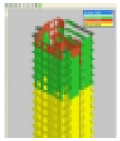
Ref.	Question	Answer	Evidence (if applicable)	Decision (by Team Leader)
G1.1	Are you prepared to issue your native CAD / BIM format files?			
G1.2	If you are not prepared to issue native CAD / BIM format flies. Why not?			
G2.1	Do you work to a CAD / BIM Standard?			
G2.3	Do you work to the national standard BS 1192: 2007?			
G2.4	If your Standards are not BS 1192: 2007, what are they based upon?			
G2.5	Do you produce a BIM model as an iterative process? E.g. RIBA Plan of Work stages.			
G2.6	Do you understand the Model Progressive Strategy?			
G2.7	Do you understand the 'Level of Information' required at each of the project delivery stages?			
G2.8	Do you understand the 'Level of Detail' required at each of the project delivery stages?			
G3	How do you demonstrate or what measures do you have In place to ensure compliance with your CAD / BIM Standard?			

3 - 12 Areas of BIM

The projects have identified 12 Areas or functions that projects will benefit from BIM Tools, Applications and Data Management. Please complete the following table to show your understanding of each of the areas and which areas you could support us with; please include supporting evidence.

Application / Area	Examples	Benefits Expected	Understanding	Supporting Evidence
Design / Construction Intelligent 3D-Modelling 	• Architectural • Structural Design and Fabrication • MEP Design and Manufacture. • Civil • Landscaping	• Accurate and visual design, no shortcuts (completed design in all details). 'As Constructed' re-measured and verified with adequate detail to enable Asset Type and Asset Unique Numbering and Location to be applied. • Project Common Design Elements and Product Components in use, libraries and catalogues • Information on materials and components available from model to meet O&M/FM & Investor's needs		
LCC and LCA analysis 	• History • Database links • Optioneering	• Accurate life cycle cost estimation • Reduced risk in life cycle fund management • Life Cycle Assessment to evaluate environmental aspects where required		
Facilities Mgt. 	• Optimised handover • Asset register • Linked H&SF • Linked O&MM • Linked CAFM	• Computer aided facilities management to ensure effective maintenance of assets • Ensures maintenance and asset performance history maintained • Enables FM contractor to effectively manage and optimize maintenance services		
Quantity take-Off, costing 	• Schedules • Material lists • Component lists • BoQ • Re-informed Cost Plans	• Rapid and accurate take off of materials quantities (but needs care) • Easier to evaluate design changes and impact on costs (5D design) • Supports rapid optioneering • Easier to connect quantities to costing, scheduling and procurement		

Application / Area	Examples	Benefits Expected	Understanding	Supporting Evidence
Sales / Visualizations 	• Bid & Tender • Visualization • Marketing • Client sign off	• Visualizations of highways and buildings for marketing/sales • Virtual models and animations, "fly over/through" highways and tunnels, buildings inside and outside • Supports customer interface, choices etc (assortments, catalogues, selection tools - shopping lists)		
Safety Planning 	• Roof access • Confined spaces • Future safe operations • Enhanced toolbox talk / safety briefings • Visual review of planned work prior to commencement • Improved method statements	• Safety details and structures in libraries (standardization) • Safety installations pre-planned, railings and fixings for safety equipments • Visual safety tours / area plans and presentations		
Clash Detection 	• 2D in Plan • 3D Co-ordination • Rule based clash • 'Hard & Soft' clash • Virtual snagging • Plant & equipment installation	• Zero error design: No defects in construction phases, below ground and above ground assets/services • Better production planning with sub contractors, visual plans • Project checking rules: better design quality • Zero clash thro collaboration and sharing BS1192:2007		
4D-Scheduling 	• Vehicle movements • Materials deliveries • Crane & Hoist positioning • Targeted sequencing • Construction site layout	• Information for scheduling from model based quantity take-off • 4D design – 4D simulations (VDC) possibilities, optimized schedules • Visualization of schedules for workers and suppliers		

Application / Area	Examples	Benefits Expected	Understanding	Supporting Evidence
Production BIM 	• Targeted rehearsals • Progress monitoring • Planned vs Actual • Sub contractor payment	• Virtual design and construction methods: 4-D schedule simulations • Constructability analyses, prints of 3D details and drawings, visual planning • Exact material lists for production: reinforcement, concrete, fixings • BIM enables GPS machine control (excavators, graders, pavers)		
Procurement 	• Accurate quantities • Re-informed Cost Plans • Sub contractor payment • Reduced tender periods • Optimised procurement plans	• Codes for identification, RFID tags, follow-up with model viewers • Location based material / component deliveries • JOT deliveries (easier to manage and plan, delivery times in models)		
Supply Chain Management 	• Secondary Clash Prevention • Reduced tender periods • Early warning	• Exact material / component definitions and codes from models (libraries) • Bills of materials from models, accurate quantities per locations • Follow-up of deliveries (RFID –tags) • Transparency project status for all key suppliers and sub-contractors		
Simulations Energy, Fire etc 	• Environmental • Structural • Thermal • Daylight • Ratios	• More accurate and easier energy calculations • Possible to simulate indoor climate conditions • Helps to achieve green construction goals, CO2 footprint, LEED, BREEAM, WRAP and Embodied Carbon • Supports smoke and fire simulations (buildings , tunnels etc)		

4 - BIM Project Experience

Please provide details of a minimum of three recent projects using BIM undertaken for reference purposes

	Project 1	Project 2	Project 3
Title			
Sector			
Customer			
Contractor			
Contact			
Tel No			
Project Value			
Fee Value			
Contract duration			
Scope of BIM Services			
Benefits realised by BIM			

5 - BIM Capability Questionnaire

The following BIM Capability questions are intended to help the Skanska UK BIM Team identify training, coaching and support required for your organisation.

No.	Question	Answer / Understanding	Supporting Evidence
B1	What does BIM mean to you?		
B2	What does BIM mean to your organisation?		
B3	What does BIM mean to your staff?		
B4	Who drives BIM within the organisation?		
B5	Who drives BIM within the office(s)?		
B6	Who drives BIM on each project, what are their titles and responsibilities?		
B7	Where has BIM been implemented already and to what extent?		
B8	Does your organisation have BIM standards?		
B9	Have you experience of implementing client standards and where?		
B10	How have your design agreements been influenced by BIM?		
B11	What are the issues of IP rights and ownership of the BIM models?		
B12	Have there been any changes to your design deliverables with respect to BIM?		
B13	What is your current status and future plan for BIM rollout?		
B14	What are your future plans for BIM implementation in respect to staff and their command and process training?		
B15	What does coordinated design mean to you?		
B16	Explain the discipline and rigour in the design process?		

No.	Question	Answer / Understanding	Supporting Evidence
B17	Has / would BIM enable you to engage in 'Optioneering' early in the design process and how?		
B18	What has BIM enabled you to do differently and to what benefit and to whom?		
B19	What impact has BIM had / will have on projects?		
B20	How does BIM affect staffing on a project?		
B21	How has BIM affected design fees?		
B22	What in-house tools do you have? Demonstrate usage		
B23	Have Tools been specified to you and have you / would you use them?		
B24	Where on a project does BIM start?		
B25	Where on a project does BIM finish?		
B26	What is your understanding of Virtual Design and Construction (VDC)?		
B27	What is your definition of 'Collaboration'?		
B28	How do you 'Collaborate'?		
B29	What do you 'Collaborate' with?		