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ADOPTION OF PREASSEMBLED BUILDING SERVICES COMPONENTS IN SAUDI ARABIA: CONSULTANTS' AND CONTRACTORS' INFLUENCE

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DECLARATION

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

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ABSTRACT

In general, the applications of preassembled building services components (PBSC) are limited. These applications provide several advantages for stakeholders, including project delivery. Project delivery has been highlighted as a difficulty in project construction within several contexts, including that of Saudi Arabia. Such PBSC are deemed new technologies that require consideration by practitioners and users; therefore, the theory of planned behaviour (TPB) is employed in this research. This study explores consultant and contractor influence on using PBSC in complex office developments within Saudi Arabia. Methodologically, an exploratory mixed-methods approach is employed as a research design. By applying the TPB, this research explores consultant and contractor perceptions, stakeholder influence on the decision (subjective norms (SN)), and the external contextual control on the decision (perceived behavioural control (PBC)). This exploration predicts the behaviour of consultants and contractors regarding using PBSC in complex office developments.

Semi-structured interviews (N=15) were developed based on the TPB to explore the context. Then, the transcriptions of these interviews were analysed using grounded theory to build propositions that assisted in constructing a questionnaire instrument. A self-administered survey questionnaire was developed as a primary research method, including a sample of 338 consultants and 323 contractors who were randomly selected (response rate $\approx$ 38%). Descriptive analysis, ordinal regression, and t-Tests were used for the quantitative data analysis. The results reveal that respondents have a significant intention to use PBSC in complex office development. The majority of these applications include prefabricated vertical and horizontal distribution and terminal unit preassembly. Three case studies were site-visited to confirm the validity of the final adopted model of this research.

Consequently, the results reveal that the top three benefits identified are as follows: the quality of the products, the speed of the project, and the reduction in the construction cost. It is worth noting that PBSC applications include certain challenges, such as the reduction of design flexibility, the limitation of making changes onsite, and the need for extra preparatory work. The stakeholder influence on decisions includes those of the client, consultants, and regulators. Moreover, the external contextual behaviour that controls decision-making includes financial support, government regulations, and manufacturing capacity. The reasons that prevent non-practitioners from using PBSC include the increase of the overall project cost, the increase in risk, and the limitation of design flexibility.

Consequently, several recommendations are proposed, including the need for further research to assess strategies to promote the adoption of PBSC in complex office developments, as well as the enhancement of the role of subcontractors through these strategies to professionally assist the PBSC marketplace. This study provides client guidance to help practitioners to better understand the key factors that affect consultant and contractor use of PBSC in complex office developments.

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GLOSSARY OF TERMS

AIA	American Institute of Architects
BCIS	Building Construction Information Services
BEMCS	Building Energy Management and Control System
BoS	Buildoffsite
BPES	Building Performance Energy Simulation
BPS	Building Performance Simulation
BSI	British Standards Institution
BSRIA	Building Services Research and Information Association
CIB	Construction Industry Board
CIRIA	Construction Industry Research and Information Association
GTP	Government Tenders and Procurement
MEP	Mechanical, Electrical, and Plumbing
MOL	Ministry of Labour
MOMRA	Ministry of Municipal and Rural Affairs
MMR	Mixed-Methods Research
MMC	Modern Methods of Construction
NAO	National Audit Office
OCT	Offsite Construction Techniques
OSM	Offsite Manufacturing
OSP	Offsite Production
PBSC	Preassembled Building Services Components
RIBA	Royal Institute of British Architects
RICS	Royal Institution Chartered Surveyors
SAMA	Saudi Arabian Monetary Authority
SCA	Saudi Contractors' Authority
SCE	Saudi Council of Engineers
SPWC	Standard Public Works Contract
TPB	Theory of Planned Behaviour
ME	Mechanical Engineer
EE	Electrical Engineer

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CHAPTER 1: INTRODUCTION

1.1 Introduction to the Subject Matter

The FALCOM report (2018) highlights that the Saudi Arabian Government implemented several key initiatives and reforms in 2017, including in the construction industry. According to the JLL report in 2016, the office market remained inactive due to delaying certain projects' delivery until 2017. These office projects cover Riyadh, Jeddah, and Dammam (JLL, 2016). In 2017, the Government was considered the prime tenant for office developments in Riyadh. Al Faisaliah Tower and Kingdom Tower have remained 100% occupied due to the office-space shortage in Riyadh in recent years, with vacancy rates increasing to 2% in Riyadh and 7% in Jeddah (FALCOM, 2018).

Construction projects have difficulties regarding the delivery of the design and the construction phases. Project delivery is considered a problem within the Saudi Arabia construction industry. Assaf and Al-Hejji (2006) highlight many important causes of delay, such as the early planning and design of a project, contractor performance, and client involvement. They found also that 70% of projects in the Eastern province of Saudi Arabia were delayed. However, according to the same study, all parties in Saudi Arabia only agreed on one cause of delay, which is 'changing orders by the client during construction'. Rework is defined as an incorrect design or process of activity throughout sources, such as errors, omissions and change (Anil and Danielraj, 2016). The poor coordination of building services generates uncertain outcomes in the procurement and cost management of buildings due to lack of knowledge among stakeholders regarding the technology of building services (Yusuf et al., 2013).

Mitra and Tan (2012) studied large construction projects in Saudi Arabia. The study highlights 10 key problems that cause delays, including poor control, changes in design, planning and approval, shortage of labour, lack of control of project manager, productivity of manpower, and lack of skills. Assaf and Al-Hejji (2006) recommend that planning and control as on-going processes must be considered by general contractors during construction. Also, they mention that the resources and time required need to be matched with this recommendation to develop the work and to avoid disputes, cost overruns, and delays. However, AlSehaimi et al. (2013) argue that this recommendation needs clarification regarding the type of planning tools that might be applied and how this could be completed.

The construction industry adopted PBSC, which have several benefits, such as less labour involvement onsite, lower cost, better quality, and less time (Mullens and Arif, 2006). Housebuilders are more satisfied with preassembled building services than offsite MMC, as indicated in a BSRIA study (Parry et al., 2003), in which there is around 72% satisfaction with PBSC (Pan et al., 2007). The BSRIA (1999) focused on mechanical and electrical services cases. Gibb (2001) includes a series of case studies, with some examples of OSM, including modular office buildings. Also, Buildoffsite (2006) published 150 case studies covering all construction sectors, including commercial, to motivate non-practitioners in OSM to investigate the options on a project (Blismas and Wakefield, 2009). According to Nadim and Goulding (2010), the respondents had certain experience in OSP, predominantly in the residential sector (31%), followed by offices (13%). The services areas and M&E installations had the second-most OSP applications (24%), following superstructures (33%) (Nadim and Goulding, 2010). However, the literature review reveals a lack of using PBSC in complex office developments.

The construction industry comprises significant sectors, such as building services, which differ from building structure or finishes regarding design and installations, parties involved, scope, technicality, and nature of work. The complexity of modern buildings has considerably enlarged the importance of building services and their comparative cost to the total cost of building projects. Therefore, industry stakeholders often assume the cost of building services to be well controlled due to growing complexity (Yong et al., 2004; CIDB, 2009a, b; Kumar, 2009). Consequently, having a budget leads to setting a reasonable price for building services before awarding a contract (Swaffield and Pasquire, 2000). The ineffective management of increased cost jeopardises client investment, since the costs of conventional building services have risen by 10 to 30 % to be between 10 and 70 % of the entire building cost (McCaffrey, 2011). This study explores the influence of consultants and contractors on the use of PBSC within complex office developments in Saudi Arabia.

1.2 Research Rationale and Justification

Gawron (2014) characterises agglomeration areas as using widely understood socio-economic and cultural conditions, well-developed infrastructure, and rapid spatial development. Korytarova et al. (2015) describe urban agglomeration areas as including the highest density of construction projects, in which a client is regularly a public entity, and as being subject to public procurement laws. Therefore, several construction problems are encountered within the rapid development of urban agglomerations (Zielina and Kania, 2017). According to Craighead (2009, p.461), an office building is a 'structure designed for the conduct of business, generally divided into individual offices and offering space for rent or lease'. Zielina and Kania (2017) define the term 'construction project' as a description of an action to be performed to meet the client's needs as well as the end-user's. According to Kasprowicz (2010, p.177), a construction project concentrates on the preparation, providing a complete structure that is ready for operation, and the organisation and implementation of works. However, a construction project is deemed a complex process of a certain project related to exclusive external factors and individual qualities. An online search was performed by the researcher regarding complex office developments that were LEED certified in Saudi Arabia (Appendix A).

1.2.1 *Challenges Facing Office Developments*

The difficulties encountered by office developments are classified as, A) independent, and B) dependent (Korytarova et al., 2015). Independent difficulties include a densely built environment, negative influence on humans, difficulties with traffic, and space limitations for regarding work and on-site storage areas. In addition, delivering complex office developments is believed to be unachievable by traditional contracting methods (CTBUH, 2015). The dependent difficulties reviewed by Zielina and Kania (2017) and several other authors are related to clients, designers, general contractors, and suppliers (Korytarova et al., 2015).

Ultimately, the construction of office developments is challenging when performed in a large urban agglomeration (Zielina and Kania, 2017). These challenges include the space in which construction work is performed, the requirements of the client, and the long construction time generated by organisational and technological problems. Among all these challenges, this study examines the perception of consultants and contractors towards using PBSC.

1.2.2 *Challenges Facing Preassembled Building Services Components in Office Developments*

Preassembled building services component applications for complex office developments include, but are not limited to, prefabricated pipework (e.g. horizontal distribution), prefabricated services vertical risers, prefabricated pipework and cabling (e.g. ductwork), preassembled or modular buildings, preassembled plant rooms (e.g. pumps, chillers, boilers, air handling), preassembled room terminal units, and module electrical wiring (BSRIA, 1998).

The report *Prefabrication and preassembly - applying the techniques to building engineering services* (ACT 1/99) found that prefabrication and preassembly can be successfully utilised in mechanical and electrical (M&E) services to make more economical installations. Furthermore, the report includes case studies that applied PBSC in office developments. The case studies in the report include, A) preassembled AHUs and boiler modules, and B) preassembled plant modules and prefabricated boiler room pipework (BSRIA, 1998). Several challenges were encountered in these case studies, including team commitment, design to OSM, the potential for repeatability, procurement strategies, tender procedures, quality control procedure, delivery management, training, commissioning procedure, and building services programme times (BSRIA, 1998).

Pan and Gibb (2009) studied the challenges related to the maintenance performance for preassembled bathrooms. The findings reveal that the Glass Reinforced Polyester (GRP) modules had fewer recorded maintenance problems, but sinks and toilets of GRP modules were recognised as major areas for maintenance. However, the challenges of preassembled bathrooms were mostly related to the design and specifications of the modules. Also, according to Buildoffsite (2015), the challenges facing PBSC emerge during the design phase, including early decisions for adoption, early design strategies, procurement strategies, perception of higher costs, preparatory time, and the timely readiness of design information. The literature review reveals limitations in works related to the application of the preassembly offsite of building services components. On the other hand, an early study by BSRIA–Parry et al. (2003) states that the building services sector claims around 72% client satisfaction. The final decision is left to the specialised contractors (M&E subcontractor) or consultants regarding using preassembly offsite of building services components in United Kingdom (UK) building projects (BSRIA–Samuelsson Brown et al., 2003).

1.3 Initial Research Problems

Generally, offsite construction is recognised as a mean of making a change within the UK construction industry regarding environmental, social, and economic opportunities (Jaillion and Poon, 2008). Offsite construction is believed to deliver sustainable and efficient construction compared with traditional production onsite (Zhai et al., 2014). However, according to Venables et al. (2004), the uptake of offsite construction is moderately influenced by the practitioner's perceptions with regard to its attitudes. Also, the late decisions play a significant role in slowing uptake of offsite production, which is often made by those involved in the construction process such as consultants, clients, and general contractors (Pan et al., 2012b).

According to Kamar et al. (2009) the idealism behind the benefits of using the offsite construction is beyond the perceived benefits to the contractors. Pan et al. (2012b) referred to the lack of understanding of how to compare offsite to conventional construction methods. Consequently, traditional onsite methods control the construction industry (Rahman, 2014), and offsite construction fails to meet to industry and government targets (Buildoffsite, 2012). Hence, offsite construction is acknowledged as a critical approach for leading improvement within the construction industry, but the uptake is limited (Blismas, 2005). On the other hand, even with the demand to improve efficiency and productivity, the construction industry is confronted by the economic recession (Ogden, 2010) and government expenditure falls (Pan and Goodier, 2012).

The benefits of using offsite construction are well documented, but the process is not practical on a large scale (Pasquire and Gibb, 2002). The literature review reveals that the applications of PBSC in complex office developments are limited. According to Pan et al. (2007), offsite construction in 2004 represented only 2.1% of the UK construction industry, including civil engineering work, new buildings, and the refurbishment of existing buildings. A slightly higher percentage of offsite construction uptake was recorded by Pan and Sidwell (2011) in the UK, but was still low, less than a 6% share of the construction work in the UK (estimated to be up to £6 billion by Almutairi (2015, p.34)). According to Pan et al. (2007), the methods in the UK construction industry are conventional; the industry has been unwilling to adopt innovative building technologies. Lu (2008) states that the application of offsite construction in the United States (US) was limited to preassembly techniques, including preassembled trusses and precast concrete products. Furthermore, the acceptance of offsite construction processes remains low despite the recognised benefits (Zhai et al., 2014).

However, according to Buildoffsite (2015) and Blismas et al. (2005), there are several challenges when using PBSC, including the early decision to embrace offsite, the negative impact on local employment, the perception of higher costs, the strategies of procurement, the strategies of design, the availability time of design information, the lead-in time, and the skills and equipment needed. Thus, the early decision to adopt PBSC is the greatest challenge for a project team and it is vital to confirm the development of appropriate project strategies by clients and their consultant advisers (Buildoffsite, 2015). Also, early design strategies are a challenge for consultants to adopt a strategy that will not prevent the later adoption of PBSC solutions, even if the decision to adopt is made later during the design process. Similarly, the procurement strategies are regarded as a challenge if a late decision to adopt PBSC can lead to poor collaboration and engagement between consultants, manufacturers, and contractors (e.g. the lack of delivery consideration for the M&E products early in the design process).

The perception of higher costs of using PBSC is possibly the most critical challenge regarding their adoption (Goodier and Gibb, 2005). Similarly, lead-in time is a challenge because of the late decision to embrace PBSC. Thus, lead-in time for each M&E product needs to be accommodated by a developed design programme, which must be considered by the procurement strategy (Buildoffsite, 2015). The design information for PBSC is challenging in terms of change and completion within the required timetable and the lead-in time requirements. Thus, the development of the design programme is essential to enable the implementation of PBSC solutions, unlike in traditional design processes, in which the late development of M&E designs occur (Pasquire and Connolly, 2003). Also, skills and equipment are a challenge due to the required early planning to install assemblies and larger components, since large PBSC need heavy-duty cranes and care to place in position. Moreover, a factory site is permanent, skill shortages and numbers can be simply addressed, and recruiting is easier (Taylor, 2010).

1.4 Aim and Objectives of the Research

Aim: The aim of this research work is *to explore the influence of consultants and contractors on the use of preassembled building services components in complex office developments in Saudi Arabia*. Therefore, this study provides client guidance to assist practitioners towards a better understanding of the relative importance of the key factors that may affect consultant and contractor adoption of PBSC in complex office developments within Saudi Arabia, as well as forming these key factors in the model of the TPB.

Objectives:

1. To explore the current nature and extent of the utilisation of preassembled building services components in complex office developments.
2. To assess the perception of consultants and contractors towards using preassembled building services components in complex office developments in the framework of the theory of planned behaviour.
3. To examine the relationship between consultant and contractor perceptions of using the preassembled building services components in complex office developments.
4. To determine consultant and contractor intentions to use preassembled building services components in complex office developments.
5. To determine the reasons preassembled building services components are not being used by consultants and contractors (non-practitioners) in complex office developments.

1.5 The Scope of the Research

Complex office developments encompass more technological work than other building types, such as houses. Therefore, these developments require more attention to a wider range of concepts of sustainability and optimisation. The review of relevant existing knowledge regarding the research topic provides insights that allow the researcher to limit the scope to the necessary area of inquiry (Creswell, 2009, p.23). Moreover, a comprehensive literature review allows the identification of the following limitations of the research:

The research concentrates on consultant and contractor perceptions (at organisational strategic level) of design and construction processes regarding the applications of PBSC in complex office developments in Saudi Arabia. Therefore, a hierarchy of strategic and operational levels of management is used by the construction industry. However, the manufacturing process is beyond the scope of this research.

This research is limited to managerial factors that are controllable internally by construction organisations. Therefore, the external environmental and economic factors are beyond the scope of this research.

Generally, the characteristics and primary forms of offsite construction are well documented and well known to industry practitioners. Therefore, they are beyond the scope of this research.

The research is limited to the adoption of innovation at the organisation level (entrepreneur). Therefore, other scales of innovation, such as products, are beyond this research.

It is believed that defining ‘complex office developments’ is essential. Thus, the following definitions and context provide clarification:

Modern construction projects are increasingly complex in both design and the involvement of a multitude of stakeholders, forming critical challenges for both clients and contractors when delivering a successful project (Doloi, 2009). Aibinu et al. (2015) argue that attaining a dependable estimation of the costs of building services at an early stage is often the most difficult part of building design process. Building services can cost up to 70% of the capital cost of buildings, depending upon the objective of the building and the complexity of the building services (Yusuf et al., 2012). The coordination of building services generates problematic outcomes in the procurement and cost management of buildings when stakeholders lack knowledge regarding the technology of building services (Yusuf et al., 2012).

Defining project success is a complex task, especially when considering the above-stated complexity of construction projects (Toor and Ogunlana, 2010). Project management has managerial levels, such as strategic, institutional, and tactical (Cleland and King, 1988, p.24). All three levels are related to each other and all play an essential role in the management of every project. The institutional level (1) represents the senior management level and concentrates upon the firm. Also, outside issues relevant to the project environment are evaluated at the institutional level, such as industry and government targets, finance, regulatory and planning agencies, and environmental and economic issues (Cleland and King, 1988, p.22). Middle management is represented by the strategic level (2), which directs the project's technical core and buffers it from external factors. Technical management is represented by the tactical level (3), which is delivering together with the technical input of the project.

1.6 Outline of Research Methodology

Ashton (2003) states that the nature of research and the terminology of its design and operation process are critically important. Therefore, this research design includes mixed qualitative and quantitative approaches (exploratory sequential) to data collection and analysis to address the research questions, aim, and objectives. An exploratory sequential design was applied to investigate the context due to limitations of evidence. However, a comprehensive literature review was undertaken to help understand the existing knowledge and the research context regarding the benefits, challenges, applications, and forms of PBSC in the construction industry. Also, the literature review helps to understand the existing knowledge regarding the adoption of innovation theory especially the TPB. Furthermore, different research methods were used for primary data collection regarding the perceptions of consultants and contractors towards using PBSC in complex office developments in the context of Saudi Arabia (semi-structured interviews, questionnaire surveys, and three case-study projects for the validity of results).

Semi-structured interviews were designed using the TPB. The literature review provides documentary evidence (independent variables (IVs) and dependent variables (DVs)) regarding the use of PBSC. These IVs and DVs were formed in the framework of the TPB. Consequently, the semi-structured interviews included three questions that measure the three dimensions of the TPB, which are attitudes, SN, and PBC. Grounded theory was used to analyse and produce the propositions that were seminal for constructing the questionnaire.

The results of this research are classified in the TPB. The validation of the results mainly used the interviews and case studies at Stage 3 throughout the research. Chapter 4 provides the research methods adopted at each phase of the research process. The research methods used to achieve each research objective are illustrated in Figure 1-1.

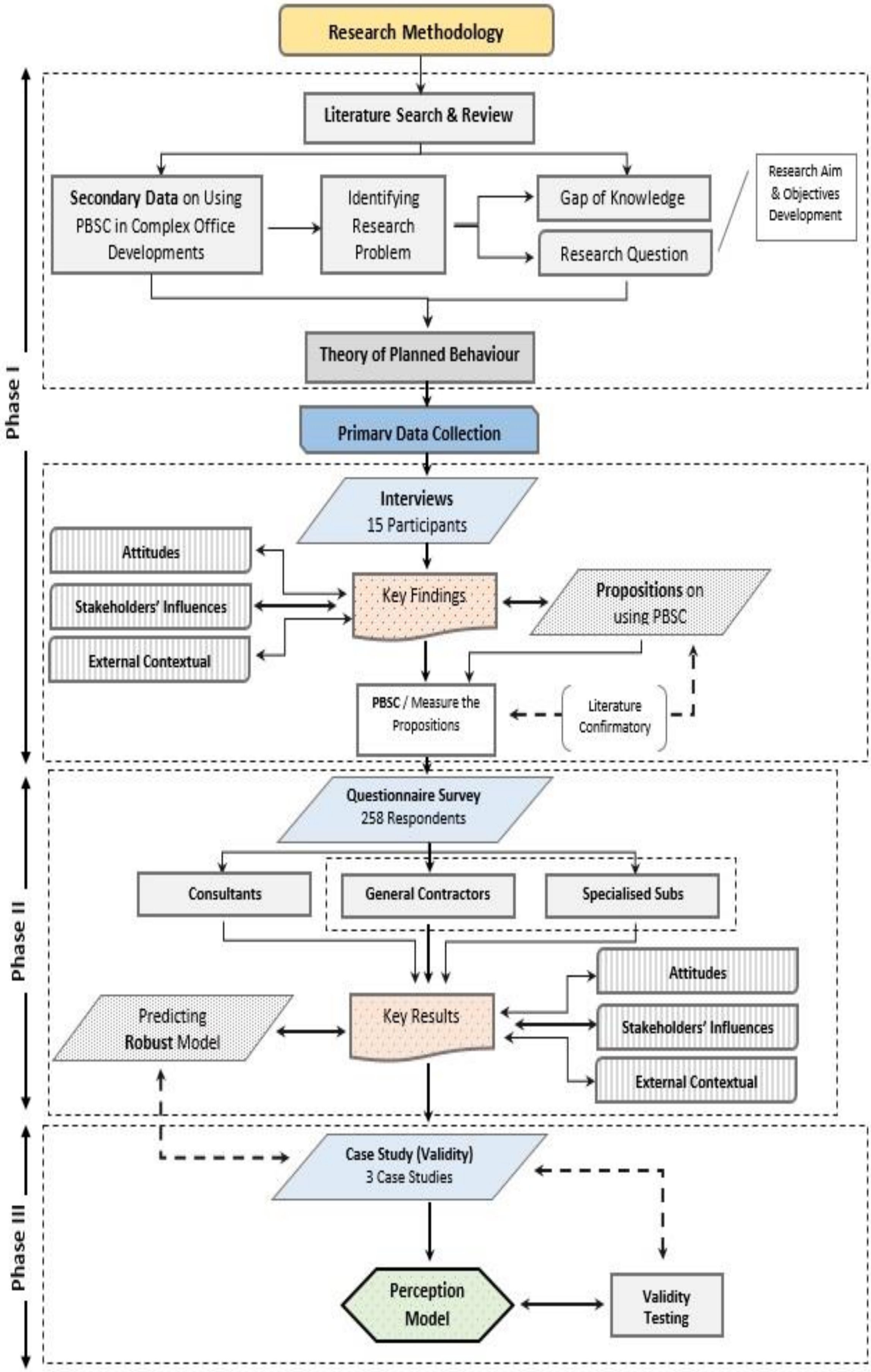


Figure 1-1 Research Methodology

1.7 Layout of the Thesis

Chapter 2 presents a literature review focusing on the general use of PBSC in the construction industry. The review addresses the definition, terms, forms, and characteristics of PBSC in construction, as well as providing the research background, development, and applications of PBSC technologies in other contexts. The chapter provides also an overview of the categories and systems of the building services, focusing on the heating, ventilating, and air conditioning (HVAC), electrical, plumbing, and fire systems. In addition, there is a detailed insight into the design process, including the role of stakeholders in the construction industry and the procurement systems applied.

Chapter 3 describes the TPB as the conceptual framework. The research background contains the definition of innovation, technology adoption models and theories, and the principles of innovation adoption. The adoption of innovation theory is reviewed, as is innovation in the construction industry regrading optimisation, improvements of preassembly, and innovation of BIM. Consequently, the independent and dependent variables reviewed in Chapter 2 are conveyed into the framework of the TPB to shape the attitudes, the SN, and the PBC.

Chapter 4 discusses the methodological approaches adopted in this thesis. Section 1.6 outlines the research methodology. Also, the pilot study used to pre-test the questionnaire is described. The analysis techniques are also discussed, and the interviews and questionnaire are described. Validation of the results is conducted through the case studies.

Chapter 5 presents the analysis of the qualitative data, which were collected via semi-structured interviews. The qualitative data include the attitudes of consultants and contractors towards using PBSC, the types of stakeholder believed to influence PBSC adoption decisions, and the types of contextual influence of consultants and contractors believed to impact PBSC adoption decisions. The findings include 26 proposition statements that were seminal for constructing the questionnaire instrument.

Chapter 6 contains the analysis and discussion of the quantitative method and the statistical tests undertaken on the data. The chapter focuses on descriptive statistics, the reliability of the questionnaire, the company characteristics, the opinions regarding using PBSC, and the reasons for not using PBSC. The validation of the study results is analysed also. The results are presented, as well as other variables of stakeholder influence and contextual behaviour control. Furthermore, this discussion chapter presents the results in the form of the TPB.

Chapter 7 provides concluding remarks on the key findings of the analysis and includes a visualisation of the adopted model of the TPB in relation to the overall aims of the thesis. Preassembled building services components are a new phenomenon in Saudi Arabia. This study is generally concerned with the objectives summarised in this chapter with the associated findings. The chapter includes also clarifications of the main results regarding the five objectives set out in the research. Contribution, recommendations, limitations, and suggestions for future research are also presented.

CHAPTER 2: PREASSEMBLED BUILDING SERVICES COMPONENTS IN COMPLEX OFFICE DEVELOPMENTS

2.1 Introduction

This chapter first presents the motivation for project delivery in the design and construction phases, in addition to a literature review of preassembly and a brief history of PBSC. The chapter defines PBSC and compares them with traditional construction methods. Forms of PBSC are addressed, including significant elements. Categories and systems of PBSC are discussed as well. The design process is discussed to understand the role of stakeholders and their influence on the process. Procurement methods are highlighted to recognise their influence on PBSC in the Saudi context. Relevant literature is reviewed to understand in depth the nature of design and construction phases regarding technical issues (systems), decision-makers, and the applications of PBSC to meet the proper procurement system, which would enhance the use of PBSC. This understanding is believed to be essential in building the theoretical framework that assisted in designing the interview questions according to the model of the TPB as a conceptual framework for this research.

2.2 Motivation for Project Delivery

The construction industry suffers from significant difficulties, such as higher costs of project delivery, poor financial performance, and an incapability to deliver value to customers on time. Rework is a key issue causing such difficulties. Rework is defined as an incorrect design or process of activity through sources such as errors, omissions, and change (Anil and Danielraj, 2016). Mahamid (2013) investigated clients' perspectives regarding the most important delay contributors in Saudi Arabia. He reports these delay contributors, respectively, as lack of site management, lack of coordination and communication between construction parties, bid award for the lowest price, lack of labour productivity, rework, and payments delay. Mitra and Tan (2012) studied large construction projects in Saudi Arabia. Their study highlights 10 critical problems that cause delays; namely, delays in obtaining a permit, manpower productivity, poor control, shortage of labour, changes in design, planning and approval delays, lack of control of project manager, lack of skills, client payment delays, and cash-flow problems. Assaf and Al-Hejji (2006) recommend that contractors must consider planning and control as an on-going process during construction. The same study notes that this recommendation should be considered in conjunction with the resources and time required to develop the work and to avoid delays, cost overruns, and disputes. However, AlSehaimi et al. (2013) argue that this recommendation needs clarification in terms of the way in which this can be done and the planning tools required.

On the other hand, Eichert and Kazi (2007) argue that the construction industry is falling behind in its use of new technologies and innovative practices compared with other industries. According to Pan et al. (2007), offsite technologies are a modern method of construction, in which work is performed at the factory and then moved to the construction site for installation. Nadim and Goulding (2011) state that offsite production (OSP) is a potential solution for improving productivity in the construction industry, meeting market demands, and shifting the heavy dependency of the construction industry from being labour based towards being knowledge based as a form of taking advantage of new technologies. Arif and Egbu (2010) claim that knowledge-based instead of skill-based work is the first factor that influences the outlook of strategic planners in the construction industry. Pan et al. (2007) report that ensuring time and cost certainties is the second driver for using offsite construction techniques (OCT) in the UK, followed by achieving high quality. The first driver is addressing traditional construction skills shortages. Similarly, Scofield et al. (2009) report that ensuring time certainty is the most important factor regarding decisions concerning offsite methods in New Zealand, followed by achieving high quality and ensuring cost certainty. However, several previous studies confirm that OCT are predictable methods regarding cost and time in both the design and the construction phases. However, offsite construction, as with any other technology, includes change, which inevitably faces resistance (Nadim and Goulding, 2011).

Alazzaz and Whyte (2014) studied the research literature on the benefits of OCT to predict future trends. The research includes a brief history and the recent value of OCT followed by a comprehensive discussion. Based on their study, the main benefits of OCT include increased time-saving, improving quality, reporting skills shortages, reducing costs, and improving productivity. According to Goulding et al. (2012), prioritising areas for OSP is one of the main deliverables. The main disadvantages are listed as manufacturing standardisation clashes with flexibility, need to retrain staff, process restructure required to encourage integration, and automation being unrealistic. Zhai et al. (2014) examined the barriers that affect the uptake of OSP in China. Their study reports the barriers to offsite as follows: preparatory stage, supply chain, costing, architectural performance, social climate and attitudes, and constructability implementation. Elnaas et al. (2014) examined constraints to OSM in the UK and classified them under the following six categories: system, logistics, process, resources, regulatory, and cost implication. The process category was the highest constraint (70%), which includes complex interfacing between systems, design freeze, and increased incidents involving large components and heavy loads. The resources category was second (64%), which contains skills shortages, limited UK capacity, and limited expertise in the marketplace of the system. The third category was system (61%), which includes culture resistance, lack of understanding from the authorities, low market demand, and lack of understanding from mortgage bodies.

Arif et al. (2012) state that, according to Indian offsite construction, the main drivers were ensuring time and cost certainty. Other drivers include client influence, side government promotion, and controlled site specifications. According to Vernikos et al. (2013), in a review of the main drivers for UK offsite construction, the drivers include cost (Gibb and Isack, 2003), profitability (Pan and Sindell, 2011), time (Goodier and Gibb, 2007), sustainability (Presquire and Gibb, 2002), productivity (Gibb and Isack, 2003), and quality (Goodier and Gibb, 2007). Elnaas et al. (2014) classified drivers into the following five main categories: technical, economic, environmental, organisational, and social drivers. The technical category is placed at the top, which comprises shortage in housing supply, projected skills shortage, and concerns regarding the quality of newly built homes. The economic category includes a reduction in overall project cost and the integration of project processes; whereas, the environmental category includes the environmental performance of buildings and the reduction of environmental impacts during construction. The organisational category includes compliance with building regulations and government concerns. Finally, the social category encompasses improving onsite health and safety, and product to end-user performance (Elnaas et al., 2014).

Construction projects face certain difficulties regarding project delivery, which is considered a problem within Saudi Arabia's construction industry. Assaf and Al-Hejji (2006) found that 70% of the projects in the Eastern province of Saudi Arabia were delayed due to the changing of orders by the client during construction. In addition, the poor coordination of building services generates uncertain outcomes in the procurement and cost management of buildings because of a lack of knowledge among stakeholders regarding the technology of building services (Yusuf et al., 2012). The benefits of OCT include efficiencies in system processes, predictability, quicker construction processes, reliability, and less construction waste (Robinson et al., 2012; Elnaas, 2015). Despite research regarding the causes of delays in construction projects worldwide, studies regarding the poor project delivery of complex office developments in the context of Saudi Arabia construction industry due to a lack of coordination between project team in an early stage. Consequently, this study, which examines the relationship between perceived consultants and contractors regarding the utilisation of PBSC via a mixed quantitative and qualitative approach, generates valuable results regarding the enhancement of construction projects. This work explores the influence of consultants and contractors towards using PBSC within complex office developments in Saudi Arabia.

2.3 Research Background

This section presents the key definitions regarding PBSC and a detailed historical background of PBSC and their integration into office developments. Additionally, the modularisation of building services is highlighted.

2.3.1 *Definitions*

Hui et al. (2005) define 'fabricate' within the manufacturing process as delivering materials with specified properties, including conductivity, dimension, density, and shape. '**Prefabrication**' in practice refers to 'the manufacture of component parts of a building and its services before their assembly on site' (Hui et al., 2005; Wilson et al., 1998). The construction process can embrace prefabricated techniques in a wide range of applications, which, in their simplest form, can be temporary site offices, or, in a more complicated form, can be volumetric units integrated into the building structure (Hui et al., 2005).

Cooper (2004) defines '**offsite manufacture** (OSM)' as 'making all or part of an object in some places other than its final position'. Wilson et al. (1998) state that 'offsite' in building construction comprises preassembly and fabrication, in which 'making' means to fabricate and assemble. By definition, '**preassembly**' refers to 'the manufacture and assembly of a complex unit comprising several components before the unit's installation onsite' (Hui et al., 2005). Consequently, an offsite approach decreases the need for onsite work, reducing times and costs for onsite installation.

'**Modular construction**' indicates that building construction is generally preassembled and transported to the site as individual units. The term 'modular' refers to a construction technique in which individual modules independently stand or are collectively assembled to create larger structures. Prefabricated modules are usually shop-made and finished to the level of 'ready to use'. These are then transported to the site and installed rapidly with minimum work onsite (Ricketts, 2005). Preassembled bathroom modules, commonly called 'bathroom pods', are manufactured and tested within factory conditions to form a volume of usable space (Gibb, 1999). Pan and Gibb, (2009) examined the maintenance performance of bathrooms pods and found that they had the fewest maintenance problems compared with conventional bathrooms.

Preassembled building services components PBSC are prefabricated electromechanical systems that involve significant elements, such as air ducts, water pipework, drainage pipework, and conduits and wiring (Hui et al. 2005). In general, offsite construction includes four categories: non-volumetric preassembly (e.g. cladding panels and frame sections); component sub-assemblies (e.g. window sets and doors); volumetric preassembly (e.g. bathroom pods, boilers); and modular building (e.g. room modules) (Pasquire and Gibb, 2002). It is important to note that PBSC are implicitly deemed to be part of all these categories, except non-volumetric preassembly.

The offsite approach was stated by Mitchell (2005) as being used in the UK for making office washrooms and toilets, lifts, complete bedrooms, hotel bathrooms, cladding units, and building services plant rooms.

2.3.2 *History of Preassembled Building Services Components*

The industrial age, from the 1850s to the 1940s, developed the main industrial society principles and created urban areas with massive growth. The introduction of the first modern ideas concerning public health was the catalyst for such changes (Marsh, 2007). Regarding building design, these changes were supposed to deliver new functions into buildings to rationalise design and construction processes. For instance, the bathroom and the kitchen were designed close to each other to reduce the nature of vertical ducts to wastewater drainage and water supply (Marsh, 2007).

The modern age, from the 1940s to the 1980s, experienced rapid technological development, such as artificial illumination, air conditioning, and ventilation. Such technological developments helped upgrade the levels of comfort in buildings that were independent from traditional building regulations. These technological changes facilitated the development of new building types, which are categorised by modern architecture and an international style. For instance, modernised construction processes allowed the development of façade systems with enormous glazing areas, which became the norm in most building designs (Marsh, 2008).

The intelligent age, from the 1980s to the present, has experienced growths in information technology (IT) that have allowed a massive on-going rise in the delivery of intelligent building services (Clements-Croome, 2004). This development includes knowledge, entertainment, and control aspects. Knowledge development has a broad application for IT, which encourages the upsurge of modern knowledge-based businesses in the form of 'New Ways of Working'. Modern business models require the innovativeness and creativity associated with flexible workstations as a driving force (Duffy et al., 2003). Entertainment development is part of the growth in IT, multimedia, and communication technologies (Sandström, 2003). These entertainment technologies are a major factor also in the increase of power consumption (Marsh, 2008). Control development refers to the evolution of intelligent control systems in all buildings, especially indoor climates, the control of environmental energy usage, and facilities management, etc. (Baird, 2003). Such systems usually place another layer of intelligent control over the current preassembled building services (Marsh, 2008).

Prefabrication is defined by White (1965) as, 'a useful but imprecise word to signify a trend in building technology'. Gibb (1999), in his book *Offsite Fabrication*, provides an example of the main preassembled systems for a multi-storey commercial building that includes building services systems. The building services were confined to the distribution network and plant rooms, and the distribution network included access platforms and insulation as well as multi-service, vertical riser sections complete with framing, and plug-in modules for horizontal distribution.

Multi-storey concrete modular construction was used during the 1960s and 1970s. A famous example is the Hilton Palacio del Rio Hotel, where plumbing and wiring channels were placed between modules for rapid links to individual rooms, and removable panels were added in the corridors to provide access to the vertical electrical and mechanical chaseways (Modular Building Institute, 2007; Velamati, 2012).

Hawkins (1997) considered prefabrication and preassembly as means of improving the productivity of building services, rather than a change in construction philosophy. His view drove Wilson et al. (1998) to conduct a research project to discover how prefabrication and preassembly could be economically used in building services to make effective installations.

The BSRIA report *TN 13/2002 Site Productivity* by Hawkins (2002) investigated the application of innovative products and well-trained personnel to improve processes during the pre-construction and construction phases of a project. The findings enabled preassembled building service elements to be installed in less than 10% of the traditionally estimated timeframes.

In 1999, Gibb proposed, in *Offsite Fabrication*, various examples of prefabricated building use, of which some are appropriate for an office building. The examples comprise building service components such as office bathrooms, lift shafts and elevators, preassembled mechanical or electrical rooms, and preassembled M&E distribution systems (Molavi and Barral, 2016). Table 2-1 summarises the history of PBSC.

Table 2-1 Summary of PBSC history (Source: Author)

Time	Example
1850s to the 1940s	The industrial age experienced the main industrial society principles
1940s to the 1980s	The modern age experienced rapid technological developments, such as HVAC
1980s to present	The intelligent age experienced growths in IT, including knowledge, entertainment, and control aspects

Different building services are essential for today's buildings, especially those related to providing users with the required functionality. There has been considerable growth over the past 100 years in the levels and quantities of these building services (Marsh, 2008).

The change process is necessary to investigate adaptation possibilities of innovation realities (Beerel, 2009). Regarding change, the first application of preassembled building services was functionally made to rationalise design and construction, including where bathrooms and kitchens being placed close to each other. This rationalising minimises the extent of vertical ducts to wastewater drainage and water supply in housing (Marsh, 2008). Continuous processes of social and economic change helped categorise modern society and naturally influenced the perception and use of buildings (Marsh, 2008). In complex office developments, both the employees' and the building's capability to adapt over time are required, especially as IT and the knowledge economy are realised as innovative, competitive fundamentals (Marsh, 2008).

2.3.3 *Building Services Integration in Office Developments*

The development of office designing during the modern age, from the 1950s to the present, involves the integration of building services into office projects. The main origination of office buildings placed traditional building services in service areas. The service areas (M&E room) on each floor comprise the vertical services (e.g. ducts) to be positioned in accordance with kitchen and toilet services (Marsh, 2008).

Due to functional and technological changes, there has been major growth in the degree of building services placed in office areas. Such growth comprises data communications and systems, new IT, and wide cooling and ventilation systems to control the indoor climate. This growth was driven by the electrical and electronic equipment established in these office areas (Marsh, 2007).

Thus, the design strategies for building services delivery were not primarily altered due to the change in building services requirements. However, the large air volumes needed for the significant floor areas enforced the enlargement of vertical ducts where they are centralised in the service areas and connected to large horizontal ducts for ventilation (Marsh, 2007).

2.3.4 *Modularisation of Building Services*

The communication between client, consultant, and contractor has a historical context, and building industry firms have been economically controlled by the demands associated with high construction costs. The demand for more efficient buildings has led to critically automating the building industry, concentrating on the loadbearing structure and façade elements (Marsh, 2008). The growth of preassembled building services increases over time due to greater technical demands for more functional buildings. This growth leads to a greater portion of the total construction costs (Marsh, 2007).

Furthermore, some conflicts occur between traditional and modern methods of construction regarding building industry firms. Similarly, the decision regarding the specification of building services often occurs at a late stage in the procurement process. Therefore, preassembled building services products are considered for buildings in a craftsman-like way because of the inconsistency in the construction sector's traditional firm, as well as the difficultly of installing preassembled building services (Marsh, 2008).

Many studies in the UK have revealed that PBSC contribute to reducing construction costs and times. Ultimately, the primary productivity gains from modularisation are arguably accomplished by concentrating on building services that are a significant proportion of total construction costs (Dicks, 2002).

2.4 Forms of Preassembled Building Services Components

Preassembled building services components are implicitly considered part of the main offsite construction categories. The main four categories of offsite construction are as follows: 1) modular building, 2) volumetric preassembly, 3) non-volumetric preassembly, and 4) component sub-assemblies (Neale et al. 1993; Gibb, 1999; Lu, 2007; Boyd et al. 2012). However, Gibb (2001) includes examples of PBSC in only three of the four categories of offsite construction: non-volumetric preassembly (e.g. pipework assemblies), component manufacture and sub-assembly (e.g. light fittings), and volumetric preassembly (e.g. toilet pods, plant room units, preassembled building services risers, and modular lift shafts).

Wilson et al. (1998) state four main approaches to using preassembled components for building services: 1) integrated building services with modular buildings; 2) preassembled vertical and horizontal distribution (e.g. ductwork, pipework, and wiring); 3) preassembled building services modules/units (e.g. toilets, bathrooms, and plant rooms); and 4) terminal unit preassembly (e.g. fan coil units and sanitary fittings).

2.4.1 *Modular Buildings with Integrated Services*

O'Brien (1998) defines modular buildings as factory-built buildings of one or more units completely assembled or fabricated in a control manufacturing environment away from the site, then transported and assembled onsite. Modular buildings usually contain three-dimensional multi-rooms that are constructed and preassembled complete with trim work, electrical, mechanical, and plumbing installed.

2.4.2 *Preassembled Building Services Units / Modules*

Pan et al. (2004) state that preassembled units are considered to be a grouping of any two or more non-volumetric or volumetric systems, creating a hybrid system that includes plant rooms, bathrooms, toilets, and kitchens.

2.4.3 *Prefabricated Horizontal / Vertical Distribution*

Tatum et al. (1987) define offsite preassembly as a method by which several building materials and equipment are mutually gathered offsite for later fitting. Offsite preassembly is generally focused on systems such as pipework, ductwork, and wiring preassembled with insulation, platforms, piping, and ladders.

2.4.4 *Terminal Unit Preassembly*

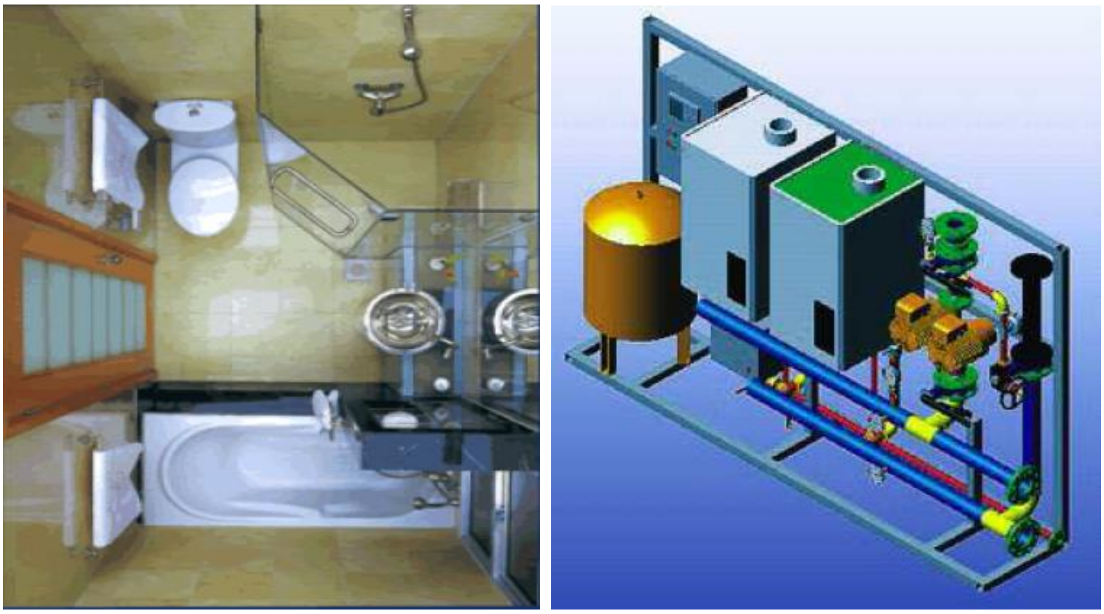
Tatum et al. (1987) define preassembly as a practice by which prefabricated equipment and components are mutually gathered offsite for later fitting.

Preassembly is generally focused on units such as fan coil units and sanitary fittings. The main appropriate elements of preassembled building services systems are provided in Table 2-2.

Table 2-2 Systems and elements of preassembled building services (Source: Hui and George, 2005)

Building services systems	Major elements
Mechanical ventilation and air conditioning	- Air duct system - Water pipework and fitting - Refrigerant pipework and fitting - Air-conditioning equipment (e.g. air-handling unit)
Fire services	- Water pipework and fitting - Pump sets and fittings
Plumbing and drainage	- Water supply pipework and fitting - Drainage pipework and fitting - Pump sets and fittings - Bathroom and toilet sanitary fittings
Electrical services	- Cable and busbar trunkings - Conduits and wiring - Power outlets and telecommunication - Electrical switchgear

Hui and George (2005) state that several trades are engaged with building services installations. The labour aspect is estimated to be two-thirds of the cost in building services, which can be improved through using an offsite approach. For quality assurance, completely integrated building services modules are designed and preassembled offsite, accomplished with all the required work comprising, but not limited to, pipework and fittings, valves, containment, insulation and even supply and extract ductwork. Modular wiring systems can be used to provide a more flexible alternative for electrical services, under-floor power, and data/voice distribution systems. To achieve savings in space with building services, the entire plant room can be manufactured in the factory. Figure 2-1 displays examples of preassembled building services units.



(a) Preassembled Bathroom **(b) Integrated Building Services Plant**

Figure 2-1 Examples of preassembled building services units (Source: Hui and George, 2005)

2.5 International Application of Preassembled Building Services Components

In Germany, offsite construction methods have been utilised in building construction using a range of building materials. Timber-based preassembly construction systems can be formed as structural insulated panels (SIP), post–beam construction, or a combination of both (Lu, 2007). Figure 2-2 illustrates the integration of PBSC in a modular building.

Basement Plant Room **Balcony Bathroom**

Figure 2-2 Examples of preassembled building services components (Source: Venables et al., 2004)

Figure 2-3 Pipe modules for a commercial office building (Source: Pasquire et al., 2006)

Examples of modular building with integrated services are provided in Venables et al. (2004). Exterior finishes usually involve cladding or rendering. Timber construction specifications are deemed to be a higher standard than those in the UK, and neater for the finished quality of the final product. Masonry and concrete systems are utilised for roofing elements and building panels. Moreover, the automated production of concrete panels for walls/basements and modular concrete housing is also utilised (Lu, 2007).

In the UK, Pasquire et al. (2006) investigated a case study of pipe modules for a 12-storey commercial office building – the regional office for The Royal Bank of Scotland in Manchester city centre, with 60,000 m^2 total floor area, including a basement and rooftop plant room. Fan coil units were the main heating and cooling systems for the 10 floors of office space. The main distribution pipework was prefabricated and installed as pipework modules. The main drivers for applying OCT were to reduce the number of workers on site, reduce the supervision, and the lack of available skilled labour. The evaluation of this case study revealed that many benefits were added, such as cost-saving, time reduction, quality improvement, health and safety, sustainability, as well as site benefits such as reduction in risk exposure. Figure 2.3 depicts pipework in a commercial office building.

Andrew Robinson, Project Manager at Sir Robert McAlpine, stated that the benefits of OCT include ‘programme certainty, improved site productivity, a reduction in work face congestion and a high-quality installation’ (Pasquire et al., 2006).

In China, Mini Sky City was finished on 17 February 2015. The contractor, Broad Sustainable Building, fabricated the building’s 2,736 modules in 4.5 months prior to construction at an installation rate of three floors per day (see Figure 2-4). Mini Sky City was assembled from prefabricated sections in the final location using modular methods. There was a reduction in time because the foundation of construction was completed while components were prefabricated offsite. The benefits of such projects include, but are not limited to, increased construction quality and safety, decreased completion time of construction, reduction in the overall costs, reduction in material waste, and reduction in the environmental impact (Boafo et al., 2016).

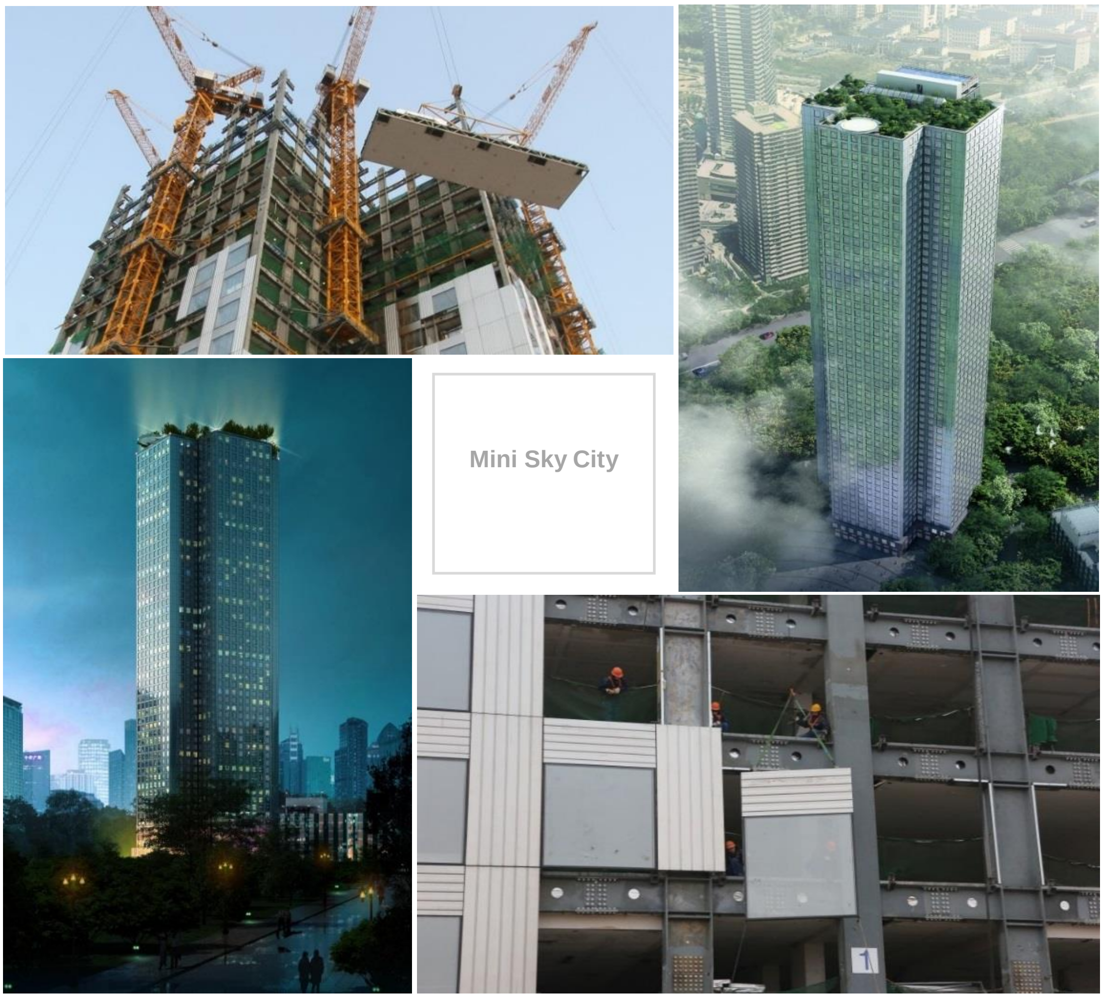


Figure 2-4 Mini Sky City – Through Construction, Cladding Systems, to Complete Tower. Accessed: (17 Feb 2017) (Source: https://www.skyscrapercenter.com/building/j57-mini-sky-city/19743)

2.5.1 *The Application of Preassembled Building Services Components in Saudi Arabia*

Aburas (2011) organised a workshop to measure the current situation of OCT in Jeddah, Saudi Arabia. All the participants had 5-10 years of experience as project managers either in government departments or private construction companies. When asked about the perception of offsite construction in Saudi Arabia, the results reveal that the applications of OCT often include façade panels for multi-storey buildings and temporary structures, such as portable toilets and site offices.

Almutairi (2015) states that OCT application in Saudi Arabia is regarded as new due to lack of use and a number of challenges. He investigated the application of OCT in the Saudi Arabian context. The analysis of his study indicates that almost two-thirds of participants practised offsite preassembly, such as prefabricated horizontal/vertical distribution and terminal unit preassembly; less than two-thirds practised penalised systems; one-third practised modular building, including modular buildings with integrated services; and more than half of the participants practised the hybrid system, including preassembled building services units/modules. All the participants displayed notable satisfaction with using OCT.

2.5.2 *Example of Saudi Arabia*

This research involved some PBSC construction practitioners in Saudi Arabia via interviews and field notes taken on PBSC available onsite. Three case studies are included: the first site visit was with a consultant, the second was with a general contractor, and the third with a specialised subcontractor. The applications of PSBC in the case studies include an air duct system, air conditioning equipment, electrical switchgear, cable, power outlets, and telecommunication. The nature of these applications was included in the contract documents especially appointed by the client to have certain components; a certain factory or supplier could be appointed in other cases. However, this procedure is considered exceptional when the procurement system encourages more bidders for the contract.

Figure 2-5 External compressor and chillers (Source: Author)

Preassembled mechanical services must comply with the Saudi Building Code SBC 501 and all related Saudi Arabian standards, including HVAC and smoke control systems. The concepts of PRAME, LEED, and ESTEDAMA are applied. The client requirements involved several features, including reliability, minimal maintenance cost, accessibility for maintenance, using an energy management system, durability, heating provided by hot-water coils, and car park ventilation systems to incorporate carbon monoxide. In addition, retail and basement ventilation is used to minimise unpleasant odours. The design conditions were drafted to meet the guidelines for conditions in accordance with the Saudi Building Code. The thermal comfort conditions were also highly considered to comply with the ASHRAE standard (see Figure 2.5). Furthermore, the regular office hours (8.00am to 5.00pm) required after-hours heating and air conditioning via an on-floor button interface to the building control system. The preassembled duct sizes were reviewed by representatives prior to production. The roof fans are used for ventilation as a typical exhaust system for amenity areas. The tempered supplementary outside air and supplementary exhaust complement the fan, which is capable of delivering the specified air quantity, including the need for future space connection. The preassembly included also controls to maximise operational efficiency and to monitor energy consumption. Similarly, the system monitors fire alarms and other building services, including after-hours A/C control.

Moreover, lift design specification must meet international standards regarding the average lift interval of car departure from the ground floor regarding up-peak, lift speed, a rated load, and levelling accuracy. In the plant, the testing and commissioning are performed in accordance with ASHRAE requirements. Consequently, several procedures are followed in pre-commissioning and testing for PBSC, such as pressure and leak testing all riser ductwork and pipework (see Figure 2-6). Additional procedures include checking all control and power wiring for the specific operation of equipment, providing manufacturers' test certificates for all proprietary equipment, balancing air systems, running all air-handling systems with temporary filters, and preparing a commissioning management plan.

Figure 2-6 Valve assemblies and external ductwork and pipework (Source: Author)

Moreover, mechanical rooms are usually preassembled, which is also mentioned in the contract, but conventionally supplied power to the room. Large construction projects often involve medium to large chillers. There are two types of chiller: centrifugal and reciprocating. The plant rooms were also preassembled based on the design specifications, but the preparation requires more time to align with traditional designs. Some example are illustrated in Figure 2-7.

Preassembled electrical services must comply with the Saudi Building Code SBC 501 and all related Saudi Arabian standards and authorities' requirements. Preassembled electrical services include lighting fittings, switchboards, power supply substation, main distribution centres, general power and light sub-circuit cabling, distribution boards, power connections to all electrically operated equipment metering (Saudi Electricity Company), standby power generation substation (UPS), and power supply to external signs.

Preassembled chillers　Mechanical room　Plant room

Figure 2-7 Examples of PBSC available in Saudi Arabia (Source: Author)

The preassembled power supply is provided and connected through a high voltage, subject to confirmation by the Saudi Electricity Company and the Electricity and Cogeneration Regulatory Authority. The main preassembled switchboard is designed to deliver distribution to office spaces, essential services, and HVAC, including surge protection. The energy metering system allows SEC access for energy reporting and monitoring. For future consideration, the plant room has space for a generator system that is provided with switches, exhaust, cabling, and riser space for fuel lines. Figure 2-8 illustrates the spiral ductwork (SAFID) with levelling for the lights.

Also, the client’s requirements included that the general office lighting be preassembled with high efficiency to a minimum average lighting level. Similarly, the lighting of core areas, the entry area, and corridor lighting are to be preassembled with energy-efficient less-maintenance lighting, as is the lighting of the toilet, car park, storeroom area, and the external lighting. On the other hand, the main riser of data telecommunications for data and voice cabling is preassembled using a separately dedicated riser for worker voice and data cabling. In addition, external areas on the roof are available for microwave and satellite dishes and/or other telecommunication tools.

A card security system monitors the building boundary, the main entry door, car park vehicle access, rooftop, plant rooms, and fire stairs. Access control is provided by gate entry, all of which are controlled via the access control system. Electrical control magnetic locks and CCTV cameras cover exterior gates, the main entrance and car park access, loading dock, and fire stairs. The security office is located on the ground floor.

Figure 2-8 Exposed wiring, power supply, and internal/external ductwork (Source:

The preassembled plumbing services are designed and installed in accordance with Saudi Building Codes and all relevant standards and authorities' requirements. The water supply and sanitary plumbing on each floor are provided with hot and cold water to amenities in accordance with SBC requirements. Rainwater drainage is provided in accordance with MOMRA Authority requirements. The cold-water system, the hot-water system, and the gas services are provided in accordance with SBC 601-701. Furthermore, the building fire protection system is designed to comply with Saudi Building Codes and all related standards and authorities' requirements, including those of The General Directorate of Civil Defense (see Figure 2-9). Fire sprinklers and smoke detectors are provided in the car park areas and substation, in accordance with SBC. The sprinkler pipework and heads are provided throughout the main lobby level, office areas, and retail areas. The PBSC are designed, built, and commissioned in accordance with the SBC 601, the Saudi Electricity Company and the National Water Company.

Figure 2-9 Washroom pod and concealed AC return, supply, and fire alarm (Source: Author)

Example – SGC Headquarters

A new world-class complex office development located in Riyadh, KSA with a total area of more than 250,000 m² and BUA of 122,685 m² is planned to be completed in 2019. The new, semi-government company headquarters represent an original approach to sustainable design and construction. The consultant has performed various tasks, such as architecture, interiors, landscape, preassembled building services, and site supervision. Furthermore, the consultant developed a strategy that is focused on the four central fields of sustainability: cultural, environmental, social, and economic. Themes were provided from current proforma models, such as BREEAM, LEED and Estidama (Gulf Construction, 2017).

The design goal is to deliver long-term employee health and satisfaction, which are believed to play important roles in meeting the project requirements. Similarly, achieving better staff health and productivity requires considering the most desirable matters for sustainability. Consequently, sustainability frames both the facility’s energy-saving technologies as well as protecting and fostering human resources (Gulf Construction, 2017).

The designers mainly considered healthy environmental measures; the corporate headquarters is designed to minimise the interior incidence of ‘sick-building syndrome’, which affects employee health. Consequently, the designers implemented certain measures to meet that consideration, such as specifying only toxin-free materials and low- or zero-VOC finishes, while engineering building services and systems maintained optimal air quality, with a built-in capacity for regularly scheduled testing and maintenance. Furthermore, a number of standards were developed to ensure that cleaning contractors do not use chemicals known to cause health issues. Figure 2-10 displays 3Ds of the exterior and interior panelised systems, including outdoor connections (Gulf Construction, 2017).

3D outdoor of HQs – Shows vertical and horizontal connections with

3D interior of HQs – Shows complexity of maintaining daylight with glazed frames.

Figure 2-10 3Ds of interior and exterior panelised systems (https://omrania.com)

2.6 Categories and Systems

To find improvements within the building service systems, an overview of current practice is needed. The purpose of this section is to provide the reader with an insight into the complexity of the MEP systems, concentrating on the design criteria of the MEP systems, which guide the design process of the various building systems. The building systems addressed here are the HVAC system, the electrical system, the plumbing, the fire protection system, the process piping system, and the telephone/data system.

2.6.1 *Overview*

Building services is a modern term that describes the mechanical, electrical, and plumbing systems (historically referred to as MEP) in building and industrial projects (Olanrewaju and Anahwe, 2015). These MEP involve different trades, including HVAC packages, lift and escalator installation, electrical wiring, plumbing and drainage, and fire services installation (Wong et al., 2012). The functionality and complexity of MEP systems are growing. Such growth is driving current projects to comprise more than the traditional MEP systems. The expansion of the scope of MEP allows for additional systems, such as process piping, fire protection, telephone/data, and controls. These additional systems are included within the old classes of MEP. Building services are commonly installed by individuals within contractors (Tatum and Korman, 1999).

The concept of preassembled building services is as deep-rooted as the idea of prefabrication in buildings. Figure 2-11 A portrays the use of a crane to upstand a three-floor building service wall. Electricity, remarkably, was not greatly involved for power and telecom, since wire canalisation was less weighty at the time, with fewer media (Lennartsson and Björnfot, 2010). The first attempts to prefabricate full bathrooms with all essential preassembled building services were completed in the 1980s. The kitchen’s ‘wet area’ is often placed at the back of the bathroom wall to simplify assembly in the design of floor plans. All preassembled building services are grouped in a canalisation in a shaft located in the building.

A B

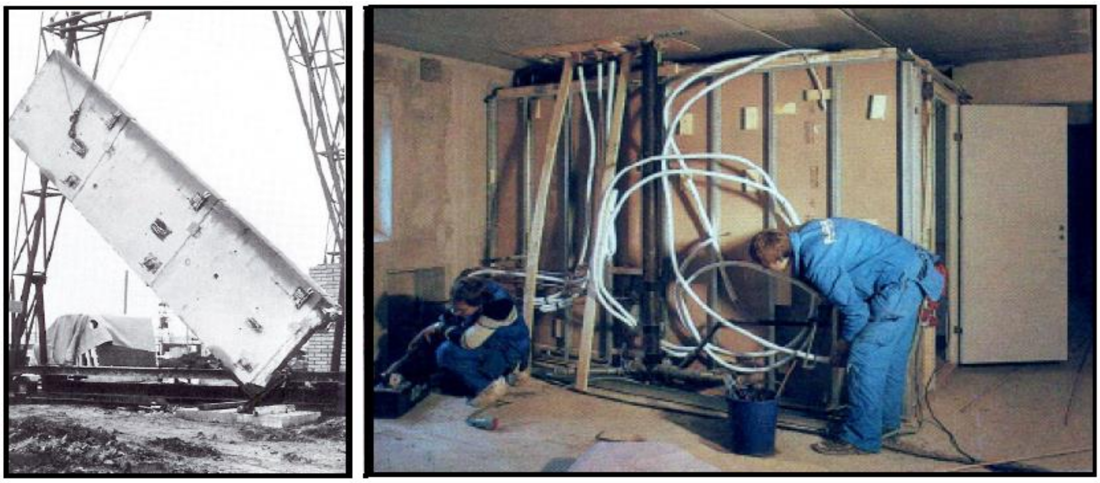


Figure 2-11 History of preassembled building services. A) Using a crane to upstand a three-floor building service wall. B) Connection of a shaft assembly to a stairwell (Source: Lennartsson, 2009).

The first building system solutions appeared as shafts in the 1990s and were placed in assembly in the stairwell (Figure 2-11B). New building materials are driving those solutions, for example, a plastic material with corrosive, pressure, and thermal resistant characteristics (PEX). Furthermore, technical solutions for testing, such as standardised ventilation shafts, are eligible for both onsite assembly and prefabrication. The preassembled building service wall is used for horizontal canalisation, which can similarly be used for wall-assembled toilets. Therefore, all connections are hidden and positioned in the bathroom but with outside placement in the wall.

Building services in the 2000s were greatly extended with communication and automatic control systems. Also, the addition of sprinkler systems resulted in the allowance of visibility both outside and inside timber buildings (Lennartsson, 2009).

2.6.2 *Mechanical Systems*

Heating, Ventilating, and Air Conditioning Systems

Heating, ventilating, and air conditioning systems are commonly abbreviated as HVAC systems. The four essential components of HVAC systems are as follows: 1) a heat-generating system, 2) a cooling system, 3) an air-handling system, and 4) a control system for monitoring the system operation, either by hand adjusting or automatically. The main function of the HVAC system is to completely deliver conditioning of the air, including filtering, freshening with outdoor air, and adapting temperature and relative humidity. The design considerations are set, depending on the building purpose and use, by the architect and design consultant (Tatum and Korman, 1999).

Generally, the size of HVAC equipment is very large and it is noisy. Thus, appropriate space must be strategically allocated. For operational feasibility, easy accessibility is required for maintenance and replacement purposes. A number of important aspects need to be considered during the design phase, such as noise and vibration, especially for cooling equipment and large fans. Air duct networks require large spaces within HVAC systems to serve the building's interior spaces and join the operating equipment. The connections between the air intake, outdoor air, and exhaust need to be appropriately located (Tatum and Korman, 1999).

2.6.3 *Electrical Systems*

The main electrical system types are supply, distribution, and lighting (Tatum and Korman, 1999). Modern building practice regarding the assembly of electricity includes a local plant linked to a high-voltage power line. Mechanical rooms are supplied by power through the central power supply, which, in return, supplies buildings with power. Multi-storey buildings commonly use canalisation within shafts that are positioned to join to the local central. Thus, each floor is supplied with power through these links. A thermoplastic mantle is used to insulate twice-applied wires surrounded with a flexible plastic pipe. Different methods are assigned for the placement of wires, including:

- Concealed or setting into the wall installation, where wires are positioned in frames of wood, sheet metal, or concrete walls or floors.
- Open or external installations, where wires are positioned in pipes, edgings, or canals.

Compression fittings and connector boxes are used to create connections and joints (Lennartsson, 2009).

SHAFT solutions encompass two principles: 1) a single vertical shaft providing the entire building with more horizontal canalisation on each floor (Figure 2-12 A); and 2) multiple shafts for each section of the building. For instance, a shaft consisting of the building service canalisation to nurture the building with media (Figure 2-12 B). These solutions mean that the shaft attaches to the building sections and avoids installing canalisation in corridors and access balconies (Lennartsson, 2008).

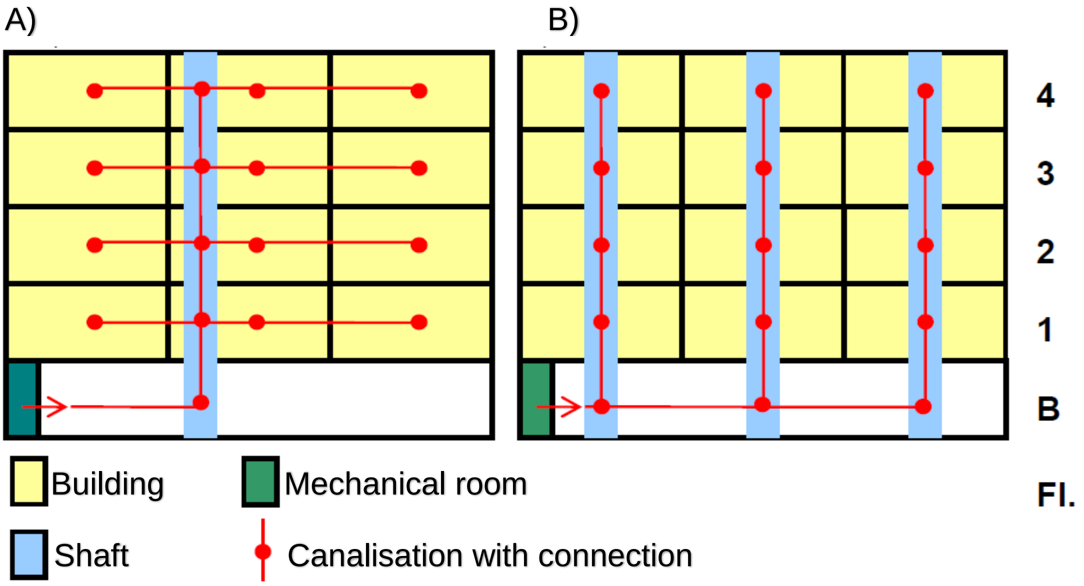


Figure 2-12 Shaft solutions: A) Horizontal canalisation with single shaft; B) Multiple shafts with vertical pipes and wires (Source: Lennartsson, 2008).

2.6.4 *Plumbing Systems*

The main plumbing system types are pressure-driven systems, gravity-drained waste systems, and pumped waste**.** Pressure-driven systems provide several places in the building with hot- and cold-water lines. Gravity-drained systems are sloped lines that require a natural grade line and vent lines for the entire system to let the open channel flow into the drainage network. Ultimately, pumped-waste systems drive all waste lines that need to be pressured (as opposed to just gravity) in double-contained piping systems (Tatum and Korman, 1999).

Water Supply

Heat exchangers provide hot water in the building's mechanical room, where the well-cut pipe system, with right-angled edges, should be clean. Pipes are usually made of copper and stainless steel, with protection against corrosion due to the chrome alloy. Additionally, plastic pipes can be used both in buildings and foundation installations. Pipes with PEX characteristics are commonly used as they resist pressure and extreme temperatures (Lennartsson et al., 2009).

The pipe-in-pipe system involves water pipes being located in a protective pipe without joints. This system allows for the detection of water leakage, as water flows out via the protective pipe. Pipe grommet installation allows for the expansion of pipes in walls and floors due to temperature variations. However, pipe systems potentially require replacing because they have a lower life expectancy than the building. Concealed systems involve securely using pipe-in-pipe solutions, but visible systems easily detect leakages (Lennartsson, 2009, p.23).

Drinkable and cold water (tap water) needs quality installations and, consequently, governmental authorities regulate water quality. There is a risk of pollution in water installations, such as metals' precipitation and the growth of microbiological organisms. The growth of Legionella bacteria is possible. These bacteria infect humans through respiration and thrive in temperatures from 20 to 50°C (Lennartsson, 2009, p.24).

Drainage

Sewage systems remove water from toilets, water stands, tubs, or other drain units. Self-slope and pressurised are two kinds of drainage system application. Self-slope systems have a built-in slope in the flow direction to facilitate sewage transport. Permitted products and components must be tested for density, flow characteristics, and noise. Drain pipes are made from cast iron, plastic, or stainless steel. Drainage pipes are positioned either freely or by cast: vertical pipes are freely positioned, while horizontal pipes are positioned freely or cast in concrete (Lennartsson, 2010).

2.6.5 *Fire Suppression Systems*

The ability of a building to withstand fire is closely related to the design of the ventilation system. Backvik et al. (2008) state that buildings with residences must resist fire for at least 60 minutes (EI 60 – where E is for integration and I is for insulation), but the class can commonly be dropped by half in cases of sprinkler installation (EI 30). Ventilation shafts are either open or closed. However, shafts cannot be designed using flammable material (Lennartsson et al., 2009).

Fireproof material is required for the construction of all shaft walls. Furthermore, the designs of open shafts must be enclosed top and bottom in EI 60. However, firewalls with closed shafts can be reduced to EI 30. An isolated wall with class EI 15 and radiation protection or insulated ventilation ducts with EI 15 are required in cases with mixed shafts, including electricity and telecom, due to the enlarged risk of starting a fire in the shaft (Lennartsson, 2009, p.24).

2.7 Design Process

This section mainly reviews the role of design specifications in construction projects. A general description of the design specifications is provided as well as the client's requirements and the design process in Saudi Arabia. In addition, the Royal Institute of British Architects (RIBA) and the American Institute of Architects (AIA) plans of work are discussed to understand the hybrid Saudi construction industry plan of work regarding the design and construction processes.

2.7.1 *Design Specification*

According to Darlington and Culley (2004), design specification is a description of the preferred solution to a problem. In the design process, the role of design specification is significant. Therefore, the description of the preferred solution is expressed by a set of requirements in the specification document. A comprehensible description of the preferred solution increases the likelihood of attaining a successful design. A comprehensible description includes sufficient statements directing the design team to proceed from the abstract to the concrete solution to achieve the goal of the product. Furthermore, the identification of the problem enables the establishing of the criteria regarding the selection of a feasible concept in the form of a design specification as a list of requirements. The role of the specification, 1) provides the design team with the shaped solution space to design a product, and 2) assesses and ensures that the proposed solution falls within the acceptable limits (Sudin et al., 2010).

Founding a design specification is critical for design research (Chakrabarti et al., 2004). The literature suggests some procedures for producing requirements for a specification (Sudin et al., 2010). For instance, Ulrich and Eppinger (2000) recognise the advantages when a comprehensive specification is available at the beginning of the design process. A number of rules for the preparation of a good specification are introduced by the literature, such as being measurable (qualitative or quantitative), unambiguous, clearly linked to customer needs, and a solution-independent formulation. Also, the requirements are classified into demands and wishes to ensure that the specification is practical (Ulrich and Eppinger, 2000). Therefore, the content and form of a specification differ from one project to another and are influenced by the complexity of the factions, design difficulty, the requirement for extra properties, appearance, and problem initiator or sponsor (Sudin et al., 2010).

Andersson (2003) states that, ‘completeness is a criterion that is unachievable’. Frequently, new requirements are added as the design process proceeds into the advanced stage. Therefore, the requirements are explored, developed, changed, and expanded throughout the design process into a final specification (Sudin et al., 2010). Hansen and Andreasen (2007) found that design engineers produce specifications during the design process. However, changes in requirements during the design are vital for improvement or fixing errors, but could consequently cause schedule delay and an increase in cost. Nonetheless, these effects depend largely on the difference between the initial specification (prior to the design process) and the full specification (the complete design process). Therefore, consequences can be significantly reduced by minimising the differences between the initial and full specifications (Sudin et al., 2010).

In the construction industry, the specifications are a mean of linking the design team with the contractors to perform the required procedures and quality standards of building projects. Therefore, specifications should match drawings without ambiguities. Similarly, specifications play an important role in contract documentation for controlling work carried out on site. Ultimately, the acceptance of completed works depends on satisfactorily meeting specification requirements (Lam et al., 2001).

2.7.2 *The Design Process in Saudi Arabia*

Commonly, in the design process, the public client in Saudi Arabia commissions a consulting firm to develop the complete construction documents (Alsuliman, 2014, p.33). However, this phase is exempt under the GTP, in which no formalised approach is applied to public clients to commission a consulting firm (Mohammed, 2007), but is appointed either due to a recommendation from the client’s representative or the reputation in the market. Alsuliman (2014, p.34) states that the adopted system among Saudi consulting firms depends upon the firm itself, who generally adopt an international system that is compatible with the nature of the project, their engineers, and their clients.

The practices of the RIBA and the AIA are the most well-known for the design process in the Saudi construction industry (Mohammed, 2007). The adoption of these models is mainly due to the lack of institutional organisation in the Saudi construction industry. Accordingly, depending on the experience and background of the design management in the consulting firms, a familiar existing practice is applied, which is typically either that of the RIBA or the AIA (Mohammed, 2007).

To clearly understand the design and construction process in the Saudi context, a plan of work is provided from both the RIBA and the AIA. The RIBA plan of work consists of eight phases (see Table 2-3 and Appendix E). On the other hand, the AIA plan of work involves seven phases for design and construction projects. Normally, construction projects undertake these seven phases, but these phases may be combined or other phases may be added in some projects (AIA, 2018). The AIA plan of work is displayed in Table 2-4 and Appendix F.

Table 2-3 RIBA plan of work (Source: www.ribaplanofwork.com, 2013)

Phases							
0	1	2	3	4	5	6	7
Strategic Definition	Preparation and Brief	Concept Design	Developed Design	Technical Design	Construction	Handover and Close Out	In Use

Table 2-4 AIA plan of work (Source: www.aiaetn.org, 2018)

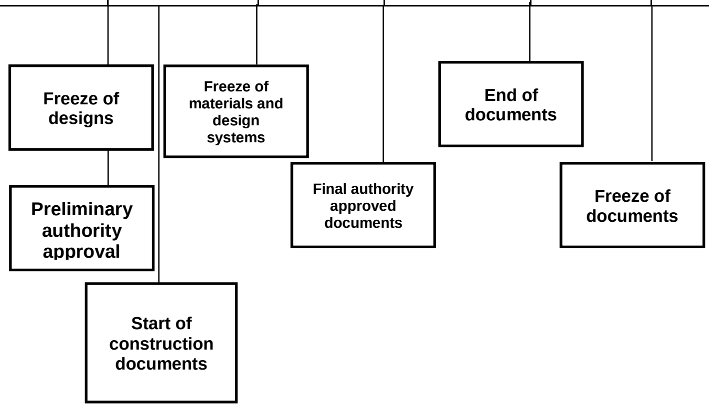
Phases						
1	2	3	4	5	6	7
Programming / Deciding What to Build	Schematic Design/Rough Sketches	Design Development / Refining the Design	Preparation of Construction Documents	Hiring the Contractor	Construction Administration	Project Close Out

In comparison, Alsuliman (2014) points out that the design process in the Saudi construction industry is categorised into four main stages. According to Mohammed (2007), these four stages are as follows: 1) briefing (programming), which covers the pre-design phase; 2) sketch plans (master plan, preliminary stage), which cover the site analysis phase and schematic design phase; 3) working drawings (design development phase and contract document phase), which cover the final design phase (e.g. all drawings types); and 4) the construction documents phase (e.g. contract, specifications, bills of quantities, and any other required documents).

Table 2-5 summarises all the phases of the design process relating to AIA, RIBA and Saudi practice applied in the Saudi construction industry (Mohammed, 2007).

Table 2-5 Design process in Saudi Arabia (Source: Mohammed, 2007)

Phases							
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Programming	**Concept master plan**	**Conceptual architectural plan**	**Design development**	**Final detail design**	**Contract documents**	**Tendering period**	**Start of construction**



2.7.3 *The Role of Building Information Modelling in Design Process*

Building information modelling (BIM) was highlighted in RIBA levels 0, 1, 2, and 3. Thus, these levels are broadly referred to the extent where the UK Government's phased implementation is based on these levels. Since summer 2012, projects must implement Level 2 BIM. However, the UK Government aimed to have an application of BIM entirely within documentation, with all asset information, project, and data being electronic by 2016 at the latest. Furthermore, Level 0 BIM is defined as the use of 2D computer-aided design (CAD) files. Level 1 BIM recognises the enlarged application of both 2D and 3D information on projects. Level 2 BIM involves the production of 3D information models by all critical members of the Integrated Team. Level 2 BIM requires working collaboratively under new forms of procurement within the design team for design subcontractors to be replaced by Integrated Teams. Hence, moving from level 2 BIM to level 3 BIM involves the greatest BIM challenges, such as early design analysis of environmental performance, health and safety aspects associated with the construction and maintenance, and asset management, KPI, and other feedback information.

Moreover, AIA document E203-2013 is an attachment to an existing agreement, such as B101-2007 (owner and architect agreement) or A101-2007 (owner and contractor agreement). This form aims to establish the anticipations of stakeholders regarding the use of BIM on a project and to provide a process and procedure for governing BIM and digital data on said project. Following the agreement, AIA documents G201-2013 and G202-2013 are set forth. G201-2013 is a project digital data protocol form, while G202-2013 is a project BIM protocol form (AIA, 2018).

Also, according to the discussion at the field survey, BIM is applied to the combined plan of work in Saudi Arabia in design development and the final detail design stages. Also, BIM is applied to the construction process, as discussed in Section 3.6.3, and in the operation phase for maintenance.

2.8 Types of Stakeholder

According to Freeman (2010), the traditional definition of a stakeholder is ‘any group or individual who can affect or is affected by the achievement of the organisation’s objectives’. The stakeholder concept, in general, is a redefinition of the organisation, which concerns how the organisation should be conceptualised and what it should be (Fontaine et al., 2012). Friedman and Miles (2006) state that the organisation should be realised as a cluster of stakeholders, and the purpose of the organisation should be to manage stakeholder needs, interests, and viewpoints. Such stakeholder management is to be conducted by the administrators of a firm. The administrators should ensure their participation in decision-making and stakeholder rights. Also, the management must ensure the survival of the organisation to protect the long-term stakes of each group (Fontaine, et al., 2012).

Stakeholder management identifies and classifies types of stakeholder to simplify initial and succeeding involvement with stakeholders in a planned, timely, and coordinated manner (Alsuliman, 2014, p.51). Stakeholder involvement includes, 'identifying different categories; gathering information about them; identifying their missions; predicting their behaviour and developing and implementing a strategy for managing these stakeholders' (Cleland and Ireland, 2002). However, Winch and Bonke (2002) state that stakeholders in any given project can be classified as internal or external. Internal stakeholders include those involved in or financing the project (e.g. consultants, clients, and general contractors). External stakeholders include those significantly influenced by the project (e.g. government regulators, neighbours, and local community). This present study includes only consultants and contractors as internal stakeholders, since it investigates their technical perceptions.

2.8.1 *Stakeholders in the Saudi Construction Industry*

Alsuliman (2014, p.74) states that stakeholders at the design stage in Saudi public construction projects mainly include two types: the design consultant and the public client. Furthermore, the Government accounts for around 67% of the nation's construction industry volume and is considered the major client in the Saudi construction industry. The governmental clients are often the ministries that have construction management departments, which are represented by either client representatives or project managers in building construction projects. In addition, public bodies in Saudi Arabia are also deemed stakeholders by influencing organisations and individuals via their authorities and regulatory policies (Alsuliman, 2014, p.74).

Design consultants are regarded as another stakeholder in the Saudi construction industry. The satisfaction of client requirements and expectations regarding design quality is the responsibility of such consultants (Almazyad, 2009). The recognition of design consultants in Saudi Arabia occurs in two forms: either via the Ministry of Municipal and Rural Affairs, or via the Saudi Council of Engineers. Public projects require the recognition of both bodies, while private projects can be achieved through the recognition of the Saudi Council of Engineers only (Alsuliman, 2014, p.74).

2.9 The Role of Stakeholders in Design

This section discusses the role of the main parties involved in the design stage. The types of stakeholder are discussed, including those in the Saudi construction industry. The main stakeholders are clients, architects (consultants), governmental regulators, and general contractors. In addition, the change orders in construction projects are discussed to understand their causes, the role of stakeholders in such orders, and the types of change order. Similarly, project size as a factor of change orders and the likelihood of change order influence are highlighted.

2.9.1 *Change Orders in Construction Projects*

Change is a feature that encompasses nearly all projects, even in unique cases. Change in a construction project is often associated with certain features, such as finance, aesthetic, design, or geotechnical issues (Ssegawa et al., 2002). Change is considered a fact-of-life for a construction project (Revay, 2002). Hao et al. (2008) note that, 'Project changes and/or adjustments are inevitable as they are a fact-of-life at all stages of a project's life cycle'. Arain and Pheng (2007) state that change might be required regardless of the causes, even in the most well-planned projects. Change in a construction project can be caused by a change of mind by the consultant, their clients, or unexpected snags raised by the subcontractors or main contractor (Ssegawa et al., 2002).

2.9.2 *Stakeholder Role in Change Orders*

A change order is identified as an 'approved change in a specification or project' (Alsuliman, 2014, p.26). Gbeleyi (2002) states that change orders are 'change[s] in specifications, changes in scope, adjustment of PC and provisional sums, errors/omissions in contract documents, discrepancies in contract documents, changes in government policies/legislation, and natural occurrence'. In the same context, Fisk (1997) and O'Brien (1998) define a change order as an official document that amends the initial contractual agreement and becomes part of the project's documents. Therefore, a change order is as an alteration to both the work and the procedures by which such work is to be completed (Ssegawa et al., 2002). However, Alsuliman (2014, p.26) states that a change order is a written order to the contractor signed by the client or (the client's representative) and delivered after the notice to proceed with the contract. Moreover, a change order authorises the contractor regarding a change in the work or an alteration in the contract time or the contract sum.

2.9.3 *Causes of Change Orders*

Change in construction projects is directly caused by the actions of different stakeholders (e.g. architect, client, general contractor), which can occur for different reasons; for example, aesthetic, financial, design, weather or geological, changes in drawings, and geotechnical reasons (Ssegawa et al., 2002). The causes of change are generally categorised into consultant-related changes, client-related changes, general contractor-related changes, combinations of causes, and other changes (Arain, 2005). A list of common causes of change orders within the construction industry is provided by Gbeleyi (2002) and Oladapo (2007), including consultant – Architect/Designer (due to the faults in the design); general contractor (due to the faults in the construction); unexpected circumstances – project funding, errors (in the documentations, drawings, and specifications); laws and protocols; procurement method; site conditions; and delay of materials supply.

2.9.4 *Project Complexity and Size*

Complex projects are categorised according to many factors, including instability, randomness, degree of disarray, developing decision-making, irregularity, non-linear processes, uncertainty, and repetitive design and planning. The factors can interact/react with each other in dynamic ways within a system, which makes the project complexity dynamic. In addition, complex projects contain high uncertainty regarding what the objectives are and how they can be implemented (CCPM, 2006). Table 2-6 illustrates the comparison of a traditional project with a complex one.

The size of a project is a significant indicator of the occurrence of change orders within the type of construction project. Change orders are very common in most projects, especially in large construction projects (Hao et al., 2008). Therefore, suitable management strategies that are critically determined by project size are an important factor. Furthermore, project size is identified as a key factor to enhance the occurrence of change orders (Sidwell, 1983). Similarly, Akinsola (1997) indicates that project size, due to the physical features or value, with large projects being commonly complex, is considered a cause of change orders.

Table 2-6 Comparison of traditional vs. complex projects (Source: CCPM 2006)

Traditional Projects	Complex Projects
• Standard practices can be used Design — Funding — Contracting	• Standard practices cannot be used Design — Funding — Contracting
• Static interactions	• Dynamic interactions
• High level of similarity to prior projects creates certainty	• High level of uncertainty about final project scope

In addition, the reduction of onsite construction or developing new methods for the management and controlling of the construction process is a strategy to overcome the challenges of productivity. Bertelsen (2004) believes that the productivity and quality of construction are affected by complexity. Bildsten (2011) states that the uniqueness of a construction project increases the complexity and uncertainty of that process, which creates variability among construction projects.

2.9.5 *Likely Impact of Change Orders on Projects*

The likely impacts of change orders are well recognised by Arain and Pheng (2007). Alsuliman (2014, p.22) highlights some of these impacts on construction projects: quality degradation, progress impact, increase in overhead expenses and cost, rework and demolition, productivity degradation, logistics delays, poor professional relations, poor safety conditions, and completion schedule delay.

2.9.6 *Type of Change Orders*

Arain and Pheng (2005b) categorise change orders as either beneficial or detrimental. A beneficial change order enhances the quality standard, reduces cost, shortens the timetable, or reduces the degree of complexity in a project. However, a detrimental change order is ‘one that negatively impacts the client's value or project performance’. Cox (1999) places the types of change orders into three categories: formal, productive, and principal. A formal change order is a document issued by a client to modify contract terms, plans, or specifications. A productive change order is additional contract work approved by the client (either verbally or implicitly), or as an outcome of problems caused by the client. A principal change order involves important work required beyond the scope of the original contract.

2.10 Procurement Methods

This section discusses the role of procurement methods in construction projects and highlights the influence of the procurement method on change orders. The traditional procurement method is the most applied in the Saudi context, yet both traditional and non-traditional procurement methods are described to understand their nature in Saudi Arabia. Additionally, the procurement regulations of the Saudi context are provided to understand the main applied method.

2.10.1 *Procurement Method Influence on Change Orders*

It is essential to clarify the influence of procurement methods on change orders to understand the process of originating change orders and to effectively manage them, especially in the Saudi context. Generally, construction practitioners include architects, clients, engineers, project managers, and general contractors. Normally, a procurement method is considered a form of contractual arrangement between the parties involved. Therefore, each procurement method is different regarding causing change orders (Alsuliman, 2014, p.26). It is worth noting that non-traditional procurement methods are subject to more change orders and errors in specification than conventional methods (Love, 2002), but the cost of change orders is not notably different between the methods.

Change orders can be issued by any party engaged in the project, either in written or oral form (Charoenngam et al., 2003). The processing of change orders requires a notable amount of time to acquire approval from all the parties in the project. Subsequently, a change order is requested to modify the original contract after submission and approval, making the change order part of the contract. Therefore, a construction contract is deemed professional when it has sections that deal with change orders to the project and a process to resolve disputes (Alsuliman, 2014, p.27).

2.10.2 *Traditional Procurement*

Generally, in traditional procurement, a client requests a design consultant to produce drawings of the proposed project. In the case of a large project, a client hires a quantity surveyor to produce the required documentation to allow a contractor to arrange a bid price (Alsuliman, 2014, p.27; Ashworth, 2014). The client hires the main contractor to perform the construction work after the construction documents are fully developed and completed by the designer. The programme permits adequate time to increase the quality of the documents and reduce errors (Mohammed, 2007, p.32; Turner, 1997, p.66). Change orders in traditional procurement are minimised and simply managed because of proceeding to work onsite after finishing the designs. However, Turner (1997) claims that the separation of design from construction in complex projects increases the faults and errors related to the buildability and constructability of the project. The design-bid-build diagram is illustrated in Figure 2-13.

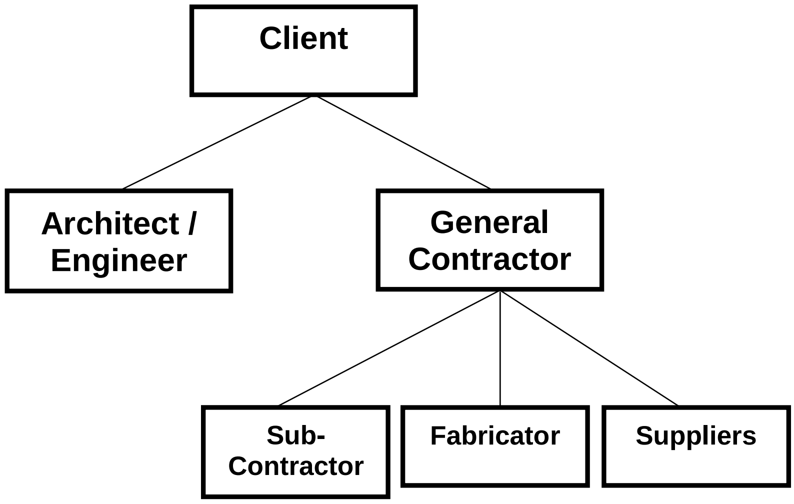


Figure 2-13 Design-Bid-Build diagram

The more time and money paid by clients during the design phase, the fewer change orders, especially when compared with a design phase with insufficient money and time (Koushki et al., 2005). Thus, the possibility to avoid inconsistencies in contract documents, together with errors and omissions in the design, depends on the time spent finishing the contract documents before beginning the actual work (Alsuliman, 2014, p.28).

The separation between the design and construction stages is the main characteristic of traditional procurement (Hughes et al., 2015). This separation is believed to increase the overall project duration and total cost when compared with other types of procurement methods. Alsuliman (2014, p.35) states that this usually occurs when the client hires a consultant to produce the contract documents, which include drawings, specifications, design, and documentation for tendering. The client invites general contractors to tender over a competitive process after finishing the contract documents.

2.10.3 *Non-Traditional Procurements*

The forms of non-traditional procurement have developed over time (Alsuliman, 2014, p.29). The reason for moving away from the labour base to the introduction of offsite manufacturing is due to the change orders in procurement methods (Ashworth, 2014). Other reasons include the broader application of equipment and mechanical plant, the use of industrialised components, the involvement of the contractor in both the design and construction phases, and improved knowledge regarding production methods, which all result in better quality (Alsuliman, 2014, p.29).

Design and build, for example, is a procurement method that enables the general contractor to be responsible for both the design and the build to control the difficulty of change orders (Alsuliman, 2014, p.29). The design-build diagram is displayed in Figure 2-14. The commitment to construct the project may be based on a schematic design or even on a performance specification that involves no design when the client contracts with a single design-and-build firm (Mohammed 2007; AIA, 1994, p.708).

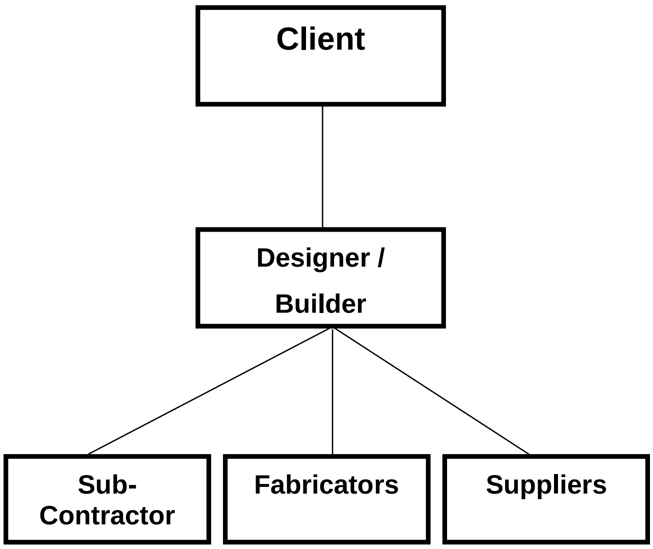


Figure 2-14 Design-Build diagram

The features of the design-and-build procurement method are less likely to cause disruption by reducing change orders from the original design. The contractors' embracement of the design process allows less scope for change orders because they employ specialised knowledge and methods of construction from their own design department (Ashworth, 2014). However, both cost overruns and delays in completion can occur due to the lack of flexibility for making change orders that design-and-build offers. Also, the design-and-build method involves a clear statement of client requirements and discipline at the beginning (Alsuliman, 2014, p.30), which includes secure code approvals, a set of documents to describe the project, and procuring design/build services (Mohammed, 2007).

Construction management is another non-traditional procurement method. Murdoch and Hughes (1997, p.81) state that projects involving construction management are often fast-tracked. The construction management method may also involve ‘scope documents’ as a base for providing the client with a guaranteed maximum price or fixed price (Mohammed, 2007), which prepares and develops all construction documents at an earlier stage. The construction documents must designate material qualities to provide both the client and the construction manager with reasonable assurances regarding the accuracy of the price.

On the other hand, a robust working relationship between the client, the designer, and the construction manager is essential to control any possible disputes when the price is based on incomplete documents. Furthermore, the contractual and management nature of the construction management procurement method better manages the consequences of faults and errors regarding the quality of documents even with difficulties involved with the fast-track procurement. The construction management diagram is displayed in Figure 2-15.

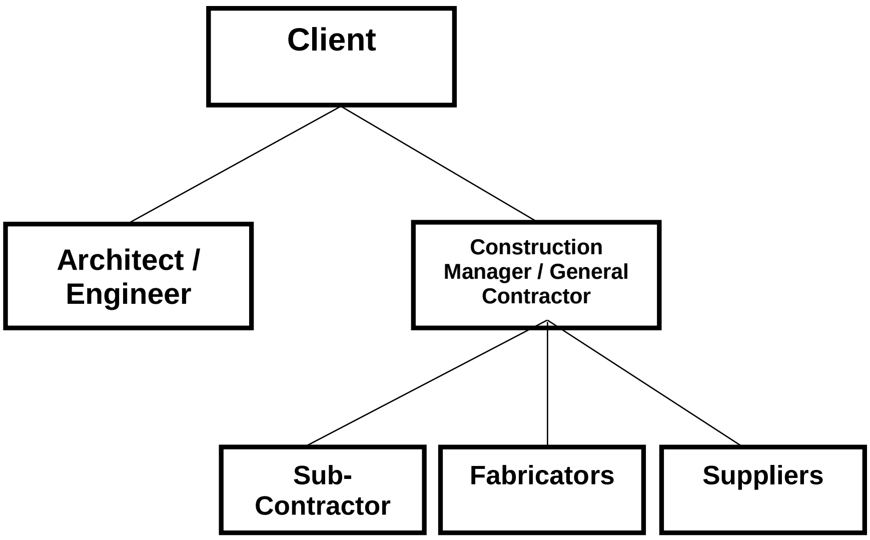


Figure 2-15 Construction management diagram

2.10.4 *Procurement Regulations for Saudi Arabia*

The Government Tenders and Procurement (GTP) law was introduced by The Ministry of Finance in the Kingdom of Saudi Arabia in 2006 (Alsuliman, 2014, p.29). According to this law, all public sector bodies, including ministries, public institutions, and public agencies, are deemed to be client representatives. The Government authorises public sector bodies to procure works and services, such as construction projects, with entire contracting authority. Therefore, the works or services must be driven through public tender (some works are exempt under the provisions of this law, such as design consultancy). The client's representative can invite a design consultancy via recommendation. Moreover, applying the Standard Public Works Contract (SPWC) is critical following the completion of the process and hiring the contractor. This type of contract is designed based on the traditional procurement method (Alsuliman, 2014, p.29).

2.10.5 *The Traditional Procurement Method in Saudi Arabia*

Traditional procurement is the most commonly implemented method in governmental construction projects in Saudi Arabia (Alturki, 2000; Alsuliman, 2014, p.30). Most clients in Saudi Arabia, both in the public and private sectors, use the well-known traditional procurement method (Al-Seadan, 2004) because of the cost certainty that is both reasonable and known prior to proceeding to the actual work. Article 5 of the SPWC mentions the cost certainty for public construction projects in Saudi Arabia. However, Article 5 is subject to price changes depending upon the wish of the client, within the limits stipulated in the contract conditions, to match changes in the amount of actual work performed by the consultant or general contractor. In addition, non-traditional procurement methods (e.g. the construction management procurement method and the design-and-build procurement method) are also used in Saudi Arabia. However, the application of non-traditional procurement methods is limited to the construction of private projects and few public projects

(Alsuliman, 2014, p.31). Figure 2-16 displays the total percentage of each procurement method used in construction projects in Saudi Arabia (Al-Seadan, 2004).

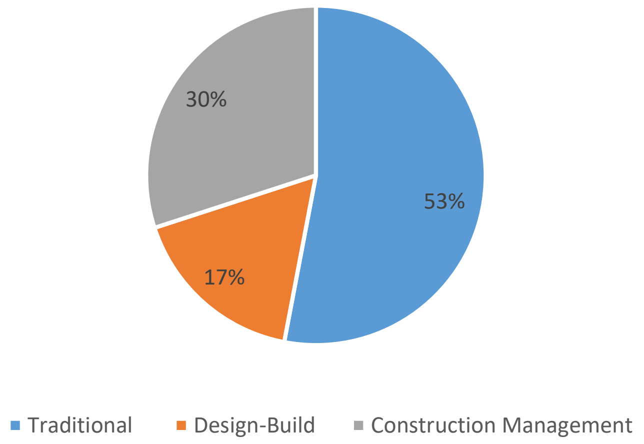


Figure 2-16 Frequency of procurement methods used in the public sector in Saudi Arabia (Source: Al-Saedan, 2004)

2.11 Summary

This chapter introduced the motivation for enhancing project delivery in the design and construction phases, including benefits, demerits, drivers, barriers, and constraints. It highlighted also the literature review regarding PBSC. A historical overview regarding the definitions related to preassembly was provided, as well as the integration of building services components into office buildings. Furthermore, the modularisation of building services was discussed. Moreover, PBSC are regarded as prefab electromechanical systems that involve major elements, such as air ducts, water pipework, drainage pipework, and conduits and wiring, which are implicitly deemed to be part of all these categories, except the non-volumetric preassembly. The forms of PBSC were addressed. Furthermore, the applications of PBSC in the Saudi context were reviewed in association with other experiences. A comprehensive review was provided regarding building systems, which included mechanical, electrical, plumbing, and fire suppression systems. The systems review was essential for enhancing the nature of this study regarding technical aspects.

In addition, the design process was reviewed via specifications and client requirements, as well as reviewing the design process in the Saudi context. The types of stakeholder were covered, in general and in particular, to understand the nature of their influence in the Saudi context. The review of stakeholder influence allows for greater understanding of their role in the design process in terms of change orders. Thus, an additional review was performed to understand the causes of change orders, the effect of change orders on the construction projects, and the types of change order. Additionally, the types of procurement system were reviewed to understand the relationship between stakeholders in each type. Change orders were noted as being different from one procurement method to another. Furthermore, procurement methods were classified into traditional and non-traditional types. The RIBA and the AIA plan of work were also reviewed to understand the nature of the Saudi plan of work, which includes four phases derived from both the RIBA and the AIA.

Chapter 2 reviewed the forms of PBSC, the applications of PBSC, and the building services systems. Also, the design process and the main types of procurement process were discussed. These references form the fundamental dimensions for understanding the mechanism of these applications, which assists in categorising these dimensions into the TPB. Similarly, these references form the seminal aspects of this research that are believed by the practitioners. The TPB consists of three pillars: attitudes, SN, and PBC. These pillars are believed to constitute behavioural intention (i.e. performing the behaviour). Therefore, the following chapter presents the conceptual framework used to place PBSC features and characteristics into the TPB. The benefits and challenges (attitudes), SN, and PBC are also reviewed as part of the conceptual framework.

CHAPTER 3: CONCEPTUAL FRAMEWORK

3.1 Introduction

This chapter presents the TPB as the conceptual framework for this study. The theoretical framework regarding PBSC in Chapter 2 is employed in a conceptual framework. The TPB is one of several technology adoption models in the innovation theory. The TPB consists of three dimensions: attitudes, SN, and PBC. It is essential in this chapter to present a research background on innovation, including definitions, organisation features, and innovation adoption. The attitudes towards using PBSC in complex office developments are also reviewed. Furthermore, stakeholder influence and external contextual influence on the use of PBSC are covered. The adoption of innovation theory, particularly the TPB, is highlighted. This theory is later employed to conceptually embrace the benefits, demerits, drivers, barriers, and constraints towards the use of PBSC in complex office developments in Saudi Arabia. The expected outcomes are presented in the form of attitudes, SN, and PBC.

3.2 The Theory of Planned Behaviour

The TPB (Ajzen, 1985, 1988) was first introduced by Fishbein and Ajzen (1975) as an extension to the theory of reasoned action (TRA), which is a prominent model in health psychology research (Francis et al., 2004). Montano and Kasprezyk (2015) note that the TRA defines measures of attitudes and social normative perceptions of a specific behaviour that drive the intention to perform a behaviour. The TPB is a developed model that, based on the principle of aggregation, assumes that the collection of specific behaviours across events has a better predictive validity of attitudes and other characters than analysing the perceived locus of control alone. Essentially, the TPB attempts to explain the overall execution of a specific behaviour through predicting individual motivational factors within unique contexts (Ajzen, 1991). The TPB has been applied to both the maintenance and change of health-associated behaviours, the behaviour of healthcare professionals, the mechanisms to change behaviour, and the specific beliefs of professionals regarding commitment to clinical guidelines (Francis et al., 2004). Bagozzi (2007) states that the TPB is based on three independent constructs of intention, which are attitude, SN, and PBC.

Intentions capture motivational factors that affect doing a behaviour as assumed by the TPB. An intention is a sign of how hard an individual is willing to try, and how much effort an individual actually makes (Ajzen, 1991). It was proposed by Ajzen (1991) that, as a rule, the stronger an individual's intention to involve in a given behaviour, the more likely the behaviour will be performed. The behaviour, however, must be under an individual's volitional control or will to decide whether to perform the behaviour (Ajzen, 1991). Either an individual's volitional control or willing must be on top of the behaviour to decide whether to perform the behaviour. Figure 3-1 represents the basic TPB model.

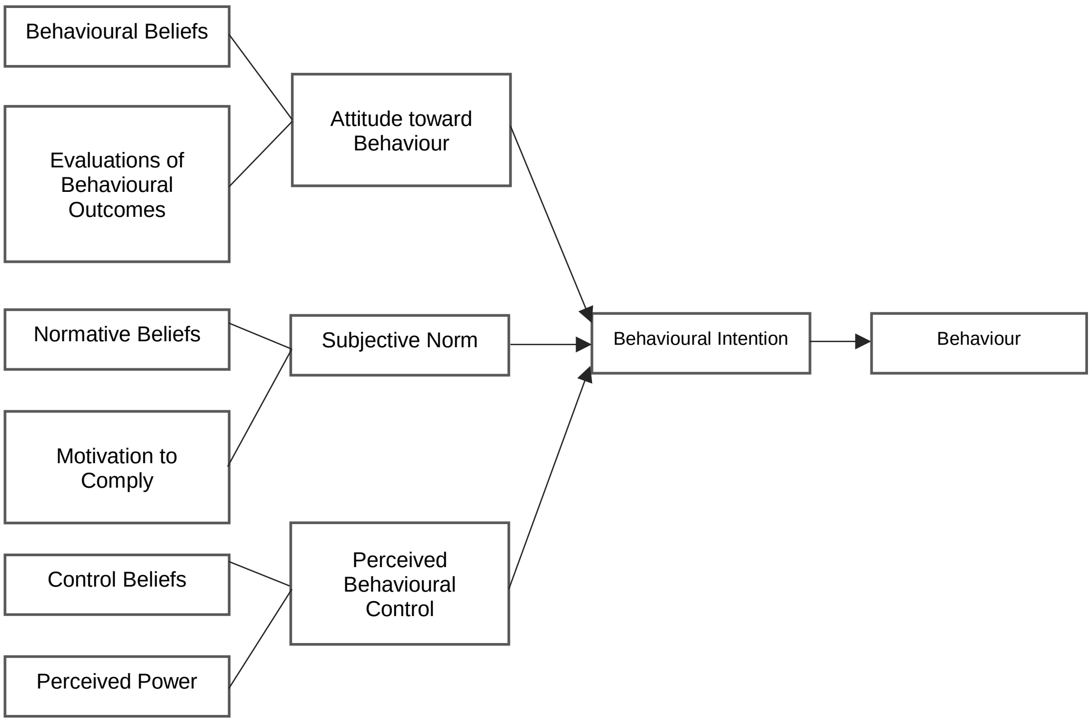


Figure 3-1 Theory of planned behaviour model (Source: Ajzen 1985)

3.2.1 *Attitudes*

Edberg (2015, p.43) identified attitude towards a certain behaviour as an individual's 'beliefs about what will happen if he or she performs the behaviour'. Ajzen (2011) states that attitudes are formed by either the positive or negative judgement of an individual regarding the expected outcomes of performing a behaviour. Consequently, a behavioural belief is defined as the individual's perception of the likely results of performing the behaviour (Ajzen, 2011).

3.2.2 *Subjective Norms*

Ajzen (2011) describes normative belief towards behaviour as an individual's perception of the pressures of SN or another person's beliefs (such as a partner or spouse, doctor). These SN are expressed as an individual's perception regarding a specific behaviour and the force of motivation to obey or conform to others' beliefs (Ajzen, 2011).

3.2.3 *Perceived Behaviour Control*

Ajzen (2011) notes that the TPB was constructed based on the TRA by introducing either an individual's control beliefs or the presence of factors that can support or prevent the performance of a behaviour. Perceived behavioural control is formed by an individual's assessment of their capability to be involved in the intended behaviour, which is based on one's perceived power of performing the behaviour, including perceived difficulty (Ajzen, 2011). Perceived behaviour control varies across situations and forms of action and does not remain stable. In addition, PBC was founded based on the partial control of individuals over their intended behaviour, especially in unstable and uncontrolled external contexts. This allows the TPB to be used to predict and examine individuals' intentions and behaviour in such conditions, and it is also assumed to reflect experience (Bagozzi, 2007).

The TRA was developed by Fishbein and Ajzen in 1975. It is used to determine behavioural intention of a person towards a particular behaviour. This determination depends on two factors: attitude and SN. 'Attitude' is defined as the individual's evaluation of an object; 'belief' is defined as a link between an object and characteristics; and ‘behaviour’ is defined as an intention. On the other hand, the theory of diffusion of innovations was developed by Rogers in 1995. He defines ‘innovation’ as a new idea, new process, new object, or new practice. Furthermore, he considered diffusion to be the process by which an innovation spreads into the social system. Therefore, the theory of diffusion of innovations has five factors that affect adoption and acceptance behaviour. These factors are relative advantage, compatibility, complexity, trialability, and observability. However, the TPB was developed by Ajzen (1991) and is an extension of the TRA, in which the two factors of ‘attitude’ and ‘SN’ are supported by a third factor, which is ‘PBC’. This third factor is perceived to control users, and, thus, may limit their behaviour.

The technology acceptance model (TAM) was developed by Davis, Bogozzi and Warshaw in 1989. The model is as an adaptation of the more generalised TRA. It was developed to predict and explain the factors of computer acceptance that lead to explaining user behaviour. This development helps also to identify the factors that lead to user acceptance or rejection of a technology by integrating technological aspects with organisational behaviour concepts. Therefore, the TAM includes and tests two specific beliefs: perceived usefulness and perceived ease of use (PEU). These two factors can shape attitude towards using technology, which is the factor that determines the intention to use. Davis argues that the influence of SN on behavioural intention to use can be ignored. The TAM 2 was developed Venkatesh and Davis in 2000 and is an extension of the original TAM, in which social influences and cognitive instrumental processes are added. The social influences include SN and images, while the cognitive instrumental processes include job relevance, output quality, result demonstrability, and PEU. Also, there are two moderating factors: experience and voluntariness. In comparison with TAM, the factor of attitude is removed in TAM2, while the factor of SN is reconsidered. The TAM 3 was a further modification by Venkatesh and Bala in 2008. This modification is designed to provide a higher level of significance to the factor of PEU. This model includes the factors of computer self-efficacy, perception of external control, computer anxiety, and computer playfulness.

Also, two adjustment factors were added: perceived enjoyment and objective usability. However, the model is criticised for having many factors and many relationships between them.

Consequently, previous studies regarding preassembly technologies discuss technology classification in terms of advantages, disadvantages, drivers, and barriers. Thus, the TPB is the most appropriate framework for embracing these classifications because it has three clear pillars. Also, none of these theories or models have a manual for constructing a questionnaire survey, except the TPB, which helps when applying a mixed-methods approach. Therefore, this study adopts the TPB as a conceptual framework.

3.3 Research Background

Innovation is universally considered in scientific and technical literature, social literature (e.g. history, sociology, management and economics), and in the humanities and arts. Innovation has become the symbol of the modern society and of problem-solving, making it a phenomenon worth studying (Godin, 2008). Innovation embodies the advantage of new ideas and how we perform them. It is worth noting that innovation is present many areas, including markets, systems, products and services, processes, as well as social behaviour, organisational structures, and their management (Bucciarelli, 2015). A common perception among both academics and practitioners is that organisational innovation is a priority to be effective or even to survive, and that research leads to the management of innovation in organisations (Damanpour, 2006).

Sociological literature categorises innovation into tasks and processes, with the production of an invention and its usage being discoursed instead of contrasted (Godin, 2008; Nimkoff, 1957). In contrast, economists understand innovation as a process, and realise it as the commercialisation of ‘technological’ invention. Unlike the sociological definitions of innovation, this description is recognised among economists and others, as well as sociologists. Godin (2008) categorises the phases of invention and imitation in chronological order into ‘adoption’ and ‘diffusion’ (see Table 3-1).

Table 3-1 Sociologists' order of innovation (Source: Godin 2008)

Sociologists' Order of Innovation	
Trade (1890)	Invention, imitation, opposition
Ogburn (1920)	Invention (and diffusion), maladjustment (lag) / adjustment
Bernard (1923)	Formula, blueprint, machine
Chapin (1928)	Invention, accumulation, selection, diffusion
Ogburn and Gilfillan (1933)	Idea, trial device (model or plan), demonstration, regular use, adoption
Gilfillan (1935)	Idea, sketch, drawing, model, full-size experimental invention, commercial practice
Gilfillan (1937)	Thought, model (patent), first practical use, commercial success, important use
US National Resources Committee (1937)	Beginnings, development, diffusion, social influences
Ogburn and Nimkoff (1940)	Idea, development, model, invention, improvement, marketing
Ogburn (1941)	Idea, plan, tangible form, improvement, production, promotion, marketing, sales
Ogburn (1950)	Invention, accumulation, diffusion, adjustment
Rogers (1962)	Innovation, diffusion, adoption
Rogers (1983)	Needs / problems, research, development, commercialisation, diffusion and adoption, consequences

Diaconu (2011) states that the literature distinguishes between invention and innovation. Malerba (1997), for instance, explains that invention is a new idea, a new scientific finding, or a discovery of technological originality (for which implementation and diffusion are not yet applied); whereas, innovation is a result of integrating invention into economic and social practice through the application of an invention. This definition makes innovation an outcome of a process that begins with a new idea and lasts through its embodiment. The Oslo Manual (2005), on the Schumpeterian context of innovation, describes innovation as the task of generating new or improving products or services, processes, marketing approaches, or business organisation. Similarly, Frascati (OECD, 2002) notes that technological innovations include new or altered technological products and processes, in which technological originality arises from their performance features.

Many organisations consider innovation and place generating new ideas to be a priority. Innovation is a competitive benefit due to high international competition and technological development (Lala et al., 2010). Research on innovation highlights a number of methods, such as utilising levels of innovation in teams/projects, individuals, or organisations (Lala et al., 2010), while others focus on the strength of innovation (Hollenstein, 1996).

Diaconu (2011) states that, in 1934, Schumpeter regarded economic development as a qualitative change process and the consequences of innovation. According to Schumpeter, innovation is a task of business activity in which 'new combinations' of current resources happen. Schumpeter's 1934 definition of the term 'innovation' provides 'new combinations' of the production of new services and products that remain valid for current production processes, marketing, and business organisation.

3.3.1 *Defining Innovation*

Pan et al. (2004) state that many definitions of innovation exist in the literature (e.g. Rogers, 1995). Innovation is a collective process rather than an individual matter. Entrepreneurs, as individuals, played an important role in the 20th century. However, entrepreneurs are only one part of the innovation process (B. Godin, 2015). Morton (1968, p.57), an engineer and Research Director at Bell Laboratories, explains that:

> Innovation is not a single action but a *total* [my italics] process of interrelated parts. It is not just the discovery of new knowledge, not just the development of a new product, manufacturing technique, or service, nor the creation of a new market. Rather, it is *all* [my italics] these things: a process in which all of these creative acts, from research to service, are present, acting together in an integrated way toward a common goal.

Pan et al. (2004, p.2) combine ideas of definitions and suggest that, '*newness, unit of adoption, and successful exploitation of new ideas are the elements of innovation but these elements embrace rich context which should be understood appropriately.*'

3.3.2 *Technology Adoption Models and Theories*

The existing literature widely contributes to the applications, concepts, and development of technology adoption theories and models. The existing literature includes, but is not limited to, the TPB (Ajzen, 1985, 1991), the theory of diffusion of innovations (DIT) (Rogers, 1995), the TRA (Fishbein and Ajzen, 1975), decomposed theory of planned behaviour (Taylor and Todd, 1995), the TAM (Davis, Bogozzi and Warshaw, 1989), technology acceptance model 2 (TAM2) (Venkatesh and Davis, 2000), and technology acceptance model 3 (TAM3) (Venkatesh and Bala, 2008). These models and theories contributed largely to conceptualising, differentiating, and understanding the fundamental technology adoption in the past, present, and future (Lai, 2017).

Table 3-2 Summary of adoption models and theories (Source: Author)

Models or Theories	Author
Theory of Reasonable Action	Fishbein and Ajzen, 1975
Theory of Planned Behaviour	Ajzen, 1985, 1991
Theory of Diffusion of Innovations	Rogers, 1995
Technology Acceptance Model	Davis, Bogozzi and Warshaw, 1989
Technology Acceptance Model 2	Venkatesh and Davis, 2000
Technology Acceptance Model 3	Venkatesh and Bala, 2008

In 2006, Ajzen introduced a full process to construct a TPB questionnaire that included tagging direct and indirect measurement scales for three TPB predictor variables, which were adopted from Francis (2004) (Appendix C). The TPB was used by Roos et al. (2010) to investigate the influence of architects and structural engineers on construction's perceptions and roles. This present research adopted the TPB as a framework to predict the intention of consultants and contractors towards the use of PBSC in complex office developments in Saudi Arabia.

3.3.3 *Innovation Adoption*

Adoption is typically required when a necessity exists, and then begin searching for resolutions. The 'early decision' is to adopt a solution; whereas, the 'strategic decision' is to try to continue with the implementation of the solution (Damanpour and Schneider, 2006). A strategic decision that is carried out by an organisation to adopt innovation suggests cultural, functional, technical features with resources and further external dynamics, such as client engagement (Bucciarelli, 2015).

The adoption process of innovation is classified by Wisdom et al. (2014), based on Greenhalgh et al. (2004), as pre-adopting (e.g. innovation perception), peri-adopting (e.g. constant admittance to innovation data), and settled adopting (e.g. adopter's promise to the adoption decision). Two phases related to adoption were introduced by Frambach and Schillewaert (2002), these were the organisational decision to use adoption and the acceptance of workforce and their individual compliance to the innovation. Adoption of innovation often follows two main paths: either to proceed to early implementation phases or to return to de-adoption. Mendel et al. (2008) state that the advantages of adoption are well known in terms of rate, level, or degree of adoption, in which the decision of adoption is considered a process. Moreover, adoption barriers can be possibly addressed via a deep understanding of the adoption process; thus, leading to early implementation (Wisdom et al., 2014).

The adoption process is difficult on a larger scale, such as an organisational or system level. Garland et al. (2010) state that encouraging change in a routine practice is challenging, especially with a misperception of change needs from decision-makers within organisations. Although organisational adoption is similar to the individual level of adoption, it is still difficult for individuals to adopt. Aarons et al. (2011) state that individuals within organisations hardly recognise, evaluate, or choose suitable innovations to resolve specific problems. Also, it is often difficult for individuals to adopt innovation within organisational aspects, such as hierarchy, culture, or values, which are unnecessarily practised in individual problem-solving (Wisdom et al., 2014).

Rogers (2003) classifies organisations, in a similar way to individuals, into low, medium, or high adopters, irrespective of the innovation of interest. Such categorisations include expressive for planning and evocative purposes, which requires further experiential reviews regarding whether there are strategies that initiate change in organisations from medium or low adopters to high adopters (Wisdom et al., 2014).

3.4 Adoption of Innovation

Adoption is firstly formed through the existence of recognition until searching for solutions. Consequently, the original decision for the adoption of a solution is tested, and then the real decision to continue with the implementation of the solution is carried out (Mendel et al., 2008). The adoption process is categorised into three phases: 1) pre-adoption, such as awareness of innovation; 2) peri-adoption, such as continuous access to innovation information; and 3) establishing adoption, such as the adopter's obligation to the adoption decision (Greenhalgh et al., 2004). Furthermore, adoption is classified into two phases: 1) the organisation's decision to follow adoption and the approbation of workforces; and 2) the beginning of their affiliate processes of compliance with the innovation (Frambach and Schillewaert, 2002). It is important to categorise the adoption process in terms of level, rate, or degree of adoption (Mendel et al. 2008). Furthermore, adoption challenges are more likely to be addressed via a better understanding of the process of adoption, leading to the first implementation (Wisdom et al., 2014).

The adoption process is complex at both an organisational and system level. The complexity within organisations is mainly due to difficultly in changing routine practice, especially when decision-makers' perceptions of change is of it being unnecessary (Garland et al., 2010). The organisational or system level is similar to the individual level of adoption (Wisdom et al., 2014). Consequently, both the organisational and individual levels are categorised into low, medium, or high adopters (Rogers 2003). Therefore, individuals within organisations are subjected to the difficulty of weighing, knowing, or selecting appropriate innovations to solve specific problems. Similarly, the individual's decision to adopt is difficult due to organisational factors such as hierarchy, culture, or values (Aarons et al., 2011).

Adoption of innovation theories claim that adoption is a process. Therefore, the adoption process proceeds from pre-adoption, such as the staff's awareness within an organisation and accessing information to support decision-making regarding an innovation, and to found adoption, such as the decision of an organisation to proceed with the innovation (Greenhalgh et al., 2004). Similarly, adoption of innovation theories combine mechanisms within the contexts of external influence (e.g. socio-political), organisational features, innovation features, staff/individual features, and client features (Wisdom et al., 2014). Figure 3-2 illustrates the features that form the adoption of innovation.

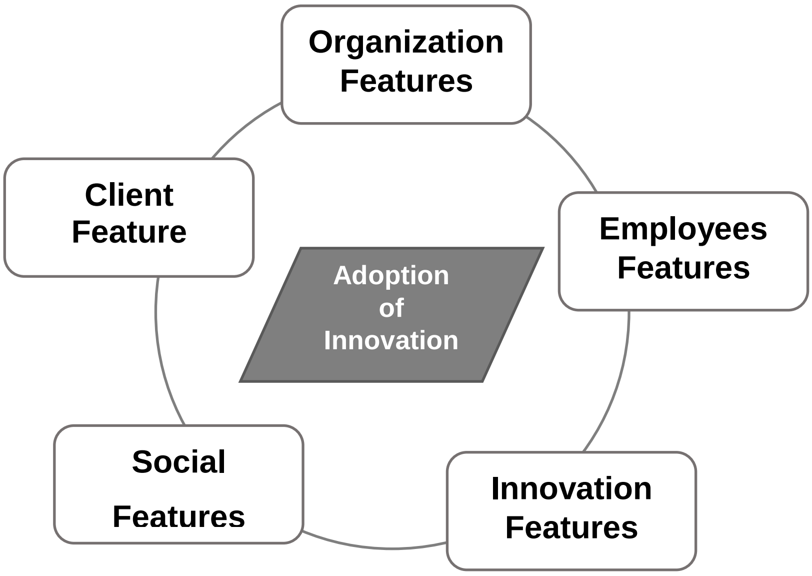


Figure 3-2 Adoption of innovation (Source: Wisdom et al., 2014)

3.4.1 *Organisation Features*

The absorptive capacity of an organisation is the capability of applying innovative and current knowledge to the organisation within pre-adoption and adoption phases (Wisdom et al., 2014). Aarons et al. (2011) state that organisations that have good knowledge and skills, that are capable, and that have mechanisms in place for new knowledge or innovations, should be initially determined before applying adoption of innovation.

Organisational leadership is essential to pre-adoption and adoption phases, especially when supporting innovations. Organisational leadership is addressed in four theoretical frameworks and is related to the pre-adoption stage. Organisational leadership can take the form of the CEO's impact, the viewpoint of the leader, top management support, and leadership promotion (Aarons et al., 2011). The adoption stage includes more inconsistency in the suggested direction. According to nine theoretical frameworks, the adoption phase relates to similar leadership variables: champions, CEO impact, viewpoint of leaders, etc., organisational and managerial brace for innovation, and past practice in adoption (Wisdom, et al., 2014; Aarons et al., 2011). Backer et al. (1986) note that top-down leadership is harmfully related to adoption.

Innovation developers, including organisations and staff, play an important role in the implementation phase of innovation. The implementation phase involves inconsistency, during which innovation developers should realise the barriers of implementation through service systems and organisations (Aarons et al., 2011). Organisational networks and partnerships are well associated with pre-adoption. Six theoretical frameworks discuss networking with innovation consultants, developers, potential users, and professional associations (Mitchell et al., 2010). Both indirect and direct networking are associated with adoption (Feldstein and Glasgow, 2008).

Organisational norms, values, and cultures play important roles in the pre-adoption and adoption phases. Organisational norms and values are significant in determining preferred attitudes and behaviours, which affects the structure and procedure of adopting an innovation (Aarons et al., 2011). Three theoretical frameworks address norms and value features that are positively related to pre-adoption (Solomons and Spross, 2011). In the adoption stage, two theoretical frameworks address organisational norms and values (Wisdom et al., 2014). Furthermore, Oldenburg and Glanz (2008) and Rogers (2003) introduced the culture of problem-solving as being positively related to adoption.

Organisational size is a crucial feature that increases the probability of innovation adoption. Larger organisations are more capable as they have more resources available to pledge, evaluate, and explore the potential usefulness of various innovative practices (Aarons et al., 2011). Regarding the adoption stage, seven theoretical frameworks discuss the essential roles of technical and organisational size and resources in dedicating innovation through a centralised, formalised, administrative, differentiated structure, and the fit between organisational size and the scope of practice (Aarons et al., 2011). In the same context, Greenhalgh et al. (2004) state that a formalised, centralised organisational structure is negatively related to the adoption phase, while Solomons and Spross, (2011) negatively mention a lack of formal research infrastructure.

The social climate and impact on an organisation are related to the pre-adoption and adoption phases. Mendel et al. (2008) theoretically note that constructive social knowledge, social climate, and enhanced social force to adopt are related to the pre-adoption phase. Similarly, Simpson (2002) states that social aspects and adoption decisions, at either a group or an individual scale, are positively related to the adoption phase. Social impact and communication among individuals within an organisation, for instance, can assist in recognising and achieving adoption of innovation (Frambach and Schillewaert, 2002).

Social networks (InterOrganizations) on the organisational scale play an important role in pre-adoption and adoption phases. Valente (1996) points out that various inter-organisational networks promote the pre-adoption phase. Similarly, through the adoption phase, three theoretical frameworks recognise various, causal inter-organisational networks and general communication among organisations as being positively related to the adoption of innovation (Greenhalgh et al., 2004).

The adoption of innovation requires training and performance endeavours, which are both related to pre-adoption and adoption phases. Frambach and Schillewaert (2002) theoretically propose organisational and managerial support for training and tailored approaches for preserving staff capability and performance as being positively related to the pre-adoption phase. Two frameworks recognised extension of training, resources delivery, a combination of innovations into programmes, and communication regarding innovations as being positively related to the adoption phase (Mitchell et al., 2010).

An organisation, however, can be categorised in terms of character and willingness to change. Aarons et al. (2011) theoretically classified openness and willingness to change as being positively related to the pre-adoption phase. Similarly, Frambach and Schillewaert (2002) theoretically suggest that willingness to change, the innovativeness of an organisation, and tendency towards risk reduction are all positively related to the adoption phase.

3.4.2 *Social Features*

Organisations are regarded as part of contextual and environmental impacts, and organisation adoption includes external and socio-political factors that can influence adoption. The external environment is affirmed in the literature as being associated with adoption via relationship differences, but none are related to the pre-adoption phase (Wisdom et al., 2014). Some researchers indicate urbanisation and development as a positive related example regarding the adopting of organisations (Damanpour and Schneider, 2006). However, various theoretical sources for a competitive environment to succeed (Frambach and Schillewaert, 2002; Mendel et al., 2008) state that financial inducements and a reward system are considered positive for the pre-adoption phase to improve quality service delivery.

External government policy and regulation are positively related to both the pre-adoption and adoption phases. Regulation in pre-adoption comprises certain legislation and policies on innovation adoption (Oldenburg and Glanz, 2008). Similarly, the increase of adoption in the adoption phase is related to the legislation and regulatory agencies and accreditation standards (Berta et al., 2005). However, government policy and regulation affect the relevance in political and cultural conditions (Glasgow, 2003; Glasgow et al., 2003).

Some studies reveal that the pre-adoption phase embraces social networks and relationships that positively influence organisation systems (Mendel et al.,

2008) and the adoption phase (Berta et al., 2005). Therefore, the behaviour of organisations within the network is encouraged by such networks and relationships within the same system (Mendel et al., 2008). On the other hand, adoption is negatively affected by the limitation of external support (e.g. regulatory and advisory issues) and poor coordination among systems (e.g. administrator-managed and governance task systems) (Wisdom et al., 2014).

3.4.3 *Innovation Features*

The adoption phase must clarify essential features, such as complexity, relative advantage, and observability (Wisdom et al. 2014). Accordingly, adoptable innovations are described as follows: 1) simple to use; 2) clear in purpose; 3) more beneficial than existing practice; and 4) less proficiency desired for implementing, observable, and transferable (Oldenburg and Glanz, 2008). Nonetheless, the implicitness of innovation is harmfully related to adoption (Berta et al., 2005).

Several researchers identified forms of costs related to the pre-adoption phase, such as feasibility, cost efficacy, evaluation of feasibility and cost efficacy, and perceived benefits, as exceeding the expected costs to adopt (Mitchell et al., 2010). However, the adoption phase, regarding innovations, has an unambiguous benefit in cost-effectiveness compared with existing practice (Damanpour and Schneider, 2006, 2009).

Furthermore, some studies note that the pre-adoption phase of innovations includes strong research practice efficacy and evidence coupled with compatibility with existing practice (e.g. Feldstein and Glasgow, 2008). Other studies identified the following features: 1) compatibility with practice norms; 2) adaptability to suit organisational desires; and 3) evidence of practice efficacy as part of the adoption phase (e.g. Oldenburg and Glanz, 2008).

Regarding obstacles and facilitator features, the pre-adoption phase encompasses facilitators, such as training, the assessment of facilitators and obstacles, interest in practice, and empowerment (Graham and Logan, 2004). Other obstacles have been identified also, including familiarity, lack of awareness, autonomy, time, and ability to access research (Solomons and Spross, 2011). The adoption phase classifies some facilitator features, such as training, the continuous management and assessment of obstacles and facilitators, interest in practice, and empowerment (Feldstein and Glasgow, 2008). Additionally, obstacles facing the adoption phase were identified as familiarity, lack of awareness, autonomy, time, and ability to access research (Solomons and Spross, 2011).

Innovation matching with end-user values and norms is essential to the pre-adoption and adoption phases. Therefore, the pre-adoption phase identifies the features of innovation that match the end-user norms and values, such as assessment of such a fit, and the exact fit with current practice, user goal, value, and skills (Greenhalgh et al., 2004). Furthermore, the adoption phase indicates features of innovation that match the end-user values and norms also, such as organisational culture, accepted schemes, abilities, knowledge, values, task performance, and current practice (Weinstein et al., 2008).

Innovation adaptation involves risk-taking. The pre-adoption phase has a low risk of innovation (Greenhalgh et al., 2004; Mitchell et al., 2010), but the adoption phase is jeopardised when an innovation has a perceived uncertainty of adopting (Frambach and Schillewaert, 2002).

3.4.4 *Employee Features*

The relationship between team associates and organisational culture is positively applied in the pre-adoption phase (Aarons et al., 2011). Many researchers have identified company features that definitely relate to the pre-adoption phase, such as, 1) an affiliate willingness and incentive to change; 2) attitude assessment to change; 3) adopting a full approach to quality development; and 4) applying a reward system (Solomons and Spross, 2011). Additionally, researchers have identified the main affiliate features that are related to pre-adoption, including 1) innovativeness; 2) awareness of innovations assessment; 3) knowledge of spread on innovation; 4) skills and experience; and 5) learning style with a tolerance for ambiguity (Oldenburg and Glanz, 2008).

Nonetheless, other researchers have specified company features that are absolutely related to the adoption phase, including 1) enduring authorisation of a full approach to quality development; 2) adopting both pro-innovation and affiliate-positive attitudes; and 3) both affiliate- and organisational level motivational willingness and perception for change (Damanpour and Schneider, 2009). Furthermore, affiliate features related to the adoption phase include 1) knowledge base, 2) exposure to media, and 3) tendency to risk-take (Aarons et al. 2011).

The adoption phase largely depends on the feedback of execution and loyalty more than the pre-adoption phase (Wisdom et al., 2014). Managerial features are also mentioned, in which managers directly impact employee morale, inspiration, and reward change and innovation (Damanpour and Schneider, 2006, 2009). Furthermore, researchers note that feedback often includes, 1) adoption rate assessment; 2) observing adoption progress periodically; and 3) commenting to employees regarding either deviation from or alignment with best practice (Mitchell et al., 2010).

The pre-adoption and adoption phases significantly depend on social networks at the individual level, but this is more critical in the adoption stage (Wisdom, et al., 2014). Forms of social networks related to the adoption phase include the social links within and outside a company, extensiveness, quality, and diversity (Mendel et al., 2008).

3.4.5 *Client Features*

Client capacity to adopt innovation and their readiness for change includes the early involvement of potential users (staff or client), which positively relates pre-adoption to networking with the innovation developer and researcher (Wisdom et al., 2014). The client's SN, such as beliefs, attitudes, willingness to adopt and adapt innovations as needed, and readiness towards change, are positively related to the adoption phase (Weinstein et al., 2008). Furthermore, the attention and pre-existing conditions of client demands can either enable or hinder their contribution to adoption (Feldstein and Glasgow, 2008).

3.5 Client Values

In a book entitled *Lean Thinking*, value is defined as ‘a capability provided to a customer at the right time and at an appropriate price, as defined in each case by the customer’ (Womack and Jones, 1997). In lean construction, construction practices are linked to the transformation-flow-value model of Koskela (1992, 2000), in which fulfilling client value is achieved through the production process in-site. The main characteristics of value are subjective and objective, dynamic, extrinsic, intrinsic, and context (Salvatierra-Garrido and Pasquire, 2011). Emmitt et al. (2005) claim that lean construction must begin with ‘the briefing and conceptual design stages and managing the flow of decisions through to the completed building, thus helping to deliver value within a lean framework’. Client values are classified as 1) whole-life cost, 2) functionality, 3) predictability, 4) duration, 5) environmental impact, and health and safety (Thomson and Austin, (2006). Figure 3-3 shows the key of client value.

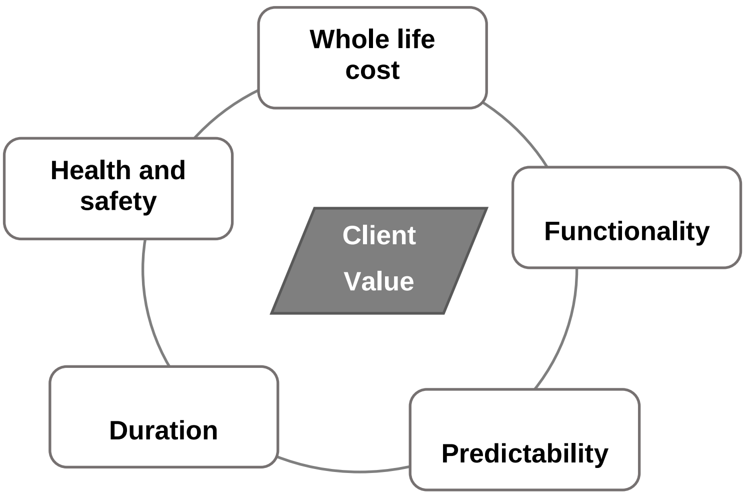


Figure 3-3 Client value (Source:

3.6 Innovation in Construction

The construction industry produces more waste, greenhouse gases, and consumes more energy than other industries. It is common in construction practice that projects exceed budgets and deadlines in both the public and private sectors (Abanda et al., 2017). In terms of diffusion of innovations, the construction industry is often traditional and slow (Sheffer, 2011). Latham (1994) states that increasing challenges are facing the construction industry to innovate to meet the expectations and needs of both clients and society, and to increase competitiveness (Kulatunga et al., 2006). The CIRIA (1999) identified 'failure to stimulate innovation' as one of the major barriers for applying standardisation and preassembly in the construction industry.

Although the tendency of construction industries appears similar worldwide, categorisation may slightly vary from one country to another. Globally, construction industries need to improve performance through innovation, such as BIM and offsite construction. The adoption of such innovations is recommended by most UK governmental reports to overcome the challenges facing the construction industry (Abanda et al., 2017). Pan et al. (2004) indicate a lack of integration regarding offsite techniques in the design process. Accordingly, the implementation of offsite innovation was proposed to obtain social, economic, and environmental benefits. Lovell and Smith (2010) note modular construction as a theme, in which the diffusion of innovations has been slow in practice. Vernikos et al. (2011) state that recent initiatives (e.g. lean construction, BIM, and offsite) are intended to decrease costs through enhanced data management and improved resources. Therefore, the UK construction industry has increasingly embraced BIM in recent years (Vernikos et al., 2015).

3.6.1 *Innovation of Lean Construction (Optimisation)*

Mastroianni and Abdelhamid (2003) state that construction projects maintain the incessant drop in profit margins and high competition. Therefore, construction contractors continue to search for alternatives to eliminate waste and to increase profit. The efficiency and effectiveness of construction processes are improving through many developed approaches, such as lean construction techniques, which propose the ability to minimise non-value-adding work. The principles of lean production have been considered by the construction research community since the early 1990s (Paez et al., 2005).

The concept of understanding construction as production was first discussed by Koskela in 1992. The formulation of a theoretical base for lean construction was contributed by the International Group for Lean Construction (IGLC). Such a contribution was made by applying the core concepts of lean production to the management of construction processes (Salem et al., 2005). The key classifications of planning, operation, and execution highlight the differences between manufacturing and construction (Paez et al., 2005). In 1992, the Last Planner system of production control was announced to highlight the relationship between scheduling and production control as the best, entirely advanced lean construction tool (Ballard, 2000).

3.6.2 *Innovation and Improvements of Preassembly*

Pan et al. (2004) found many definitions of innovation in the literature. These ideas and definitions were combined into the following definition: '*newness, unit of adoption, and successful exploitation of new ideas are the elements of innovation, but these elements embrace rich context which should be understood appropriately*' (Pan et al., 2004, p.824). Trott (2002) argues that a variety of viewpoints occur between companies regarding perceive current being new or old, a success or failure, and contextually dependent to judge success.

Pan et al. (2004) present a contextual model to enable the identification of the drivers of and barriers against innovation. Furthermore, an inclusive range of contextual features is covered, including spatial, historical, political, social, economic, technological, environmental, and legal. The results conclude that technical and human factors are much combined, which hinders preassembly applications, and human perceptions have blocked the progress of uptaking. The importance of preassembly techniques, with appropriate integration into good design and process, is noted as providing benefits in economic, social, and environmental features, etc. Ultimately, exploring the relationships among the barriers to the adoption of preassembly techniques should enable approaches to overcome perceptual and human barriers to preassembly innovation in housbuilding (Pan et al., 2004).

3.6.3 *Innovation of Building Information Modelling in Modular Construction*

Building information modelling is defined as a ‘multifunctional set of instrumentalities for specific purposes that will increasingly be integrated’ (Miettinen and Paavola, 2014). Bryde et al. (2013) note that BIM is one of the most significant innovations in the construction industry because of its ability to assist project management in procurement, construction, prefabrication, and facility management ranges. Murray and Langford (2008) state that, comparable to BIM, offsite (such as prefabrication, preassembly, and so on) in construction has been endorsed by the UK Government for generations.

Vernikos (2015) states that hindrances, implementation methods, drivers, and case studies for both offsite and BIM construction were investigated in several pieces of literature regarding the construction industry (Nadim and Goulding, 2010) and by industry reports (National BIM Report, 2013; Miles and Whitehouse, 2013; McGraw Hill Construction, 2010, 2011). The decision-making process in the construction sector is promoted by using BIM at an early stage of designing projects (Shafiq et al., 2015; Peng, 2015).

Hanna et al. (2013) reveal that utilising BIM has been applied more in larger building services firms than in smaller companies. Furthermore, around 60% of building service contractors use BIM – electrical contractors utilise BIM more than mechanical contractors (70% and 51% respectively).

3.7 Construction Process

This section discusses the construction process in general. It introduces the role of modularisation and standardisation in building services. Conflicts between building services systems, and traditional and preassembled construction process are also highlighted. Similarly, decision-making in the construction process is reviewed.

3.7.1 *Modularisation and Standardisation of Building Services*

The prefabrication and product development industry are very familiar with terms such as modularisation and standardisation. These terms are collectively applied in several construction cases as concepts, but there is a true difference between them when applied to product development (Samarasinghe et al., 2017). Some of the main differences between the two concepts were defined when utilised for product development (Börjesson, 2012).

One of the reasons for the lack of preassembly in building services systems is poor judgement regarding modularisation and standardisation concepts. Although a building has a strong reliance on building services, both concepts can be utilised for building services systems. For instance, the cooling load of a building greatly relies on the data centre size; therefore, standardisation can be utilised. However, the cooling system can be standardised to meet the cooling requirement when standard sizes for data centres exist (Samarasinghe et al., 2017). Offices, hotels, and shopping malls (as commercial buildings) differ regarding heating and cooling loads due to architectural and functional aspects, which makes it difficult to achieve standardisation in HVAC systems. Onsite limitations during construction are another difficult factor that limits standardisation. Several limitations occur onsite due to the late installation of building services systems (Samarasinghe et al., 2017). Usually, building services systems are located in the basement of tall buildings in urban areas, which restricts transporting equipment onsite because of the limited consideration of the existing building structure. Limitations of both an architectural and structural nature differ from one project to another. Therefore, the use of standardised building services systems is limited by variance in design (Samarasinghe et al., 2017). Modularisation is a faultless solution for building services systems in commercial buildings because of the limitations during construction and variations in design. In the modularisation process, a constraint-based method should be considered from the initial stages in the construction industry (particularly for building services systems), unlike in product modularisation. However, modularisation provides building services engineers with the choice to design the optimum system for each building, and the modularisation process will mainly deem the limitations in construction and maintenance in operations (Samarasinghe et al., 2017).

3.7.2 *Conflicts Between Building Services Systems in the Field*

Building services work creates the most waste due to its instability and uncertainty in comparison with the uniform and predictable progress of structural work in building construction. The design changes and conflicts between building services crews are time-consuming, as rework is sometimes required (Samarasinghe et al., 2017). Khanzode (2010) states that building services systems contribute 40-60% of the total construction cost of commercial buildings. Court et al. (2009) identified the main issues in building services construction that create waste and delay the completion of the project. These issues include health and safety, productivity, overcrowding on site, worker availability, crew relationships, and skills.

Hanna et al. (1999) note that client late design changes cause significant drops in labour efficiencies regarding the mechanical aspects of projects. All interrelated services in a building can be affected by such changes. For instance, changing the space function in the building requires changes to the ventilation system to meet new usage, as well as duct sizes, which will consequently affect other services, such as plumbing that shares the same service shaft. Accordingly, major rework occurs due to late design changes, which leads to delays, additional costs, and a reduction in labour efficiency (Samarasinghe et al., 2017).

3.7.3 *Traditional and Preassembled Building Services Components Construction Processes*

A key step for identifying the differences between the preassembled and traditional systems is to realise the current coordination process in a traditional construction system. The traditional construction process is not involved in coordination with the scope of the design engineer in design-built schemes. Furthermore, a speciality contractor onsite is in charge of developing shop drawings that identify the conflicts between the systems when the contract is awarded. Also, a coordinated shop drawing is submitted to the engineer for approval after all the conflicts are determined. This traditional coordination process is time-consuming and can affect the critical path for system installation (Tatum and Korman, 1999).

When the coordinated design greatly differs from the initial design submitted by the engineer, the initial cost of the design significantly expands. Thus, the ease of construction and maintenance depends on the reflection of both the construction and operational phases in the coordination process. The design engineers and speciality contractors are required to strongly maintain communication from the initial stages of the design process in preassembled construction.

Furthermore, almost the entire building's services systems are preassembled in an offsite facility prior to installation on site. Consequently, the project master programme is subject to modification if changes occur (Samarasinghe et al., 2017).

Traditionally, building services installations in construction are classified in three main stages: initial, installation, and testing and commissioning. The involvement of building services engineers occurs in the design and construction phases, especially for larger commercial projects. Also, construction phase involvement occurs at a later stage, when the building structure is complete or near completion. However, building services engineers are involved onsite from the notice to begin the construction. Such involvement occurs to ensure that the penetrations and openings, building canal placings, and earthing are delivered prior to concreting some zones in the initial stages. Consequently, the main installation of building services occurs once the project approaches its completion date (Samarasinghe et al., 2017).

A late start for the installation of building services jeopardises many issues, including insurance, equipment warranty, security, and the requirement of storage to preserve the original condition of the equipment prior to commissioning. Accordingly, in many cases, construction managers choose to build services installations at the project completion stage. Similarly, the design engineers perceive that the tendency of architects and clients making slight changes – while the building under construction may even be at the project completion stage – is another reason to proceed with installation at a late stage. Changes to the space functions while the building is under construction have a major influence on the installation of building services. Consequently, building services designers account for about 20-25% of the design safety factor in HVAC systems in case of any changes. However, energy efficiency is poor in cases in which a building's original design remains unchanged, since the HVAC system are oversized (Samarasinghe et al., 2017) (see Figure 3-4 and Figure 3-5).

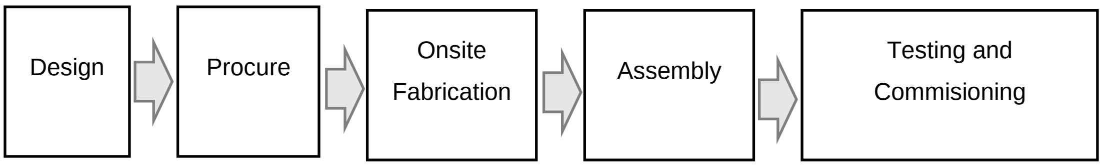


Figure 3-4 Traditional B.S. Construction Process

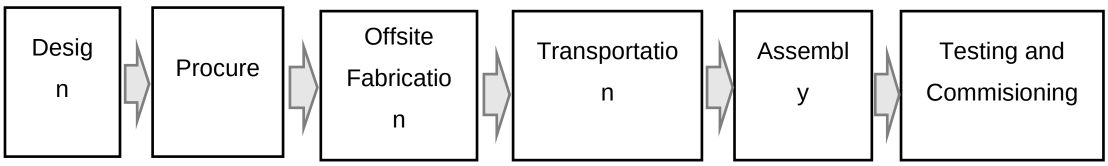


Figure 3-5 Prefabricated B.S. Construction Process

A major barrier for PBSC is the temporary design approach practised in the construction industry. Thus, entire building services designs are finalised at the initial design stage prior to the construction onsite in modular preassembly construction. Early involvement assists the simultaneous manufacturing of preassembled building services modules while civil work and structural are being performed onsite (Samarasinghe et al., 2017).

Preassembly of building services systems should be considered in the preliminary concept design stage. Therefore, preassembly requires major changes in the design process of the building services industry. Figure 3-4 and Figure 3-5 clarify the traditional and preassembly design process.

Traditionally, the performance of the building services system is typically evaluated in the design phase. Systems, following the completion of the designs, are escalated into the procurement phase, in which items in the design are to be purchased. The delivery of items occurs to site to begin the fabrication. The assembly of equipment and elements occurs once they are already fabricated. Testing and commissioning are completed once the assembly process is complete. The traditional process is a ‘push process’ in comparison with prefabricated construction (Samarasinghe et al., 2017).

The preassembly approach is similar to Design for Manufacture and Assembly (DFMA) in the product development industry (Samarasinghe et al., 2017). The DFMA concept is reduction-based; the number of parts is reduced for every component, and the type of component is decreased (Barbosa and Carvalho, 2013). Bralla (1996) introduced the design for excellence (DFX) concept, which is different from the DFMA, to address the challenges that prefabrication faces in the design phase, such as transport. Preassembly requires the involvement of construction managers and building services site managers to influence building services design from the preliminary phases. Therefore, the building services designers discuss site constraints in the concept design phase prior to the preliminary designs. Site constraints help to acknowledge the limitations in module weight, size, and assembly methods (Samarasinghe et al., 2017).

3.7.4 *Construction Decision-Making*

Construction decisions are usually difficult and inconstant in nature because of the intrinsic uncertainty and risk related to the construction process (Elnaas, 2014, p.99). Mohemad et al. (2010) state that making the right decisions ultimately results in the successful completion of a construction project. Armstrong et al. (1999) note that indicators for decisions depend on the analysis of sums of data, facts, and beliefs that shape the construction professionals’ knowledge (Elnaas, 2014, p.92). The success of a construction business depends on the decision-making knowledge and decision quality in a competitive marketplace (Elnaas, 2014, p.93; Buildoffsite, 2010), the form of a decision statement, and a set of alternatives and a set of selection measures that categorise the decision-making (Elnaas, 2014, p.93).

Li (2008) claims that decision-making is a basic duty of all management levels and essential processes in business. Decision-maker knowledge determines the complexity and difficulty of decisions (Elnaas, 2014, p.93). Decisions require that construction practitioners choose from a number of possible alternatives based on economic, policy, environmental, and technical considerations (Turskis et al., 2009). This requires the input of data at different phases of the decision process (Blismas et al., 2005). Pan et al. (2008a) state that many decisions are either very complex or very important for decision-makers in the construction industry, because choosing among possible alternatives is only based on instinct and past experience. A construction project has distinctive features and several stakeholders with diverse interests. Therefore, decision-makers must select the right choice for each situation, meeting all parties' interests and optimising the project (Elnaas, 2014, p.94).

Ozorhon, (2013) states that the construction industry is a varied and project-based industry, and a combination of both the environment and the requirements of the project encourage the use of new technologies (Ozorhon et al., 2014). Therefore, bringing the full benefit of preassembly early to the strategic project level is essential (Buildoffsite, 2008). Employing preassembly as an innovation in construction is vital at the project level, while identifying the factors and components for successful implementation is critical (Ozorhon et al., 2014). Many preassembly technologies are collectively improved at the project level, as construction companies always innovate at that level (Ozorhon, 2013).

3.8 Attitudes Towards Preassembled Building Services Components

Attitudes are classified into two groups: benefits and challenges. Benefits are classified into project management, site management, and sustainability benefits.

The costs of preassembly construction techniques have recently dominated the dialogue regarding the negative impact of a well-balanced viewpoint (Nadim and Goulding, 2011). The cost-savings of preassembly construction techniques are frequently encouraged, even though it is a challenge to define the potential of cost-savings objectively (Steinhardt and Manley, 2016). The cost-saving promises of preassembly construction techniques often depend on the building task in term of complexity and uniqueness, including the co-dependency between subcontractors and suppliers (Bildsten, 2011).

Preassembly construction methods promote automation and pledge to reduce both process and product complexity (Eastman and Sacks, 2008). Onsite construction tasks are facilitated through the installation of preassembly construction techniques, such as modules or panels, which reduce the requirement for subcontractors and the encumbrance on staff management (Pan and Sidwell, 2011). Consequently, the speed of construction is increased due to these simplifications (Lu and Korman, 2010). The reduction of time onsite can counterbalance the higher costs experienced because of new materials or pre-construction planning processes (Aburas, 2011). The transport of bulky modules as a part of new sources of complexity occurs due to the shifting from non-conventional manufacturing processes to preassembly construction techniques. Consequently, substantial efforts are required in reworking and planning new processes to maximise efficiency (Shewchuk and Guo, 2011).

Furthermore, direct costs outline the relationship between preassembly construction techniques and increased long-term sustainability, which has long been addressed in both the academic and industry literature (Zainul Abidin, 2010). The rigorous specifications and better level of control in manufacturing are considered to reduce waste during construction and deliver a more energy-efficient final product (Monahan and Powell, 2011).

However, the positive outcomes related to preassembly construction techniques are insufficient to change robust negative community perceptions of prefabrication in buildings because of its association with temporary, emergency, or low-quality housing (Goulding et al., 2012). Nevertheless, increased consistency in quality and a stronger final product are often considered outcomes of the repeatability of construction tasks, in addition to better opportunities to inspect and review output in preassembly construction techniques (Lu and Korman, 2010). Consequently, modifications can improve community perceptions, and increasing the quality of housing remains a key driver for change within the industry of preassembly construction techniques (Nadim and Goulding, 2011).

'Boxy' designs, related to repetitive manufacturing processes and low-cost construction, have shaped the negative perceptions of preassembly construction techniques. Therefore, increasing the efficiency and speed of construction can play a major role in the level of flexibility in designs and processes (Barlow et al., 2003). Thus, compromises from both the client and industry perspectives are required for the success of total standardisation and total customisation (Bertelsen, 2005). However, some continue to believe that a higher degree of flexibility in design is delivered via conventional building methods (Thuesen et al., 2009). Table 3-3 lists most of the covered literature review regarding offsite construction.

Table 3-3 Recent research regarding construction companies' views on preassembly (Source: Steinhardt and Manley, 2016)

Research	Scope	Benefits	Challenges
P **Pan et al. (2007)** H **Halman, Voordijk and Reymen (2008)** BW **Blismas and Wakefield (2009)** N	Survey of top 100 UK house-builders by volume, using interviews and a postal survey. Interviews with 'customised housing' academic specialists and construction industry stakeholders in the Netherlands. Three discussion workshops and case studies of Australian companies. Interviews with a variety of industry	- Cost issues: lower costs prioritised as a key aim; increased cost certainty, and earlier return on investment **B/N/P/BW** - Factory production improves work environment **G/N/P/BW** - Factory production reduces theft, weather impacts, storage, and material double handling **G/B/N/BW** - Strong linkage of manufacturing and construction schedules reduces	- Manufacturing standardisation conflicts with flexibility **G/B/N/P/BW** - Cost issues: High initial development costs and higher selling costs **B/N/P/BW** - Cultural industry resistance **N/H/BW** - Reliance on particular suppliers, and possible monopoly creation if limited availability **B/N/BW** - Need to retrain or requalify staff **G/N/BW**

Nadim and Goulding (2011) B **Bildsten (2011)** G **Goulding, Rahimian, Arif and Sharp (2012)**	stakeholders in Germany, Sweden, the Netherlands, and the UK. Interviews and case studies with two Swedish modular house-builders. Workshop with industry specialists, based on online interviews.	lead times and allows just-in-time manufacturing **G/B/BW** - Improved sustainability and reduced waste **G/N/BW** - Improved quality control and overall build quality **B/P/BW** - Addresses skill shortage and encourages skill diversification **N/P/BW** - Serves niche sub-markets well, such as remote locations **N/BW** - Standardisation of materials **B** - Lowers staff requirements **N** - Facilitates move towards automation **N** - Improved stakeholder cooperation **H**	- Large number of regulatory issues **N/H/BW** - Poor mainstream consumer acceptance and lack of sufficient demand **B/N/H** - Process restructure required to encourage integration **G/N** - Increases number of actors and process complexity **H/P** - Automation not realistic or developing **G/N** - Necessary economies of scale **N/P**

3.8.1 *Benefits*

Gibb (2001) identified numerous issues in manufacturing that could be beneficial at the strategic level. In the UK, both Latham's and Egan's reports highlight the benefits and significance of modular and industrialised systems to ameliorate construction performance through the application of standardisation and preassembly (Nawi et al., 2011). The decision to utilise preassembled construction techniques is essentially considered a project-wide viewpoint from key project drivers. Consequently, an appropriate strategy is established to optimise outcomes during the evaluation stage, which can differ from one project to another (Elnaas et al., 2013). Several researchers (Gibb, 2001; Blismas et al., 2005; Goodier and Gibb, 2005a; Goodier and Gibb, 2007; McKay, 2010; Nadim and Goulding, 2010) have studied in detail the benefits of preassembled construction techniques. Alazzaz and Whyte (2014) reviewed a number of studies on the benefits of preassembled construction techniques to shape future direction. Based on these studies, the main benefits of preassembled construction techniques include reduced time, improved quality, fewer skills shortages, reduced cost, and improved productivity.

Jaillon et al. (2009) note that waste reduction benefited from implementing OCT is 52% in Hong Kong. Tam et al. (2007a) state that skilled supervising can achieve a better environment and quality of final product in Hong Kong. According to Jaillon and Poon (2010), benefits include improved quality control, reduced waste, improved health and safety, reduced labour, improved productivity, improved site management, reduced duration, as well as project cost-saving and a rapid return on investment. Arif et al. (2012) highlight some of the benefits of preassembled construction, such as improved quality, speedier construction, lower cost, reduced risk and time issues, and reduced labour hours. Elnaas et al. (2013) introduced the advantages of using preassembled production as follows: reduced time, cost, health and safety risks, defects, and environmental impact. On the other hand, preassembled production increases whole-life performance, predictability, and profits in the long term. Based on various case studies, Tam et al. (2014) identified a number of potential benefits, including the cost-saving of utilising material, site manpower, benefits of gross floor area and added works during the construction stage. Zuhairi et al. (2016) state the benefits as less labour, site cleanliness, less material wastage, shorter construction period, etc. Moreover, essential benefits at no extra cost are noted as high levels of sound insulation, integral fire resistance, and robust finishes.

Vernikos et al. (2013) documented the drivers of implementing preassembly in the construction business. These drivers include cost certainty, time certainty, high-quality achievement, health-and-safety risk reduction, incentives from local authorities, good transport networks, and demand for housing. The main benefits of preassembled construction techniques are discussed in the following section. Table 3-4 summarises the benefits of using PBSC.

Table 3-4 Summary of benefits of using PBSC (Source: Author)

Benefits Of Using PBSC		
PM Benefits	**SM Benefits**	**Sustainability Benefits**
- Product quality - Schedule - Construction cost	- Coordination - Facilitate onsite tasks - Construction waste	- Onsite safety - Design efficiency - Energy efficiency

3.9 Project Management Benefits

Project management includes disciplines such as planning, organising, and managing resources to attain specific goals (Ma et al., 2014). Furthermore, project management is defined as both the exercise of professional expertise and academic knowledge (White and Fortune, 2002). The most common project failures occur because a project exceeds the appointed time and budget goals or fails to fulfil the client or company expectations (Sauser et al., 2009). Therefore, this section discusses the main three project management benefits gained from using PBSC, which are quality, time, and cost.

3.9.1 *Increased Product Quality*

Preassembled construction techniques offer rigorous quality control (Arif and Egbu, 2010). The use of preassembled construction techniques can improve product quality through standardised design and professional supervision onsite, which reduces the number of change orders and rework activities (Goodier and Gibb, 2007). Currently, CAD and construction software, such as MIB, assist in confirming alignment and, with the precision of blueprints for a given project, maintaining both the preassembled and onsite quality of a product (Russell et al., 2012). In manufacturing technology, computer-assistance allows each product to differ in the line (Johnson, 2007; Manley et al., 2009). Software integrates design with manufacturing to provide mass customised production (Larsson and Simonsson, 2012).

3.9.2 *Reduced Project Schedule*

Saving time is one of the most significant benefits of the preassembled construction techniques used in the construction industry (Arif and Egbu, 2010). Time reduction of onsite work has a major influence on shortening overall project schedules. Several studies have found that a reduced schedule is one of the main benefits of preassembled construction techniques (Goodier and Gibb, 2007). Conventional site work is influenced by severe weather conditions, which is one of the key factors of the construction schedule (Larsson and Simonsson, 2012). The use of preassembled construction components reduces the risks of delay in a construction project (Manley et al., 2009). Productivity issues mainly occur due to scheduling problems for many construction companies. Overall, preassembled construction techniques are the primary solution to delayed schedules and to improve productivity (Blismas and Wakefield, 2009). Mawdesley et al. (2002) state that improved time is the main benefit of PBSC.

3.9.3 *Reduced Construction Costs*

Several studies have found that reduction of construction cost is one of the main benefits of preassembled construction techniques (Johnson, 2007). Mawdesley et al. (2002) state that cost-saving in the construction process is the main benefit of PBSC. The development and production of overhead costs are shared across a number of construction projects. Standardisation, therefore, has the potential to significantly contribute towards a reduction in real construction costs (Elnaas et al., 2014). Thus, general contractors receive the advantage of this cost-saving. The use of preassembled construction techniques allows construction cost-saving at every stage of the design, manufacturing, and construction; material savings during manufacturing and procurement, and labour-saving during construction (Larsson and Simonsson, 2012). Construction cost-savings mainly apply to the lower cost of preassembled labour (Javanifard et al., 2013). Furthermore, savings may be related to site overhead reductions, installation efficiencies, and the standardisation of design (Manley et al., 2009) due to less activity by and lower dependency on skilled workers, as well as fewer resources required on building sites (Khalili and Chua, 2013). Construction cost reductions can also be achieved regarding an increase of craftworker productivity and reduced labour rates onsite (Elnaas et al., 2014).

3.10 Site Management Benefits

Site management is a synthesis of tasks that produces a finished product from raw materials. Such tasks vary, including the organisation of labour, materials, and other resources for site tasks, which control the flow of finance and information (Construction IT, 1996). The effect of the management of onsite performance and productivity is detailed by a number of researchers. The construction site is the main element in terms of money-making or -losing as there is substantial scope for improving efficiency, productivity, and quality (Mohamed and Anumba, 2006). Accordingly, this section discusses the main site management benefits gained from using PBSC.

3.10.1 *Enhanced Coordination*

Coordination between the workforce and tasks can be enhanced by using preassembly components (Steinhardt and Manley, 2016). Previous studies on this subject reveal that effective competition among corporations requires meeting customer requirements by offering a variety of products (Halman et al., 2008). Product-variety management requires progressive corporations regarding product-development approaches by reducing complexity and allowing for good investment in manufacturing, product design, and marketing (Krishnan and Gupta, 2001).

Additionally, the implementation of preassembly coordination requires improved design planning (Din et al., 2012). The design team plays a significant role in designing modules and components, including the probable synthesis of modules and components within modules. Therefore, designers should cooperate with contractors and suppliers (Halman et al., 2008). Existing projects visualise the construction industry as a transparent system that includes many interrelating stakeholders, which affects innovation through the degree of sharing ideas, knowledge, and innovations (Chesbrough and Appleyard, 2007). Therefore, more transparency and cooperation between actors would enable improved innovation (Steinhardt and Manley, 2016).

3.10.2 *Facilitate Onsite Tasks*

Facilitating the installation of preassembly onsite construction task modules can reduce the requirements for outside general contractors and ‘wet trades’ (Pan and Sidwell, 2011). Such simplification can play a role in reducing the load of staff management (Roy et al., 2003). Thus, onsite construction simplifications increase the overall speed of construction (Lu and Korman, 2010). Also, the incurrence of higher costs (e.g. new materials or pre-construction planning processes) can be balanced by the reduced time for onsite tasks (Aburas, 2011). Furthermore, the simplification of tasks allows for money-saving by reducing the number of staff and costly onsite operations. The simplification of onsite construction tasks, via preassembly, can encourage more use due to the continuous increase in demand for skilled construction workers without a consistent increase in supply (Luo et al., 2005). Consequently, contractors are required to manage the higher direct costs of material and labour, as well as the costs of founding a factory environment with insufficient legislative and funding (Lovell and Smith, 2010).

3.10.3 *Reduced Construction Waste*

Construction waste forms 40% of landfill material (Nahmens and Ikuma, 2011). However, some researchers highlight the manufacturing benefits of a higher level of control and specifications to reduce construction waste and deliver an efficient final product, while others discuss the waste minimisation and higher energy performance of preassembly (Monahan and Powell, 2011). Similarly, innovative design methods in preassembly include applications such as BIM processes (Banihashemi, 2012) and BIM authoring tools (Singh et al., 2015), which have recently become popular research areas.

Research on construction procurement systems that focus on waste generation has classified four main causes: 1) poor early involvement of project stakeholders; 2) uncertain allocation of responsibilities; 3) unsuccessful project coordination and communication; and 4) inconsistent procurement documentation (Gamage et al., 2009). The improvement of construction performance is vital and is possible by adopting and implementing waste minimisation aspects. Also, the increased demand for enhanced sustainable project performance by clients has influenced the industry to cut costs and reduce onsite waste (Tseng, 2010).

3.11 *Sustainability Benefits*

The built environment is significantly growing and using sustainable development worldwide, and the construction industry in the 21st century is critically characterised by the term 'sustainability' (Zhai et al., 2013). Furthermore, the greatest potential contributor to worldwide sustainable development is promoting building and construction in a sustainable manner (Bakens, 2003). The term 'sustainable construction' was first introduced by Kibert in 1994. The term itself consists of three domains: 1) the responsible creation and maintenance of a healthy built environment; 2) ecological principles; and 3) the efficient use of resources. Accordingly, this section discusses the main sustainable benefits of using PBSC.

3.11.1 *Improved Onsite Safety*

Preassembled construction techniques assist in increasing onsite safety by reducing the exposure of labourers to heights, severe weather, onsite working time, and hazardous operations (Larsson and Simonsson, 2012). These benefits are mainly because labourers in manufacturing work in a controlled environment unaffected by extreme weather (Blismas, 2007). This controlled environment provides more working space and mitigates the potential likelihood of accidents onsite (Elnaas et al., 2014).

3.11.2 *Enhanced Design Efficiency*

Preassembled construction techniques offer rigorous quality control (Arif and Egbu, 2010). Furthermore, construction waste is controlled and minimised in the manufacturing process through optimal design and well-managed coordination and installation (Larsson and Simonsson, 2012). Reduced onsite construction time, less waste produced onsite, and less noise are all means of mitigating negative environmental impact (Blismas and Wakefield, 2009).

Moreover, preassembled construction processes can greatly reduce costs and increase material input (Blismas, 2007). Overall, preassembled construction techniques provide environmental benefits that go beyond the simple reduction of water used for the construction of a typical house, the reduction in energy consumption, and the reduction in the use of materials (Manley et al., 2009).

The quality of the final product is much easier to inspect and assure in a manufacture environment than an onsite environment (Blismas and Wakefield, 2009). Preassembled construction techniques provide optimum solutions regarding skilled-labour shortages (Blismas, 2007). Preassembled construction techniques require less work onsite work than the traditional construction approach, which facilitates work content. Onsite assembly must meet the necessary standards to enable the product to perform as designed (Manley et al., 2009)

3.12 Challenges Facing Preassembled Building Services Components

Various studies have measured and analysed the challenges of preassembled material, preassembly, and prefabrication processes. Preassembled construction techniques have encountered different barriers in many contexts, such as attitudes and social climate, constructability implementation, costing, architectural performance, supply chain, and the preparatory stage. The barriers of preassembled construction techniques are now discussed.

Badir et al. (2002), Pan et al. (2007), Goodier and Gibb (2007), Goulding et al. (2012), and Arif et al. (2012) all document the challenges of implementing preassembled construction in the construction industry. Some of the challenges recognised from reviewing the literature include expensive products, high capital cost, lack of information and guidance, complex interfacing systems, skills shortage, and low manufacturing capacity (Miles and Whitehouse, 2013). Hashemi and Hadjri (2014) state that the main barrier regarding the wider adoption of preassembled construction techniques is their extra immediate costs compared with traditional methods of construction. However, preassembled construction techniques cover higher costs through other financial benefits, such as earlier rent and quicker construction compared with traditional methods (NAO, 2005). Vernikos et al. (2013) conducted important research regarding the drivers and barriers to preassembled construction that were completed by Nadim and Goulding (2010).

Pan et al. (2007) studied barriers to the utilisation of preassembled construction techniques among the UK's leading house-builders. However, complex interfacing and higher capital cost among systems were excluded from the barrier list. The identified barriers measured include the nature of design process, fragmented industry structure, risk-averse culture, local government planning system, manufacturing capability, and anxieties of mortgage lenders. In addition, insurers are also considered a barrier to the uptake of preassembled construction techniques within the UK housing industry. Arif and Egbu (2010) identified cultural change as a barrier to using preassembled construction techniques within the Chinese construction industry, in which traditional construction has been used for many years. Education and motivation are suggested to breach such barriers.

Elnaas et al. (2013) argue that barriers include six categories: process, system, logistics, regulatory, resources, and cost implication. System barriers include a lack of understanding OCT by local authorities, culture resistance, low market demand for OCT homes, and mortgages for OCT due to a lack of awareness of the system. Moreover, process barriers include complicated interfacing among systems, early design freeze, and possible increased incidents onsite due to large units and heavy loads. The regulatory barriers include a lack of current codes, outdated regulations to cover all preassembled features and standards for OCT, and no authorised framework available to support OCT. Logistics barriers encompass crane costs, access and site constraints, and difficult transport. Resources barriers include cost implications, limited UK efficiency and capacity, skills shortages, and limited expertise in the marketplace of the system. Most of these challenges to preassembled construction techniques are now discussed. Table 3-5 summarises the challenges of using PBSC.

Table 3-5 Summary of challenges of using PBSC (Source: Author)

Challenges Of Using PBSC		
Cost Implication	**Process**	**Product**
- Overall project cost - Maintenance	- Change onsite - Transport - More preparation	- Flexibility of design - Risky - Negative perception

3.12.1 *Reduced Flexibility of Design*

The production and development costs and overheads are shared across construction projects, which is a key benefit of the use of standard elements, components, or modules. Therefore, standardisation plays a significant role towards a reduction in real construction costs (Elnaas, 2014, p.48). Furthermore, this role is due to less dependency on skilled workers, lower tasks, and fewer resources required for building sites (Khalili and Chua, 2013). Moreover, the benefits gained from manufacturing industries can only be realised by accepting preassembly for standardisation in construction (Elnass, 2014, p.49).

3.12.2 *Limit Changes Onsite*

Generally, a standardised, modularised, and repetitive design is an essential foundation when considering the implementation of preassembled construction techniques at the early stage of a project (Goodier and Gibb, 2007). Preassembled construction techniques do not allow the making of changes during the construction phase onsite, which reduces the use of preassembled construction (Blismas and Wakefield, 2009). There is an on-going argument that states that the extreme standardisation and repetitiveness of processes involved with preassembled construction prevents its wider application in the housing construction industry (Arif and Egbu, 2010). Modular buildings, as a form of preassembled construction techniques, need a well-defined scope of work prior to the project planning phase (Manley et al., 2009).

3.12.3 *Requires More Preparation Work*

The preparation phase represents the beginning of preassembly construction with reference to the early design and the length of lead-in time (Zhai et al., 2014). The long lead-in time has been identified as a significant barrier to the broader uptake of preassembly construction (Pan et al., 2007). Generally, preassembly construction relies on preparation and detailed planning at the preparation phase of the project to be successfully executed. Preassembly production processes require long preparation time to, 1) describe the architectural design; 2) check the availability of preassembly components and labour; 3) check transport accessibility; 4) coordinate between different stakeholders; and 5) discuss technological solutions and other related features (Zhai et al., 2014).

3.12.4 *Increased Overall Project Cost*

Overall project cost is associated with preassembly regarding higher initial costs, higher capital costs, and a longer capital payback period. These challenges are mostly reported by consultants, which affects the clients. Similarly, the decision-making process significantly depends on the economic parameters when selecting the optimal construction method (Zhai et al., 2014). Furthermore, the overall project cost of high-rise building construction with the preassembly method is about 20% higher than the construction costs of the conventional onsite construction process (Jaillon and Poon, 2008). The perception of overall project cost-savings has significantly increased over time when implementing preassembly (Polat, 2008).

However, the financial performance of preassembly remains debatable from the construction industry's perspective. Client perception of higher capital and initial cost is regarded as a significant barrier to improving preassembly in the long term (Blismas and Wakefield, 2009). Additionally, many practitioners in the construction industry often compare preassembly with conventional approaches in the short term, especially when dealing with customised preassembly components. However, the cost-effectiveness of preassembly is misevaluated when little attention is paid to the 'whole-life cost' perspective when adopting the optimal construction method (Zhai et al., 2014).

3.12.5 *Increased Transportation Logistics*

The feasibility of preassembled construction techniques is mostly controlled by transport logistics (Blismas and Wakefield, 2009). Transport is a logistical, yet critical problem, influencing the preassembled construction supply chain (Goulding et al., 2014). Limitations of size and weight are enforced by the technique and path of transport during transit (Manley et al., 2009). Roadway transport typically limits the size of the modular building or preassembled building components to a range between 12-14 feet in width and 50-55 feet in length (Larsson and Simonsson, 2012). Similarly, weight is limited by the capacity of lifting equipment, typically between 10-30 tonnes, while highway limits the lifting capacity of the crane (Blismas and Wakefield, 2009).

3.12.6 *Increased Risk*

The commitment to advance the industry norms challenged early innovators, and continues to depend on the system support that encourages companies. Substantially, the commitment to innovation involves risking the interest of the construction industry (Loosemore, 2014). Some of the major criteria that may increase the risks of using preassembly methods are design changes during the project (NAO, 2005), risk of maintenance (Pan et al., 2008), and risk of new construction methods (Steinhardt and Manley, 2016). Some researchers (e.g. Gibb et al., 2003) examined the health-and-safety risks related to preassembly. Blismas and Wakefield (2009) considered the high-risk involvement of the supply chain on a regional and international scale, as well as the risk of installation, such as crane use being vulnerable to stoppages, high winds, and hook-time availability.

3.12.7 *Increased Maintenance*

Wet areas, such as bathrooms, are critical areas of the building process due to their major maintenance risks and the related high number of defects (Ramly et al., 2006). However, the building gross floor area typically comprises around 10% as wet areas with an annual maintenance cost ranging from 35% to 50% of the total maintenance cost of a building (Chew and De Silva, 2003).

Furthermore, maintenance is a significant long-term cost for clients and source of dissatisfaction for end-users. Thus, the choice of procurement method is an issue when the importance of whole-life cost for preassembly is involved (Gardiner and Theobald, 2005). Nevertheless, the maintenance cost of using manufactured preassembly remains uncertain. It is worth noting that the design decision-making to use preassembly and the realisation of preassembly technology is crucially affected by the lack of perception of maintenance cost (Pan et al., 2008).

3.12.8 *Low-Quality Image*

The reviewed literature revealed that low-quality image, that is, the negative perception of preassembled construction techniques, is one of the most substantial barriers in all contexts, except in Japan and Germany (Larsson and Simonsson, 2012). Negative perceptions comprise a lack of available standards and codes, a lack of governmental support, client resistance and disbelief, and a lack of confidence in the industry regarding preassembled construction (Blismas and Wakefield, 2009). Preassembled construction is mostly perceived as a complex technology in comparison with traditional construction culture (Manley et al., 2009). Overall, government regulatory procurement and policies have a great effect on demand; therefore, they play an essential role in promoting change via the uptake of new construction technology. (Goulding et al., 2014)

3.13 Stakeholders Influence Decision to Use Preassembled Building Services Components (Subjective Norms)

The decision-making process involves significant contributors (Pan, 2006, p.221) called 'key players' who represent all the related viewpoints. ‘Stakeholders’ is a term used to refer to key players who suffer the penalties of any bad decisions taken. Stakeholders, whether they have an investment or otherwise, are often categorised as key players who participate in the decision-making process (Pan, 2006, p.221; Dodgson et al., 2009). Stakeholder interests and influences regarding project delivery are identified via important means of stakeholder analysis (Pan 2006, 221) and stakeholder mapping (Johnson and Scholes, 2002).

Sparksman et al. (1999), in the CIRIA report, argue that the design and construction method of preassembly require earlier decisions than the conventional method. Similarly, the report argues that client decisions must be identified regarding certain items that require early design input. Therefore, the timing of information requirements for standardised components is critical, especially for complex projects with short deadlines, in which some changes to the project brief or description could occur. Ultimately, changes must be strictly controlled, and their influence discovered before the implementation of changes (Pan, 2006, p.59).

Sparksman et al. (1999) suggest that a project-wide strategy is necessary, as well as earlier decisions, to use preassembly effectively. Similarly, Gibb (1999) notes that making decisions at an early stage, including a project-wide strategy, is significant for preassembly adoption. Furthermore, Gibb and Pendlebury (2005) developed recommendations through their study of the Offsite Toolkit, through which a project-wide strategy is delivered. The toolkit allows project teams to optimise the benefits of preassembly by identifying the main drivers and challenges for a project, applying strategies for actions at different phases of the project, and assessing results (Pan, 2006, p.59).

3.13.1 *Client*

The control of preassembly innovation from a broader range of stakeholder perspectives was researched by many governmental types (Pan, 2006, p.52). The barriers to innovation investigated were consultants, clients, general contractors, house-builders and developers, and suppliers inside organisations' working affairs and onsite (Housing Forum, 2001). The use of preassembly technologies was widely formed in association with implications to more stakeholders, such as offsite fabricators, developers and house-builders, suppliers, lenders, surveyors, insurers, and purchasers. However, the industry context of preassembly use was provided by these initiatives, and recommendations for in-depth investigations of house-builders are still needed (Housing Forum, 2002).

Goodier and Gibb (2004) state that, generally, in a market survey, the main challenge of preassembly use is the real or perceived additional costs by clients and their advisers. Birkbeck and Scoones (2005) share a similar perception regarding the housebuilding sector. Client confusion regarding value through the perceived high cost of preassembly results in the continued hesitancy by the industry to fully embrace the approach.

The widespread use of preassembly technology is recognised more in the commercial sector than the industrial and residential sectors in the UK. Masonry systems are popularly utilised for residential buildings in England and Wales. In the late 1980s, rapid commercial development in London created a major opportunity for expanding the use of preassembly technology. Commercial clients required a better-quality product and earlier delivery at a reasonable cost. The use of preassembly technology was a great approach to meet client needs. Preassembly is recognised as a mean of quicker completion for commercial construction buildings (Lu, 2007, p.22). McDonald's restaurants, for instance, use preassembly technology to build their new buildings. McDonald's once opened for business within 13 hours of starting construction on a prepared building site, because they place a record of the accomplished building already built (Blismas, 2006).

Edge et al. (2002) undertook a study in the UK regarding client resistance to prefabrication and standardisation in house-building. The study investigated attitudes towards many prefabricated houses through a series of interviews. The interviewees included representatives, general contractors' financial institutions, developers, and housing associations. The findings contributed to the better utilisation of preassembly in the UK.

The significance of early decision-making was highlighted by some publications to realise the potential benefits from preassembly (Pan, 2006, p.75; Buildoffsite, 2005). However, stakeholders, in practice, including clients

(Pan, 2006, p.75; Gibb and Isack, 2003) and their expert advisers (Pan, 2006, p.75) frequently make late decisions.

Pasquire and Gibb (2002) suggest that the major reason for the hesitancy among clients and general contractors to adopt preassembly is the difficulty they have in determining the benefits that could be added to a project. The decision to use preassembly in the UK is mainly based on subjective suggestions instead of solid data (Lu, 2007, p.23; Pasquire and Gibb, 2002).

Gibb and Pendlebury (2003) state that the CIRIA Offsite Project Toolkit intended to develop a strategy for optimising and implementing the benefits of standardisation and preassembly in the construction industry. The project teams and clients are supposed to use the toolkit throughout a project, from inception to completion (Elnaas, 2015).

Wilson et al. (1999) note the major perceived benefits to the client, contractor, consultant, and architect regarding implementing preassembly systems in the construction industry. Elnaas (2015, p.67) summarises the realised benefits of mentioned key project players (Table 3-6).

Table 3-6 Key project players for preassembly in house-building (Source: Elnaas, 2015, p.68)

Client	Contractor	Architect and Consultant
- Shorter construction programme - Quicker return on investment - Improved quality and reduced defects - Value added and business continuity	- Work performed offsite under controlled conditions - Reduction in onsite preliminaries - Reduced onsite management costs - Reduced deliveries and carnage time - Safer working conditions for onsite operatives - Reduction in risk through labour shortages, project overruns, and penalty clauses	- Specialist design input - Single point responsibility - Improved customer satisfaction

3.13.2 *Consultants*

Pan (2006, p.47) states that the perceptions of professionals and the overall industry regarding the use of preassembly have been largely investigated since the publication of reports by Latham (1994) and Egan (1998). Architecture, Engineering, and Construction (AEC) professionals are concerned about the sustainable performance of buildings in the UK and worldwide (Zanni et al., 2013). Baba et al. (2013) state that the construction industry is increasingly under pressure to address environmental performance earlier in the design process. Consequently, many systems and tools have been developed to evaluate building performance and sustainable design, such as BIM and BREEAM.

The reasons for designing and developing these tools and techniques are to improve the quality of decision-making in the construction industry and to support design teams deciding between options in the design process within the context of design/architecture. These tools aim to achieve aesthetic value, cost gains, or environmental impact reduction through better choices (Elnaas, 2014, p.97).

Baba et al., (2013) note other developed tools for supporting the building design process in the construction phase, such as 1) Building Performance Simulation (BPS); 2) Building Energy Management and Control System (BEMCS); and 3) Building Performance Energy Simulation (BPES). These computer application tools simulate the energy performance analysis in building design (Elnaas, 2014, p.97).

Design decisions at early design phases in the construction industry are usually evaluated by decision support systems. Design tasks include the decision-making process, needs comparison, evaluation, and the selection of design alternatives for ultimate optimisation from a systematic view (Zhai et al., 2008). All proposed design alternatives and options require careful analysis and evaluation throughout the different phases of building design (Baba et al., 2013). Elnaas (2014, p.97) highlights some design support tools, such as the Compromise Decision Support Problem technique, the Architecture Design

Support System (ADDSS) tool, the hybrid decision support model, and the fuzzy synthetic design model.

3.13.3 *Government Regulators*

Several studies indicate that building regulators and regulations are regarded as an influence on decision-making, which is considered part of a company's strategy and client influence (Arif et al., 2012a). Pan (2007) provides a recommendation regarding '*tackling planning and regulations*', which are considered influences on the decision to use preassembly. Venables et al. (2004) state that the promotion of offsite construction is slightly affected by the perceptions of the benefits and challenges of regulators and regulatory factors and the broader market (Pan, 2007).

3.13.4 *Contractors*

General contractors took the place of building contractors in the 20th century. General contractors play an important role in employing specialist trades and subcontractors to perform the actual construction work. Moreover, building systems have become more complex. Project managers were affected by these changes in the construction process; they focus on the interfaces among building elements and various trades onsite rather than the construction work itself. Therefore, the design and management of onsite interfaces and coordination among different specialised contractors were affected by the use of preassembly (Gibb, 1999).

The construction industry is considered slow in adopting preassembly technologies (Pan et al., 2007); whereas, other industries have benefited greatly from the development of preassembly, such as the manufacturing and production engineering industries (Gibb, 1999). Preassembly offers implicit benefits from the financial consideration of preassembled elements, such as cost-savings by reducing site logistics and site set-up, rather than cost-savings from preassembly itself. Thus, regarding preassembly strategically from a project-wide view is significant to optimise its applications (Gibb, 1999).

General contractors or manufacturers are expected to be involved in two-stage tendering. They are first supposed to submit initial tenders at an early stage in the project, according to outline designs performed by the design team. After choosing specific contractors, designs and approaches must be developed by chosen contractors to deliver the project. The second stage of tendering is the effective negotiation of the contract according to the first stage (Gibb, 1999). Small contractors lack the financial support to establish their own manufacturing plants, because this involves very substantial capital investment (Rahman and Omar, 2006).

3.13.5 *Subcontractors / Suppliers*

Subcontractors are usually less technology-intensive than larger construction firms, but are generally much more geared. Subcontractors also lose human and lack the scale, intellectual, physical, and financial resources to invest in innovation (Sexton et al., 2008). Successful preassembly requires three discrete groups of people with very different skill sets to work efficiently together: designers, manufacturers, and contractors. Furthermore, stakeholders, such as subcontractors, need significant assistance to adopt the changes required when using preassembly; whereas, design and manufacturing stakeholders can simply adapt (Goulding et al., 2014). Lu and Liska (2008) studied the perceptions of US general contractors, architects, and engineers regarding preassembly and found that onsite workers do not necessarily have the skills required to adopt offsite preassembly technology.

Preassembly significantly requires earlier consideration regarding costs in the short term, at least in the capability of demanding business to transfer into a stronger working capital strategy. However, financial resources are the main challenge for several subcontractors, since the majority of these firms are usually held in the form of ‘cash’ assets (White et al., 2003).

Moreover, subcontractor adoption of preassembly has obvious implications for the physical resource base, such as transport technologies, renting or purchasing new manufacturing facilities and equipment, and installing equipment, which differ from traditional construction processes. Hence, subcontractor engagement in preassembly is critically needed for the social capital resource to develop new supply-and-demand chain partnerships to protect resources and to connect and exchange the desired knowledge to make preassembly work (Edward and Loosemore, 2017). Also, close relationships and partnerships are required with suppliers and subcontractors from the early stage of project sequences (Kamar et al., 2009).

3.14 Influential Context Control Using Preassembled Building Services Components (Perceived Behaviour Control)

This section discusses the contextual controllers that control behaviour, including financial support, government regulations, manufacturing capacity, and skilled labourers.

3.14.1 *Financial Support*

Housing Forum (2004a) mentions raising concerns regarding lending house-builders and buyers for the use of offsite construction. Some requirements, such as life expectancy, durability, insurance schemes, and warranties, are essential for the security of a loan (Elnaas, 2014). Furthermore, lenders require an independent estimation for offsite construction as a new construction method before they pledge their future loan value (Ong, 2004). Lenders are often put off lending altogether when the property is built using offsite systems (Elnaas, 2014).

Similarly, Barker (2003) states that investment in offsite manufacturing facilities, including plant, factories, and other construction approaches, together with the industry's mitigation risk attitude, has prevented the use of preassembly construction techniques (McKay, 2010). In 2006, the Barker 33 Cross-Industry Group stated that investment in new techniques, such as preassembly construction, is struggling because it often involves alteration to the building regulations and clashes with different sections within the regulations (McKay, 2010).

Therefore, the UK Government and the construction industry have combined to revise the regulations and standards to classify a few aspects of new preassembly products (Elnaas, 2014). Ross (2002) states that the Council of Mortgage Lenders and BRE continue to cooperate in developing a toolkit to address the exact issues regarding lenders dealing with innovative housing (Elnaas, 2014). Furthermore, the use of preassembly approaches in construction is represented by several programmes, such as the Buildoffsite Property Assurance Scheme, the Buildoffsite Registration Scheme, and the Buildoffsite R&D Tax Credit Service (Buildoffsite, 2010; Elnaas, 2014).

3.14.2 *Government Regulations*

An MBI Report (2010a) addresses the major challenges of using preassembly technology, including building regulations. The CRC Report (2007b) states that preassembly codes and standards are very limited. Mao et al. (2011) claim that the lack of government policies was the prime challenge of the study because of inadequate progress with the application of preassembly. However, the use of cranes to handle heavy preassembled components is highly limited by safety compliance issues (McKay, 2010).

Although few regulatory policies are concerned with preassembly or prefabrication, many regulatory policies in the building industry are interested in structural quality, energy efficiency, and materials. Simultaneously, most preassembly policies fail because they depend on participation rather than on mandatory regulation, which fails to oversee the entire preassembly chain (Mao et al., 2011). The procedure for gaining permission for planning is assumed to be the lack of such an official agency (Pan et al., 2007). An effective enforcement technique exists in Singapore's public housing system, in which mandatory requirements for preassembly are indirectly imposed through statutory compliance with 'buildability' provisions (Mao et al., 2011).

3.14.3 *Skilled Labour*

Construction is a labour-intensive industry, in which labour perform in contrast to the new emergent of technologies. Labour impedance to preassembly works against technology up taking (CRC, 2007b). The labour skill difficulties are associated with several technological changes, but mainly developments in offsite construction (McKay, 2010). Saxon (2017) states that the challenge occurs when companies are incapable of affording high training, research, and development. Edge et al. (2002) claim that most construction trades experience a drop in craft skills together with an ageing workforce that is not being replaced by recruits in the UK construction industry. Luo (2008) claims that offsite construction is a more constructive choice recently due to the increasing labour cost and the shortage of skilled labour.

Furthermore, both researchers and practitioners agree regarding the issues and conditions that are contributing to form the shortage of construction labour market skills. Mackenzie et al. (2000) identified several factors, including ‘demographic decline in the number of entrants to the labour market’; ‘changes to its inherent features and the decline in operative skills’; ‘the emergence of new technologies’; ‘the increase in self-employment’, ‘the use of labour-only subcontractors’; ‘and fragmentation of the industry’ (McKay, 2010, p.62).

Also, the CITB (2002) lists some challenges that prevent the construction industry from fulfilling its skills requirements, including other industries’ competition, less training, and the gap in the labour force because of the serious collapse of the early 1990s. McKay (2010) and Dainty et al. (2005) note certain issues contributing to skills shortages, such as the labour market being informal and flexibile with contractors regarding the availability of skills in the construction planning phase (Uwakweh and Maloney, 1991).

Venables et al. (2004) examined the UK’s offsite construction industry regarding the supply of offsite components for housing – this was the second report of the Housing Forum MMC group regarding UK capacity in offsite manufacturing. The two major areas that the report considered are as follows: 1) capacity and producer issues, and 2) labour skills and supply. The problem of the shortage of skilled labour could be resolved by increasing offsite construction, as suggested by McKay (2010). Meanwhile, the expectation for skilled labour employment demand is for continual rapid growth above industry average, but available skilled labour, such as electricians, sheet metal workers, and HVAC mechanics, tends to decrease (Luo, 2008).

3.14.4 *Manufacturing Capacity*

Onsite activities and operations in traditional construction have been transferred into a controlled manufacturing environment to create energy-efficient construction. The promotion of OSP has been performed differently by many authorities in developed countries. The capacity of offsite manufacturing has been highlighted in the prefabrication building process to overcome the challenges of sustainability in the construction industry (Zhai et al., 2013).

Taylor (2010) notes that the production capacity of the UK offsite construction sector was estimated, via a questionnaire response, at a rate of 51% from a total of 61 responses (Venables et al., 2004). Taylor (2010) states also that the Mtech Group, in 2006, measured 107 responses from companies and validated the data provided by undertaking 104 comparisons with company accounts. Additionally, Taylor (2010) presents a study that considers 245 companies' financial accounts to provide a significant improvement over the previously undertaken studies, regarding manufacturer market valuations and capacity analysis.

Housing Forum (2004) states that suppliers consider production capacity to be one of the main limiting factors to market demand (Pan et al., 2004). Also, industry capacity was noted as a cause of higher costs of modern methods of construction (POST, 2003). Saxon (2017) states that specialist companies involved in creating preassembly components suffer from business failure, just as traditional building companies do. Thus, the inability to guarantee full utilisation of factory capacity causes the problem of the large costs of preassembly. However, overcapacity allows small private companies to grow, and margins remain low in this environment because of a good return on investment.

3.15 Summary

Chapter 3 presented the conceptual framework of this research. This conceptual framework is mainly built on the TPB. The TPB is one of many applied models and theories regarding the adoption of innovation theory. The purpose of using this theory is to predict the intention of consultants and contractors regarding using PBSC. Furthermore, a profound literature review was performed to understand the adoption of innovation theory from the organisations' viewpoints. The definition of innovation was reviewed also. The adoption of innovation theory features were reviewed, too, to understand the theory's application at the organisational level. Similarly, innovation in construction was reviewed, including the innovation of lean (optimisation), the innovation and improvements of preassembly, and the innovation of BIM in modular construction. The construction process was also reviewed regarding modularisation and standardisation. Moreover, the conflicts between building services systems in the field are considered essential to understand the nature of systems applications. Such applications allow for reviewing the traditional and preassembled construction process and construction decision-making.

Also, the benefits of using PBSC were categorised into project management, site management, and sustainability benefits. Project management benefits include product quality, schedule, and construction cost. Site management benefits include coordination among parties, simplifying tasks, and construction waste. Sustainability benefits include onsite safety performance, design efficiency, and energy efficiency. On the other hand, the challenges of using PBSC include reduction in design flexibility, change of onsite limitations, more preparation work, increase in overall project cost, transport logistics, increased risk, increased maintenance, and negative perception. Overall, PBSC has both benefits and challenges. Moreover, the stakeholders influencing decisions regarding using PBSC include clients, consultants, government regulators, suppliers, and subcontractors. Additionally, the influential context control decision regarding using PBSC includes financial support, government regulations, skilled labour, and manufacturing capacity.

Chapter 3 is the foundation of this research. The literature review covered the TPB, PBSC features and characteristics, and other relevant topics. The use of PBSC is considered a modern technical application that needs to be accepted by practitioners and users. Therefore, there is a need to review theories of technology adoption. The TPB is one of the technology adoption theories; therefore, this research addressed PBSC as new technologies, for which the level of acceptance must be predicted. Thus, the literature review in this chapter includes attitudes regarding PBSC, stakeholder influence, and external contextual control. The research philosophy and approach are presented in Chapter 4, which includes also a detailed methodology and the research methods for each phase of this research.

CHAPTER 4: RESEARCH METHODOLOGY

4.1 Introduction

This research focuses on understanding and identifying the factors that affect the use of PBSC in complex office developments in Saudi Arabia. This focus was translated into the following research question: *What are the influences of consultants and contractors on the use of preassembled building services components in complex office developments in Saudi Arabia?* Based on the theoretical and conceptual frameworks (Chapters 2 and 3), a methodology has been developed to provide an answer to the research question and assist in achieving the research objectives. This section outlines the methodological approaches used throughout this research and explains the methods used for data collection and data analysis. In addition, this chapter provides an explanation of the guidelines developed, the various procedures, and the process taken to obtain ethical approval. Mixed research methods – qualitative and quantitative – were employed for data collection and analysis to explore the intention of construction practitioners (consultants and contractors) regarding the use and adoption of PBSC in complex office developments in Saudi Arabia. This chapter justifies the choice of the research design, research methods, and the validity of the results.

4.2 Introduction to Research

The purpose of the relevant research-related methodologies needs to be clarified. 'Research' is defined as a contribution to the current body of knowledge through a purposely well-coordinated activity (Fellows and Liu, 2008), and as an 'understanding of a problem' (Saunders et al., 2009, p.96). A systematic sequence and order, which lead to the eventual results, shape the process of creating new knowledge (Collins and Hussey, 2003). Hence, research solves an existing problem by following a specific method of inquiry.

Research methodology is defined as a structure that comprises approaches, strategies, and techniques to conduct complete research (Collins and Hussey, 2003). The design of such methodology should be understood as 'the architectural blueprint of a research project, linking data collection and analysis activities to the research questions, and ensuring that the complete research agenda will be addressed' (Bickman and Rog, 2009, p.11). Research methodology is often formed based on the researcher's background and knowledge of the research topic, the research aim, and the research objectives. A framework, based on the TPB, has been designed for this research, including consideration of research designs and models, such as the nested model and the research onion.

The main frameworks for research methodology, in built-environment research, are the nested method and the research onion (Kagioglou et al., 1998; Saunders et al., 2012). Also, Kulatunga et al. (2007) used the research onion for research in construction. Although these two models share the same essential steps for effective research, the research onion comprises more steps. The nested model comprises an outer layer, the research philosophy, and an inner layer, the research approaches and research techniques (Kagioglou et al., 1998). The researcher and the research objectives determine the selection of a research methodology model (Omotayo and Kulatunga, 2015). This research adopts the research onion introduced by Saunders et al. (2012) due to the detailed structure of the research design model, which begins with research philosophy at the top and provides detailed phases of the time horizon and the techniques and procedures.

4.3 Research Philosophy

Philosophy is the first layer of the research onion. Research philosophy is the foundation of any research, as the researcher is supported in making the right decisions about the approach, strategy, and data collection techniques and procedures, which enable her/him to answer the research questions (Omotayo and Kulatunga, 2015). The researcher impacts the particular philosophical approach through her/his view of the relationship between knowledge and the process developed (Saunders et al., 2015). Figure 4-1 illustrates the research onion.

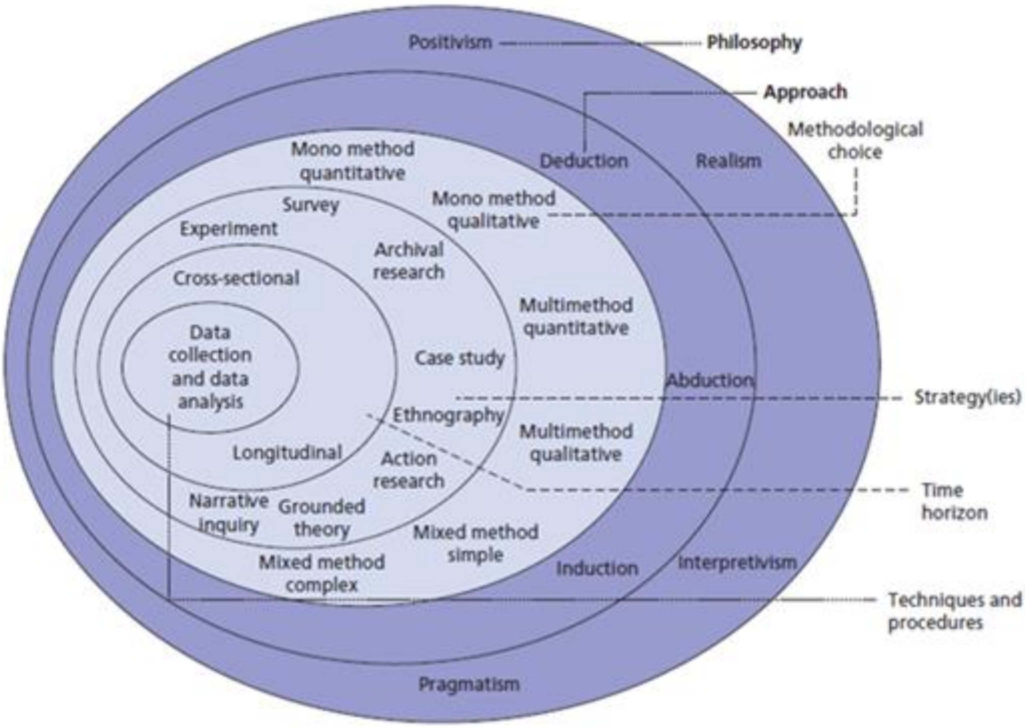


Figure 4-1 The research onion (Source: Saunders et al., 2003)

Positivism, as a philosophical perspective, is to adapt the philosophical stance of the natural scientist, in which observation of a phenomenon drives the production of reliable data. A researcher is likely to use existing theory to develop hypotheses and collect the data required and develop a research strategy. The hypotheses are then tested, confirmed or refuted, and further developed into a theoretical proposition (Saunders et al., 2015, p.113).

This research is built on philosophical values that may describe several disciplines. Philosophies are generally classified into ontology, epistemology, and axiology (William and Mays, 2002). Ontology is generally associated with establishing 'the nature of reality' and ways to understand it; whereas, epistemology is associated with establishing 'acceptable knowledge' and ways to reach it (Saunders et al., 2012). Ontology and epistemology are both themes of philosophy that attempt to clarify the being of an entity (Creswell, 1994).

4.3.1 *Epistemology and Ontology*

This section outlines the philosophical position of this research and its rationale. The term ‘epistemology’ is derived from the ancient Greek words ‘episteme’, meaning ‘account’, and ‘logos’, meaning ‘knowledge’. Epistemology is mainly associated with theories of knowledge, concerns how we obtain it, and is a sub-discipline of modern philosophy (Bickman and Rog, 2009; Trochim, 2000). Epistemology is the philosophy of knowledge (Trochim, 2000), regarding ‘how we came to know’ or ‘how we find out about the topic being investigated’ (Saunders et al., 2009). Methodology refers to the practices utilised to obtain knowledge (Krauss, 2005, p.759). Opinions on the way to conduct social research can be broadly categorised into positivism and interpretivism (or ‘social constructivism’). A research paradigm (interpretive framework) is a basic set of beliefs that guides action and contains the researcher’s epistemological, ontological, and methodological premises (Guba, 1990, p.17). The significance of understanding epistemology, in any academic research, is described and pledged that will contribute to knowledge at end of the research (Knight and Turnbull, 2008, p.65).

Ontology is socially related to the nature of entities. Bryman (2012) describes ontology as follows: ‘the central point of orientation here is the question of whether social entities can and should be considered objective entities that have a reality external to social actors, or whether they can and should be considered social constructions built up from the perceptions and actions of social actors.’ Ontology is related to the nature of reality, reports the researcher’s expectations of the route in which the world functions (Saunders et al., 2009). It is essential for this research to know the perceptions of the participants and whether a phenomenon such as PBSC is either objective or subjective. Saunders et al. (2009) state that, ‘the first aspect of ontology is objectivism. This portrays the position that social entities exist in external reality to social actors concerned with their existence. The second aspect, subjectivism, holds that social phenomena are created by the perceptions and consequent actions of the social actors.’

Positivism originated during the late 19th century with the success of science and rationalism. Positivism supports the view that observed data lead to interpretations. The approach requires systematic and transparent methods of data collection and analysis (Patton, 2002, p.93). Positivism understands the world through the existing view of the outer social world. The properties of positivism are objectively measured through scientific methods rather than subjectively inferred through reflection or intuition (Easterby-Smith et al., 2008). Positivism relies on science, supposing that science quantitatively measures independent facts about a particular reality (Healy and Perry, 2000). According to the positivist philosophical stance, the independent researcher neither influences nor is influenced by the subject of the research (Saunders et al., 2009, p.113; Easterby-Smith et al., 2008). Similarly, positivism is supposed to search for facts regarding identified correlations and associations between variables (Gephart, 1999).

Interpretivism, on the other hand, focuses on social constructions and determines reality instead of using external objective factors (Easterby-Smith et al., 2008; Gephart, 1999). A basic assumption of interpretivist research is related to meaning and attempts to understand social members' descriptions of a situation (Schwandt, 1994). Unlike positivism, interpretivists believe that the world does not contain an objective reality, but instead comprises subjective realities. Therefore, 'social constructivism' supposes that social members construct and give meaning to reality, instead of that meaning being made of objective laws or immutable facts (Easterby-Smith et al., 2008; Gephart, 1999). Ultimately, knowledge and truth are the results of perspective, according to constructivists, and, thus, all truths are related to some meaningful context of perspective (Schwandt, 1994).

Data and data analysis are value free and unchangeable because they are being observed. Positivism defines the phenomenon that we experience as a position that embraces the goal of knowledge. Generally, the target of science is to affix values to what can be observed and measured, as if science is mainly a mechanism in positivism (Healy and Perry, 2000). Deductive reasoning is applied to determine theories that can be tested. Positivists believe that the observation and measurement of ideas are at the core of scientific endeavour. Thus, a positivist stage is exploratory; it begins by identifying particular qualitative results (propositions) that require further explanation through using prior results (propositions) to direct the development of the quantitative stage.

A mixed-methods approach was utilised to analyse and integrate difficult attitudinal, stakeholder influential, and context influential phenomena into the text. This approach allows a shift from positivist to interpretive principles. Accordingly, this research begins by defining the worldwide environments that generally apply PBSC, and then discusses the particular attitudes, stakeholder influence, and contextual influence in the Saudi construction industry to analyse how construction practitioners understand activities.

Studying the above factors regarding the use of PBSC in complex office developments in the construction industry of Saudi Arabia is one of the main objectives of this research. The factors are formed based on the perception of consultants and contractors regarding the science and technical knowledge practised in the construction industry in Saudi Arabia. Generally, a positivist approach includes the formulation of hypotheses, models, or causal correlations between constructs, as well as the utilisation of quantitative methods that test theories or hypotheses, and the researcher's objectives and value-free interpretations (Chen and Hirschheim, 2004).

4.4 Research Approach

It is critical to choose the approach that best addresses the specific objectives of the research (Creswell, 2009). The key methodological approaches are either inductive (building theory) or deductive (testing theory) (Saunders et al., 2007; Yin, 2003). The deductive approach allows the researcher to develop a theory and hypotheses and design a research strategy to test the hypotheses; whereas, the inductive approach allows the researcher to collect data and develop a theory (propositions) as the result of data analysis (Saunders et al., 2009). In this research, a mixed-methods approach was used for data collection and analysis. Both inductive and deductive approaches have variances (Saunders et al., 2009) (see Table 4-1). The following subsections explain these approaches to assist and fortify this choice.

Table 4-1 Comparison of deductive and inductive approaches (Source: Saunders et al. 2007, p.120)

Deductive Approach	Inductive Approach
Scientific theories	Achieving and understanding the meaning humans attach to events
Moving from theory to data	A close understanding of the research context
Group of quantitative data	Collection of qualitative data
The application of controls to ensure validity of data	A more flexible structure to permit changes of research to emphasise as the research progress
Need to clarify causal relationship between variables	The realisation that research is part of the research process
A highly structured approach	Less concern regarding need to generalise
Researcher is independent	
The necessities of selecting a sample of sufficient size to generalise conclusions	

4.4.1 *The Deductive and Inductive Approaches*

Trochim (2006, p.1) notes two 'broad methods of reasoning as the inductive and deductive approaches'. Induction is defined as moving from the specific to the general; whereas, deduction begins with the general and ends with the specific. Therefore, arguments built on experience or observation are best expressed inductively; whereas, arguments built on laws, rules, or other broadly recognised principles are best expressed deductively (Trochim, 2006). The deductive researcher 'works from the 'top down'; from theory to hypotheses to data, in order to add to or contradict the theory' (Creswell and Plano Clark, 2007, p.23). In contrast, the inductive researcher is defined as someone who works from the 'bottom-up, using the participants' views to build broader themes and generate a theory interconnecting the themes' (Creswell and Plano Clark, 2007, p.23). Thus, the two main types of analysis in research are quantitative (deductive) and qualitative (inductive).

4.4.2 *The Employed Approach*

The qualitative and quantitative approaches can be complementary to each other; some fundamental variances exist regarding research that goes beyond the level of the data. Epistemological assumptions create variances regarding the location of knowledge, where knowledge is ‘found’, as usually expected in confirmatory research, or ‘constructed’, as usually assumed in exploratory research. Saunders et al. (2007) state that the combination of these research methods effectively assumes achieving specific research objectives. Furthermore, they argue that, depending on the nature of the research topic, it is perfectly possible to advantageously integrate both deduction and induction within the same piece of research.

Deductive research is related to the positivist paradigm, and inductive research is related to the interpretivist paradigm. Trochim (2006) states that researchers must dismiss the idea that qualitative research is always exploratory and inductive, and that quantitative research is always confirmatory (deductive). In addition, he argues that much qualitative research can be used to confirm very specific deductive hypotheses and, similarly, much quantitative research can be categorised as exploratory. Consequently, in this research, both research approaches (inductive and deductive) are integrated into a mixed research method.

Inductive reasoning (qualitative) works from the bottom-up, using the participants’ views to build broader themes and generate a theory. However, inductive reasoning examines specific information to derive a general principle. The patterns of a specific observation form the research base. The importance changes from this fact where deduction is confirmatory, but induction explores both facts and feelings. Additionally, induction is a flexible approach that inspires communication between the researcher and the interviewees. General theories or propositions are formed via an inductive approach, but both approaches are used by most social researchers. In this study, the researcher began with semi-structured interviews. The questions and contents of these interviews were derived from the literature review regarding PBSC. Then, grounded theory was used to build theories in the form of propositions, which were developed to be quantitatively examined (Robson, 2002).

Deductive reasoning (quantitative) works from general principles to reach specific conclusions. It takes a top-down approach. Quantitative research is founded on a rule, law, principle, or generalisation (Trochim, 2006). A generalisation is used to organise the research to test the rule. This approach is 'especially effective when the generalisation is widely accepted, or when there is strong evidence to support it' (Trochim, 2006, p.1). Onwuegbuzie and Leech (2005, p.269) define quantitative research as 'mathematical and statistical procedures…utilised to explore, to describe, to explain, to predict, and to control social and behavioural phenomenon'. In this study, the researcher investigates propositions based on a qualitative approach regarding PBSC, which are statistically tested.

4.5 Methodological Choices

A mixed-methods approach is a common research style to perform research that requires collecting both quantitative and qualitative data sequentially (Creswell, 2009, p.230). Quantitative theorists believe 'in a single reality that can be measured reliably and validly using scientific principles'; whereas, qualitative theorists 'believe in multiple constructed realities that generate different meanings for different individuals, and whose interpretations depend on the researcher's lens' (Onwuegbuzie and Leech, 2005, p.270). Primary data are defined as 'data originated by the researcher specifically to address the research problem' (Malhotra and Birks, 2007). Primary data are gathered by the researcher to answer specific aims and objectives. This research uses an exploratory, mixed approach for data collection and analysis. The following subsections explain these approaches to assist and fortify this choice.

4.5.1 *Qualitative Research*

Oakley (1994) describes the term 'qualitative' as research that emerges from the observations of participants. Qualitative research is 'subjective' in nature (Naoum, 1998, p.40). The collection and analysis of word data are involved in the qualitative approach (Farrell, 2011, p.6). The qualitative approach depends on text and image data, which rely on various strategies of inquiry and have unique stages during data analysis (Creswell, 2009, p.173). The qualitative approach searches for an understanding of people's perceptions, opinions, and views on a subject. This approach develops means to improve the subject being investigated by placing appropriate emphasis on the views and experiences of the participants.

Qualitative data can be detailed and rich in content and have scope for appropriate use, even if they are unstructured (Fellows and Liu, 2008, p.91). The data gathered in qualitative research are classified by Naoum (1998, p.40) into two categories: 1) exploratory research, and 2) attitudinal research. Exploratory research usually chooses the interview method for a clear and precise statement of the identified problem, and is also used when there is a limited amount of knowledge about the research topic. Attitudinal research is subjectively used to assess the opinion, view, or perception of an individual regarding a particular object (attribute, variable, or factor).

Qualitative interviews search for defined and comprehensive meanings of situations, and are a useful method for discovering the story behind a participant's experiences (Knight and Ruddock, 2008, p.112). Additionally, the interview research method is applicable for collecting qualitative data as a strategy of inquiry in which the researcher explores a process, an event, an activity, or individuals in depth. Hence, this type of research uses a diversity of data collection methods over a sustained period to collect in-depth information (Creswell, 2009, p.13).

Qualitative data are collected and analysed in three categories: language based, interpretive or descriptive, and theory-building (Tesch, 1991). Grounded theory is the best example of building a theory from the data collected during research (Knight and Ruddock, 2008, p.87). The grounded empirical approach is a methodology used to gather and analyse a fixed set of data through a systematic process to develop a theory based on that data (Hunter and Kelly, 2008, p.86). Grounded theory is used to explain phenomena, instead of solely listing a set of findings. The theory is 'grounded' in the data once the data has been analysed, without a predetermined theory or hypothesis due to originality (Allan, 2003).

Grounded theory uses three categories of data: 1) field data (notes); 2) interview data (records, notes, transcripts); and 3) existing data (literature). Furthermore, obtainable data are adequate to generate a theory when the research involves qualitative data that originated from interviews or case studies (Douglas, 2003). The number of interviews or case studies used to generate a theory is an insignificant consideration (Esteves et al., 2002). Qualitative data often build theory from interviews and other sources, such as historical books, observations, and archives (Eisenhardt and Graebner, 2007). The close link with reality is an advantage of using qualitative data in theory-building, in which the theory is likely to be testable, novel, and empirically valid (Eisenhardt, 1998). Exploratory research has raw data, which are exactly what interviewees stated or a description of what was observed (Naoum, 1998, p.40). The data gathered via a qualitative approach can later be 'quantified' by constructing a questionnaire survey, depending on the type of data required (propositions) to draw a conclusion.

4.5.2 *Quantitative Research*

The quantitative research approach is 'objective' in nature (Naoum, 1998, p.38) because it collects and analyses numerical data (Farrell, 2011, p.6) and focuses on measures such as the percentage, scale, range, and frequency of phenomena (Fellows and Liu, 2008, p.26). Furthermore, quantitative research is defined as an investigation into a social or human problem through testing a theory formed by variables, measured with numbers, and analysed using statistical procedures to determine whether the hypothesis or theory is true (Creswell, 1994, p.73). The approach is defined as a systematic process by utilising numerical data to acquire information about the subject being researched (Burns and Grove, 2009).

The quantitative approach is often used in two situations: research to locate facts, or research to collect real evidence. Research needs to locate facts about a concept, a question, or an attribute. Research needs to collect real evidence and study the relationship among these facts to test an applied theory or hypothesis against the theories and findings of previous research (literature)

(Naoum, 1998, p.40; Fellows and Liu, 2008, p.97). Moreover, quantitative research provides data through two strategies of research: 1) experimental research is used to define whether a particular treatment impacts a result through true experiments; and 2) survey research is used to deliver numeric descriptions of the trends, attitudes, or opinions of a population through structured interviews and questionnaires for data collection (Creswell, 2009, p.12).

4.5.3 *Employed Methodological Choices*

Two methods for collecting primary data were used in this research: qualitative and quantitative data collection methods. Many advantages can be obtained from adopting a multiple-methods approach. Furthermore, multiple methods are believed to comprehensively answer research questions and allow for better evaluation by the researcher to make the research findings more reliable (Tashakkori and Teddlie, 2003; Powell et al., 2008). Qualitative data collection methods are used to explore the contextual depth and find reliability and validity through selective sampling and appropriate analysis treatments (grounded theory) to develop the research aims and objectives. On the other hand, quantitative data collection methods are often used to provide research with statistical significance to achieve the research aims and objectives. Hence, quantitative data enhances interpretations by helping researchers to better generalise qualitative findings.

The multiple-methods approach supports the collection of a broader range of data, assisting the researcher's ability to answer the research questions, relay findings, and draw inferences from them (Tashakkori and Teddlie, 2003). The aim is to acquire qualitative data through interviews and to explore the context of Saudi Arabia regarding the use of PBSC in complex office developments. Quantitative data were gathered via a questionnaire to statistically define the practical factors that affect the use of PBSC in complex office developments. This approach was used to obtain greater in-depth knowledge regarding the attitudinal influence, stakeholder influence, and contextual influence factors affecting preassembly in complex office developments in Saudi Arabia.

This research synthesises both qualitative and quantitative research to employ the best of each method (see Table 4-2). The qualitative research methods are related to exploratory and confirmatory approaches (Onwueghuzie and Leech, 2005). Furthermore, qualitative research is used to explore the context of Saudi Arabia regarding the use of PBSC in complex office developments, analyse the data using grounded theory, and then confirm the findings with the literature. Also, qualitative theorists 'believe in multiple constructed realities that generate different meanings for different individuals, and whose interpretations depend on the researcher's lens' (Onwuegbuzie and Leech, 2005, p.270). Quantitative research methods are related to positivist inquiry when searching for facts. Generally, a questionnaire is a more objective research tool due to large sample sizes that produce generalisable results. Therefore, the findings can be produced again and applied to a wider population. In the final validation stage, field surveys were conducted using case studies. The data from the surveys generated the main findings, which tested the intention of practitioners regarding the use of PBSC in complex office developments.

Table 4-2 Strengths and weaknesses of quantitative and qualitative research (Source: Easterby-Smith et al., 2002)

	Quantitative Paradigm	Qualitative Paradigm
Strengths	• Provides wide coverage for a range of situations. • Quick and economical. • Considerable relevance to policy decisions from which statistics are aggregated from large samples.	• Data gathering methods are considered natural rather than artificial. • Ability to look at the change process over time. • Ability to understand people's meaning. • Ability to adjust to new issues and ideas as they emerge. • Contributes to theory generation.
Weaknesses	• The methods used tend to be rather inflexible and artificial. • They are not very effective in understanding processes or the significance that people attach to actions. • They are not very helpful in generating theories.	• Data collection can be tedious and require more resources. • Analysis and interpretation of the data may be more difficult. • Harder to control the pace, progress, and end-points of the research process. • Policy-makers may give low credibility to results obtained using the qualitative approach.

4.6 Research Strategy

Construction research contains a number of strategies for data gathering, which are generally categorised into quantitative, qualitative, and mixed-methods approaches. Research strategy, significantly, should be able to answer the research questions and objectives (Saunders et al., 2007), and be selected as a function of the research situation (Yin, 2003). Commonly, qualitative approaches are used to capture meaning (in the form of individuals' thoughts, feelings, behaviour, etc.) instead of numbers, and to describe processes instead of outcomes (Mayan, 2001). Quantitative research numerically measures an identified problem to statistically test and analyse a theory or hypothesis. Quantitative methods aim to define whether the predictive generalisations of a theory embrace a truth (Creswell, 2009). Several strategies can be used for primary data research, such as experiment, survey, case study, grounded theory, ethnography, narrative inquiry, and action research (Easterby-Smith et al., 2002; Yin, 2003; Saunders et al., 2007). These strategies are based in the qualitative or the quantitative research paradigm. This research employs a mixed-methods research strategy that employs interviews (qualitative) and questionnaires (quantitative).

4.6.1 *Mixed-Methods Approach*

Mixed-methods research is a synthesis approach that employs both quantitative and qualitative methods (Creswell, 2009, p.4). Both the nature and objectives of research work in tandem with the nature of the data collection and analytical techniques. Qualitative methods are associated with the perceptions of people regarding behaviour or beliefs; whereas, quantitative methods use statistics and numbers to find patterns regarding certain phenomena (Fellows and Liu, 2008, p.150). Often, the mixed-methods approach is a research style that collectively requires both quantitative and qualitative data sequentially (Creswell, 2009, p.230).

The planning and design of procedures for a mixed-methods approach are influenced by four important features: timing, weighting, mixing, and theorising (Creswell, 2009, p.206) (see Table 4-3).

Table 4-3 Features of mixed-methods approach (Source: Creswell, 2009, p.206)

Features	Definition
Timing	Collecting data needs to be timely reviewed either in stages (sequentially) or concomitantly collected (concurrently).
Weighting	Qualitative and quantitative approaches have weight in a certain study. Some studies may be equally weighted, but other studies may emphasise one or the other. A priority of one approach over another may be influenced by the interest of the research and what the investigator seeks to emphasise in the study.
Mixing	Mixing the data (such as the research questions, philosophy, and interpretation) is challenging, especially when considering that qualitative data consist of text and images, and quantitative data comprise numbers. Mixing happens at several phases, such as data collection, data analysis, and interpretation. Mixing means that data are either merged or separated at both continuity-ends, and the combination in some way between these two extremes.
Theory	All inquiries have theories chosen by researchers. These theories may be either made explicit in mixed-methods research or be implicit.

Quantitative and qualitative researches have different interfaces when each approach might be somehow quantifiable (Naoum, 1998, p.43). A summary of some comparisons between quantitative and qualitative research is displayed in Table 4-4. The qualitative data involve participant's views and opinions regarding the performance criteria of time, cost, and quality. However, quantitative data include time and cost performance obtained from case study project records, while quality might be considered from updated records, due to defects recorded later, measured by numbers and values (Fellows and Liu 2008, p.26). Considering the full domain of possibilities, it is beneficial for data collection approaches to be quantitative, qualitative, and mixed (Creswell, 2009, p.15).

Table 4-4 Differences between quantitative and qualitative research (Source: Naoum, 1998, p.43)

Contrast	Qualitative research	Quantitative research
Role	Attitude measurements based on opinions, views, and perceptions measurements	Fact-finding based on evidences or records
Relationship between researcher and subject	Close	Distant
Scope of findings	Idiographic	Nomothetic
Relationship between theory and research	Emergent/development	Testing/confirmation
Nature of data	Rich and deep	Hard and reliable

It is more important in the data collection stage to differentiate research methods that are either structured or unstructured data, rather than methods that are quantitative or qualitative (De Vaus, 2002, p.5). The relationships between the three approaches for data collection strategies are listed in Table 4-5. Data collecting methods influence the analyses, the results, and reliability of the research. Consequently, the validity and applicability of results are important for conclusions to be appreciated and understood (Elnaas, 2014).

Table 4-5 Quantitative, mixed, and qualitative methods (Source: Creswell, 2009, p.15)

Quantitative Methods	Mixed Methods	Qualitative Methods
Predetermined	Both predetermined and emerging methods	Emerging methods
Instrument-based questions	Both open-ended and closed questions	Open-ended questions
Performance data, attitude data, observational data, and census data	Multiple forms of data drawing on all possibilities	Interview data, observation data, document data, and audio-visual data
Statistical analysis	Statistical and text analysis	Text and image analysis
Statistical interpretation	Across databases interpretation	Themes. Pattern interpretation

The features of each distinct approach are built upon data collection, nature of research, and the type of essential data. Using a mixed-methods approach for data collection has a number of strengths and weaknesses (Burke-Johnson and Onwuegbuzie, 2004). The main strengths and weaknesses are summarised in Table 4-6. The best studies include an analysis of both quantitative and qualitative data (Follows and Lui, 2008, p.28). Moreover, using mixed approaches has recently gained popularity among researchers, mainly because they combine the strengths of both quantitative and qualitative research (Creswell, 2009, p203).

Table 4-6 Strengths and weaknesses of mixed-methods research (Source: Burke-Johnson and Onwuegbuzie, 2004, p.21)

Strengths	Weaknesses
• Words, pictures, and narrative can be used to add meaning to numbers • Numbers can be used to add precision to words, pictures and narrative • Can answer a broader and more complete range of research questions because the researcher is not confined to a single method or approach • A researcher can use the strengths of an additional method to overcome the weaknesses in another method by using both in a research study • Can provide stronger evidence for a conclusion through convergence and corroboration of findings • Can add insights and understanding that might be missed when only a single method is used • Qualitative and quantitative research used together produce more complete knowledge necessary to inform theory and practice	• Can be difficult for a single researcher to carry out both qualitative and quantitative research, especially if two or more approaches are expected to be used concurrently; it may require a research team • Researcher has to learn about multiple methods and approaches and understand how to mix them appropriately • Methodological purists contend that one should always work within either a qualitative or quantitative paradigm • Some of the details of mixed research remain to be worked out fully by a research methodologist (e.g. problems of paradigm mixing, how to qualitatively analyse quantitative data, how to interpret conflicting results) • More expensive • More time-consuming

4.6.2 *The Employed Research Strategy*

This research first relies on 15 semi-structured interviews with high-profile, professional consulting and constructing practitioners, and, second, on 258 questionnaires sent to consultant firms and contractor companies, utilising the strengths of both qualitative and quantitative research. For the first stage, the researcher used semi-structured interviews to identify the attitude, stakeholders' influence, and contextual influence towards using PBSC in complex office developments in Saudi Arabia. This evidence was used to explore the context, to develop propositions using grounded theory to be tested later, and to confirm these propositions with the literature. Subsequently, a questionnaire was constructed based on propositions derived from the interview stage to test certain behaviours and seek a numerical understanding to confirm or refute the propositions incorporated into the questionnaire. Finally, in the validation phase, surveys were conducted using the case studies for the test/methodology. The data from the surveys generate the main findings and develop and test the intentions of using PBSC in complex office developments in Saudi Arabia.

4.7 Research Design

A research design is defined as ‘a plan that describes how, when and where data are to be collected and analysed’ (Parahoo, 1997, p.142). The nature of research, development, and the terminology of its operation should be understood. The principles and procedures of rational thought processes (applied to a research investigation) create a research methodology (Follows and Liu, 2008). Similarly, a research design delivers a scheme for research regarding questions to study, relevant data, what data to collect, and how to analyse the results. A concrete research design is a study that has a good conceptual structure (Yin, 2003).

Research methodology is affected by two aspects: 1) the aim of the research, and 2) the necessary data to answer the research questions. This research adopts mixed methods (qualitative and quantitative approaches), both for the primary data collection and the analysis. Significantly, the qualitative methodology focuses on the exploratory approach to provide a rich understanding to answer the research questions. Quantitative methodology is associated with statistics to examine research propositions. The following sections outline the rationale and fortification for this approach.

4.7.1 *Rationale for Using Mixed-Methods Approach*

Generally, mixing different methods is used for multiple approaches to primary data collection; for instance, interviews (qualitative data) combined with surveys (quantitative data) (Creswell, 2009, p.14). Using mixed methods consolidates findings from a range of data sources through the emphasis of using more knowledge from one to another. Hence, considering the necessary data and other sources for data collection during the design and planning stage is significant (Fellows and Liu, 2008, p.147).

Using a mixed-methods approach has a number of benefits regarding data collection. Participants are selected for a study based on the results obtained from one method, and then investigated via another method, (Creswell, 2009, p.14). A specific approach delivers results that can develop the other approach (Greene et al., 1989). Consequently, applying a mixed-methods approach in the research helped acquire the best of both qualitative and quantitative approaches to data collection. Furthermore, mixed approaches have different procedures for collecting data, such as sequential, concurrent, or transformative manners (Creswell, 2009, p.203). Accordingly, the adoption of a mixed-methods approach in this research is essential, as its nature requires a number of different data and phases for collection. This research is interested in the perceptions of both consultants and contractors to investigate the use of PBSC in complex office developments, and to examine the exploratory results from the first stage. The outcomes are then validated at a later stage of the research process.

Construction industry research involves many published studies that used mixed methods (Naoum, 1998). Evidently, the area of offsite preassembled technologies in the construction industry has applied mixed approaches for data collection. For instance, Gibb et al. (2001) performed a pilot study to measure the benefits of preassembly and standardisation for construction projects. Danby and Painting (2006) applied a mixed approach in their study, which investigated interface problems with volumetric prefabrication systems in construction projects. A mixed-methods approach was adopted by Pan et al. (2007) to address the perspectives of UK house-builders on the use of modern methods of construction. Pan et al. (2008b) used the same approach to develop a decision matrix for building system selection in housing construction. Elnaas (2014) applied a mixed approach to investigate decision-making in the house-building industry in the UK. Consequently, the benefits and reasons considered for using mixed approaches, and the experiences of previous researchers, have inspired this research to adopt the same approach. For this study, an exploratory sequential mixed-methods research (MMR) design was selected to broadly explore and understand the context of Saudi Arabia regarding the application of PBSC in complex office developments.

4.7.2 *Research Methods for Data Generation (Primary and Secondary)*

The research methodology is introduced in this section, together with the process of data collection. The nature of the investigation and the type of necessary data form the adopted approach for collecting data (Noaum, 1998, p.53). Data collection involves two general approaches, namely desk study (secondary data gathering) and fieldwork study (primary data gathering). Malhotra and Birks (2007) define secondary data as 'data already collected for purposes other than the problem at hand'. The secondary data collection approach and its results have been previously covered in this thesis (in Chapters 1, 2, and 3), which revealed the knowledge gap and led to the research questions. Malhotra and Birks (2007) define primary data as 'data originated by the researcher specifically to address the research problem'. The process design of collecting primary data is provided in this section through the use of the qualitative and quantitative approaches for the research inquiry.

Data collection for research is performed using various techniques and, appropriately, in many studies, using a range of research methods, such as questionnaires and interviews (De Vaus, 2002). Personal interview surveys are performed face to face, which is appropriate for case study research and studies that require the respondent's reliable characteristics. Postal questionnaires are an impersonal approach appropriate for a descriptive or analytical survey (Noaum, 1998, p.53). The characteristics of these methods are illustrated in Table 4-7, which provides an explanatory comparison between the strengths and weaknesses of interviews and questionnaires.

Each research method has its own characteristics and certain necessary data for the research problem. Importantly, the relevant data-gathering relies on choosing the appropriate research methods. Therefore, the adoption of research methods for a given research project may not necessarily be appropriate for another research project.

Table 4-7 Comparison between interviews, questionnaires and case-based precedence project review techniques (Source: Naoum, 1998, p.63)

Traits	Interviews	Questionnaires
Identify respondents	Known	Unknown
Interaction between interviewer and respondent	Close	Distant
Time involving the researcher	Long time needed to conduct interview	Short time
Cost	High	Significantly lower than the interviews
Sample	Small	Large
Quality of information	Deep and detailed	Rich
Skill and experience	The interviewer needs to have the skill to ask questions	No skill required
Control of the process	High	Low
Flexibility	Allows great flexibility to reword questions and clarify terms that are unclear	Low, rigid. The answers are accepted as questions are worded
Analysis of the results	Difficult and becomes complicated in unstructured interviews	Easy to analyse
Interviewer bias	The flexibility of interviews allows for bias	If sample is selected appropriately, there should be no bias

Two or more research techniques can be applied in the mixed-methods approach to data collection (Creswell, 2009, p.206). This research uses mixed research methods for primary data collection through interviews and a questionnaire.

4.8 Data Types

This research encompasses two types of data – primary and secondary – as both forms were required for this study. Secondary data were gathered from the literature review and helped the researcher to identify the attitudes, stakeholder influence, and contextual influence towards using PBSC in complex office developments. The primary data in this research were gathered via both quantitative and qualitative data collection methods to answer the research questions.

The mixed approach (qualitative and quantitative) of research methods was used to obtain the most appropriate data to meet the aim of this research. The nature of this research required the use of both methods, which allowed the researcher to decrease or eliminate the difficulties of each approach, and, consequently, to maximise the benefits of both (Fellows and Liu, 2007). The qualitative data helped to explore the context of in-depth knowledge regarding the attitudes, stakeholder influence, and contextual influence related to PBSC in complex office developments in Saudi Arabia. The quantitative data (questionnaire survey) helped to confirm those attitudes, stakeholder influence, and contextual influence. Moreover, selecting both approaches for this study supported the research strategy.

This research utilises both primary and secondary data to investigate the intentions of consultants and contractors towards using PBSC in complex office developments in Saudi Arabia. The secondary data defined the factors associated with PBSC by reviewing the drivers, barriers, and challenges regarding this phenomenon. The primary data were derived from interviewing 15 acknowledged professionals of the Saudi construction industry and from 258 questionnaire survey distributed among consultant and contractor companies in Saudi Arabia. To assist and fortify the mixed approach adopted for this research, the following sections explain the two methods for data collection.

4.8.1 *Primary and Secondary Data*

The **primary data** are defined as 'data originated by the researcher specifically to address the research problem' (Malhotra and Birks, 2007). Therefore, the researcher collects primary data to help achieve the aims and objectives of the research. The primary data play an important role in accurately delivering more and specific information for the study once the required information from the research's secondary data are obtained.

Malhotra and Birks (2007) define secondary data as ‘data already collected for purposes other than the problem at hand’. These data were collected by others (e.g. books, journals, and company websites) and can be used by a research project in numerous means. Secondary data are means of illuminating the problem from different perspectives to improve the researcher’s knowledge and assumptions.

The **secondary data** collection was addressed in previous chapters (1, 2 and 3). The exploratory research was designed to deliver documented evidence of the research topic and a broader knowledge of the key issues. This stage contained a literature search and review across many disciplines for secondary data related to the use and characteristics of PBSC in construction and production regarding its application in complex office developments. The existing problems, as noted by the construction practitioners of PBSC, were addressed in the literature review stage. Chapter 1 identified the gap of knowledge and presented the research question. The emergent research aim and objectives were based on the findings of the literature review. The secondary data collection stage is covered in detail in Chapters 2 and 3.

4.9 Data Collection Methods

This section presents the methods employed in this research. This research used interviews, a questionnaire, and case study methods for data collection. The interviews (Phase I: Qualitative) were conducted to explore the context of Saudi Arabia in the form of propositions. The questionnaire survey (Phase II: Quantitative) was used to generalise the propositions explored to measure them. Subsequently, the results of the questionnaire are validated using three case studies. More details are discussed in the following sections.

4.9.1 *Interview Method*

The interview was designed to explore the context of Saudi Arabia regarding using PBSC in complex office developments. The TPB was used to design and frame the interview questions in three elements (attitudes, stakeholder influence, and contextual influence) related to PBSC in complex office developments in Saudi Arabia. The information and issues collected from the in-depth literature review were used to form the semi-structured interview, which provides the necessary primary data from consultant and contractor companies. The interviews are utilised to assess the extent of construction practitioners' perceptions regarding the current use of PBSC.

Generally, interviews are classified into three main types: structured, semi-structured, and unstructured. There are strengths, weaknesses, and preferences in each category (Creswell, 2009, p.222). A semi-structured interview was used in this research for data collection. The interviews were conducted with a sample of construction practitioners face-to-face onsite, at the office, or on the phone. The questions were sent in advance to the interviewees as preparation. The interview questions were flexible, open-ended questions framed by the TPB to explore and examine issues as they emerged. The main reasons for utilising the interview approach for data collection are as follows: 1) interviews help identify the in-depth factors stated in the existing literature by construction practitioners regarding the use of PBSC in complex office developments in Saudi Arabia; 2) interviews are an appropriate approach for collecting the necessary qualitative data regarding construction practitioners' perceptions related to the use of PBSC in complex office developments; and 3) interviews allow the collection of deeper knowledge and have the suppleness to spread the research further.

4.9.2 *Aim of the Interviews*

The interviews were conducted to explore and establish the existing perceptions of construction practitioners towards the attitudes, stakeholder influence, and contextual influence of using PBSC in complex office developments in Saudi Arabia. The TPB was used to frame these factors. The interviews were conducted with consultant and contractor companies, either face-to-face onsite, at the office, or over the phone, using a semi-structured interview.

The content of the semi-structured interviews includes three questions designed based on the concept of the TPB. Question 1: *What are the attitudes* *of consultants and/or contractors towards PBSC adoption?* This question was designed to address the benefits and challenges towards using PBSC in complex office developments. Question 2: *What types of stakeholder do consultants and/or contractors believe influence PBSC adoption decisions?* This question addresses the SN of using PBSC. Question 3: *What types of contextual influence do consultants and/or contractors believe impact PBSC adoption decisions?* This question addresses the PBC of using PBSC. Consequently, the answers to these questions were used to form propositions. The interview questions are included in Appendix B.

4.9.3 *Selection Criteria of Interviewees*

The sampling and selection of research participants are defined as principles and procedures used for recognising, selecting, and obtaining relevant data sources for a research project (Mason, 2006). This research aims to explore the influences of consultants and contractors by examining their perceptions regarding the use of PBSC in complex office developments in Saudi Arabia. Technically, project delivery is all related to stakeholders, such as consultants and contractors. However, this research focuses on the perception of consultants and general contractors regarding the use of PBSC in complex offices developments in the context of Saudi Arabia. The participants' responses may be 'fact' or 'opinion', depending on whether the designated interviewee is a professional in a specific topic or has certain special skills or experience (Knight and Ruddock, 2008, p.113).

The interviews were conducted using a semi-structured form with primary PBSC practitioners. The participants were 15 key players in PBSC in the construction industry and members of the Saudi Council of Engineers (SCE) 2017, the Saudi Contractors' Authority (SCA) 2017, and the Ministry of Municipal and Rural Affairs (MOMRA), which are all responsible for the construction industry strategy and developments. They collectively work to attain dynamic change in the adoption of building technologies as construction solutions in the Saudi Arabia construction industry.

The 15 participants interviewed in the study included eight consultants and seven contractors (general contractors and specialised contractors from Riyadh, Jeddah, and Eastern region of Saudi Arabia, as these regions have large sectors that drive the majority of preassembly activity in Saudi Arabia). The interview details are provided in Table 4-8. All the interviewees were senior management associates, such as directors and senior managers, with obligations related to construction strategy, including clients, contractors, project managers, design managers, and construction managers. The selection criteria for each participant include, 1) more than 20 years of work experience in the industry; 2) experience in using PBSC in complex office developments; and 3) senior management associates with a role in decision-making.

Table 4-8 Interview descriptions (N: 15) (Source: Author)

Interviewee Identifier			Type	Interviewee Title	Location	Interview Type	Duration
Consultants		**EA**	Architect	Director	Jeddah, KSA	Phone	00:39:26
		MA	EE	Director	Riyadh, KSA	Office	00:34:35
		OM	ME	Senior Manager	Riyadh, KSA	Office	00:47:26
		AC	Accountant	Company Accountant	Riyadh, KSA	Office	00:33:48
		AR	Architect	Chief Executive Officer	Riyadh, KSA	Office	00:40:19
		AM	QCE	Manager	Dammam, KSA	Phone	00:49:56
		SK	Architect	Chief Operating Officer	Riyadh, KSA	Office	00:41:04
		AS	ME	Manager	Riyadh, KSA	On site	01:57:33
Contractors	General Contractors	**BS**	ME	Manager	Jeddah, KSA	On Site	01:55:44
		MN	EE	Director	Dammam, KSA	Phone	00:41:59
		WS	ME	Director	Riyadh, KSA	Phone	00:36:37
		KS	EE	Chief Operating Officer	Riyadh, KSA	Phone	00:50:11
		AA	ME	Director	Riyadh, KSA	Phone	00:39:38
	Specialised subs.	**MS**	ME	Senior Manager	Riyadh, KSA	Phone	00:47:43
		SS	EE	Chief Operating Officer	Jeddah, KSA	Phone	00:37:19

The majority of the interviewees were located in the Riyadh region due to time limitations and cost consideration. Two interviewees were from Makkah, and two from Eastern province. The qualification of the interviewees having more than 20 years' experience in the construction industry was to ensure contribution to the research. The participants were familiar with both traditional methods and preassembly regarding building services. For the purpose of confidentiality, assurances were given regarding not publishing the names of the participants or their companies.

The interview was designed based on the TPB. The TPB (Ajzen, 1991) theorises that planned behaviours are an outcome of figuration of intention to oblige that behaviour. Thus, intentions are prophesied through beliefs, which include attitudes, SN, and PBC. The interview questions are three organised questions based on the TPB of the research inquiry.

The interview structure is based on finding data regarding the attitudes, SN, and PBC of the industry practitioners on the use of PBSC in complex office developments. The questions were sent prior to the meetings by email to the participants to acquire more solid answers and save time. The interviews were conducted in Arabic, and all the interviews were recorded using notes and audio-recording and then transcribed accurately for analysis. The transcriptions were then translated into English to begin coding and analysing. Grounded theory was employed to analyse the transcriptions.

4.9.4 *Grounded Theory*

In this research, grounded theory was employed to examine the application of PBSC in complex office developments in Saudi Arabia, avoiding earlier theoretical frameworks that adjust or steer data. Grounded theory focuses on the conceptual scheme in a contextual way to avoid any predetermined theory (Cassell and Symons, 2004). Consequently, grounded theory allows for the generating of propositions once the data have been analysed. The propositions were initially considered undeveloped, as the context had not yet been researched. Research bias is limited through the employment of grounded theory. Consequently, the conceptual theories (propositions) are founded through a series of discussions (interviews) with industry experts.

4.9.5 *Questionnaire Method*

The questionnaires were also designed based on the TPB. Factors and information acquired from the interviews were used to construct the questionnaire based on the findings for further investigation regarding the use of PBSC in complex office developments in Saudi Arabia. De Vaus (2002, p.95) notes that a questionnaire, as a research tool, is intended to measure something within a known population, which may include behaviour, beliefs, knowledge, attitudes, and attributes of participants.

According to Ajzen (2006), when using the TPB, the action comprising the behaviour must be defined at an appropriate level of specificity to allow for useful generalisation. Francis (2004) constructed a questionnaire using TPB for health services researchers. The questionnaire used in this present study was constructed according to Ajzen (2006) and Francis (2004). Labelling direct and indirect measurement scales for the three TPB predictor variables was adopted from the discussion of Francis (2004) (Appendices A and C). The main reasons for utilising the questionnaire approach for data collection are as follows: 1) simple to manage, cost-effective and saves respondent’s time; 2) allows data collection from different practitioners all over Saudi Arabia within the time limitations; and 3) presents quantified data, frequencies, etc. and comparison with data of PBSC.

The questionnaire was distributed using stratheng.eu.qualtrics.com database online. However, some of the questionnaires were manually distributed. The population of consultants and contractors was identified through registration at the SCE and the SCA; thus, invitation emails were sent for participation via those institutions. The questionnaires were designed to last for almost 10 minutes, as completion time is critical to maximise the number of responses. Five-point scales were employed for all rating and likelihood issues; however, no variance beyond a simple linear scaling was used when comparing five-and seven-item scales. Colman et al. (1997) and the TPB model's authors Ajzen et al. (2011) both used five-point scales.

4.9.6 *Aim of the Questionnaire*

This section presents the descriptive statistics and the reliability of the questionnaire. The questionnaire is divided into three parts: 1) descriptive information regarding firms; 2) opinions on use of PBSC (practitioners); and, 3) reasons for not using PBSC (non-practitioners). The opinions part was designed according to the TPB; thus, it involves both direct and indirect questions. Consequently, the procedure in the manual for constructing a questionnaire based on the TPB by Francis et al. (2004) was applied to analyse this part. For non-practitioners of PBSC, the independent t-Test analysis was applied. Employing a series of t-Tests or discriminant analyses is recommended to identify the beliefs that discriminate between the two groups (Francis et al., 2004). Therefore, this research applied the independent t-Test to compare means between two groups (consultants and contractors). In addition, a multiple regression procedure was used to predict the influence of attitudes, SN, and PBC on the intention (Francis et al., 2004). Thus, direct attitude scores were entered as the dependent variable, and the sum of the weighted behavioural beliefs as the predictor variables. The same approach was used to predict directly measured SN and PBC. Bagozzi (1984) and Schmidt (1973) argue that, 'using multiplicative composites is unsatisfactory from a statistical point of view because it involves multiplying entities by zero, when zero is part of an arbitrary scale rather than a 'true score'. According to the supplement in the manual by Francis et al. (2004) that enhances both unipolar (1 to 7) and bipolar (-3 to +3). Thus, this research applied a scoring system that only uses unipolar (1 to 5) for both unidirectional (e.g. probability) and bidirectional (e.g. evaluation).

The questionnaire was designed to include closed questions. The questionnaire targeted consultants and contractors with an aim to generalise the findings to identify the frequency and significance of the identified factors regarding the intention to use PBSC in complex office developments. What drives consultants and contractors to use PBSC in complex office developments? Ajzen’s (1985) TPB provides one of many approaches to this question. The TPB is a social-cognitive model that can be used to explain a wide variety of human behaviours.

In Section B, the theory posits that volitional behaviour is predicated on the intention to engage in that behaviour. Behaviour intention, in return, is influenced by three main factors (direct determinants): attitude towards the behaviour (AB), SN, and PBC: that is, the extent to which individuals regard a particular behaviour positively (AB), the thought that significant others want them to engage in the behaviour (SN), and the belief that they are able to perform the behaviour (PBC). These three factors serve as direct measures of the strength of intention to carry out the behaviour. Finally, these three direct determinants of behavioural intention are influenced by the following indirect determinants: behavioural beliefs (ABI), normative beliefs (SNI), and control beliefs (PBCI).

The questionnaire was piloted on five participants in the construction industry to ensure that the questions were clear and concise prior to distribution. The field survey began in September 2017 and continued until December 2017. The questionnaire is included in Appendix C.

4.9.7 *Selection Criteria of Participants*

The researcher needs to organise a sampling frame to select a sample population for the research survey (Hoxley, 2008). The questionnaire was distributed to 661 practitioner members of the SCE 2017, the SCA 2017, and the MOMRA. A total of 661 companies practised PBSC in complex office developments, including 338 consultant members of the SEC and 323 contractor members of the SCA and the MOMRA. None of these participants were interviewed. More details are provided in the population and sample frame sections (4.13 and 4.14).

The participants were stakeholders and key players in the Saudi building technology industry. Lists of the main Saudi construction parties and stakeholders were developed, including consultants, contractors, and subcontractors. Consequently, the researcher selected participants from those members and stakeholders involved in complex office developments to conduct the survey. The selection considered both the Engineering Consulting Office and the Professional Engineering Saudi Company from the SEC membership list 2017. Also, the selection considered both the general contractors and subcontractors from the SCA and the MOMRA membership list 2017 as the first and second degree of government classification.

The sampling frame includes 661 consultant and contractor companies of Saudi construction practitioners to represent the population. All the participants were senior management associates with more than 10 years' work experience, such as architects, project managers, mechanical engineers, electrical engineers, civil engineers, cost engineers, and others with obligations related to construction strategy. The selection criteria of the research design for each participant included, 1) more than 10 years' work experience in the industry; 2) experience in using PBSC in complex office developments; and 3) senior management associates with a role in decision-making.

The questionnaires were distributed in Riyadh, Makkah, and the Eastern region of Saudi Arabia. This research aimed to receive more than a 30% questionnaire response rate. Regarding confidentiality, assurances were given to not publish the names of any participants or their companies.

4.9.8 *Case Study Method*

Bryman (1989) claims that case studies can be used to confirm the findings from other studies, to explore insights into previously less-investigated areas, and to test and to generate theories (Pan, 2006, p.102). Accordingly, three case studies were selected. Each case study represents one category of respondents in this study: consultants, main contractors, or subcontractors. Each case study includes lists of benefits, challenges, stakeholder influence, and PBC. The respondents to these lists are classified as architect, project manager, cost engineer, mechanical engineer, electrical engineer, or civil engineer. Each list is presented as a matrix. The purpose of the matrix approach is to be analysed in the form of occurrence and frequency indices to obtain ranked results. Matrices and the priorities evaluation are contained in Chapter 5.

The **occurrence indices** (Oi) are repeatedly generated by the following function:

$$Oi = \sum(a * f) \quad \text{E.Q. 4.1}$$

Where:

a = weighting = 1 (since each factor is currently supposed to be equally weighted)

f = number of times the factor is considered superior

The **frequency indices** (Fi) resultant repeatedly by the equation as follows:

$$Fi = 100 * \sum(Oi/F) \quad \text{E.Q. 4.2}$$

Where:

Oi = Occurrence index of each factor

F = total number of possible factors

Moreover, the original documents at the pre-design (briefing) stage were checked in terms of matching the study indicators. The respondent was asked to pairwise-compare every two indicators (for every two variables) to build the matrix based on the actual performance of the case study (the construction project). The respondent was to answer, in the specified project, which is more significant (pairwise-comparing two variables) to meet the client’s requirement to enhance the project outcomes. Therefore, the participant selected the indicator that adds greater value to the project, depending on its set of priorities. This means that each single indicator was evaluated against the other indicators in the matrix of indicator selection.

The case study method was employed to validate the results in the final model. The evaluation procedure was intended to practically validate the proposed model to enhance the delivery for a construction project during the early stage.

The evaluation procedure was conceptually derived from the TPB model. The procedure aims to provide a structured and clear approach of validity for consultants and contractors, in the decision-making process, to support them in enhancing project delivery. This process is based on evaluating the attitudes, stakeholder influence, and PBC regarding project features and particular requirements. The TPB model is proposed to be applied at an early stage by consultants and contractors within their organisational level regarding using PBSC in complex office developments within the Saudi context.

The evaluation procedure (Oi-Fi-Ri) was adopted and viewed from a project-wide perspective and with particular requirements to confirm and validate the results of this study in the context of Saudi Arabia. Moreover, a developed process was proposed for validity, since the concept of evaluation procedure was modified to include two main phases: a matrix of selection indicators and a matrix of priorities evaluation.

The two earlier phases (qualitative and quantitative) promote the internal validity process for identifying ideal indicators that enhance project delivery. The process cautiously selects, evaluates, and measures the attitudes, stakeholder influence, and PBC regarding the decision to use PBSC in complex office developments. For practicality, the evaluation procedure uses Microsoft Excel, pairwise-comparison, occurrence indices, and frequency indices.

4.9.9 *Aim of Case Study*

The aim of conducting the case studies was to validate the findings and identify the frequency with which the previously identified robust dataset of factors occurred in real life or in recently completed complex office developments. This process was to define the criteria employed and determine the influence of each factor in each complex office development. Also, the use of a case study method for validity assists in obtaining data from different sources for each complex office development case, including documents and interviews with participants. The case study evaluation and assessment tool are included in Appendix D.

4.9.10 *Selection Criteria for Case Studies*

Proverbs and Gameson (2008, p.27) state that, 'with multiple case studies, the results will always be more compelling/strong, assuming that they are in support of each other and therefore easier to defend.' Consequently, this research employed three complex office developments case studies to confirm and validate the findings. Also, these complex office developments were on-going projects at the time of undertaking the investigation. The following selection criteria were employed to frame the case studies: 1) complex office development (e.g. several sophisticated building services systems); 2) based in Riyadh, Makkah, and Eastern province; 3) under-construction projects; 4) key decision-maker participants with more than 10 years' experience.

4.10 Data Analysis

The analysis of the data is an essential element that aims to convey findings (propositions) of the data collected from the interviews (Phase I: Qualitative) to construct the questionnaire survey (Phase II: Quantitative) for useful and reliable information. The data analysis of the questionnaire survey is critical to achieve the research objectives and answer the research questions (propositions). Consequently, the final model was validated via the case studies (Phase III: Qualitative), in which the data are collected and analysed.

This research employs a mixed-methods approach for data collection, and case studies for the validity of the final model. Accordingly, several tools and techniques are used for the data analysis. Hair et al. (2007) state that qualitative data are based on meanings expressed by words, which result in non-standardised data that require classification into categories, and analysis organised by the use of conceptualisation. On the other hand, quantitative data are based on meaning derived from members, results in numerical (standardised data), and analysis organised by the use of diagrams and statistics.

Preparation was essential for data-checking and data-entry into the computer. Initially, for Phase I, recorded data were transcribed and then translated from

Arabic to English. Then, transcriptions were entered into Nvivo for coding using grounded theory. Consequently, the findings of the interviews (Phase I: Qualitative) were in the form of propositions that were seminal for constructing the questionnaire survey (Phase II: Quantitative). Furthermore, the preparation of quantitative data was completed in this research by entering the data collected from the questionnaire using the Statistical Package for the Social Sciences (SPSS). The data were coded in SPSS using a Likert scale, multiple-response method, and percentages (frequency of the answers). Moreover, the ordinal regression model was used, as well as the independent t-Test. Consequently, in the case studies (Phase III: Qualitative), preparation was critical for data-checking and data-entry into the computer. Thus, for Phase III, the case studies' data were entered into Excel for coding using the occurrence (Oi) indices and frequency indices (Fi) to evaluate the ranking (Ri) of factors. More detailed information about the analysis is available in the analysis chapter (Chapter 5).

4.11 Ethical Considerations

The ethical considerations of the research are discussed in this section. Ethical issues need to be considered in any research work; they are one of the important concerns in research. Indeed, ethical issues will appear among the researcher and research participants more broadly in the research. There are ethical considerations relating to everything people do and consider doing (Fellows and Liu, 2008, p.246). Attention to ethics is assumed in this research regarding integrity when collecting data from practitioners in the construction industry and the storage, use, and disposal of those data. Furthermore, other aspects of moral and ethical concerns for research are significant, including the use of other people's work, confidentiality, analysing data, and disseminating results and findings. Confidentiality is a similar ethical issue to anonymity: anonymity concerns persons and organisations, but confidentiality relates to the data (Fellows and Liu, 2008, p.256). Confidentiality anxieties concern neither exposing data to anybody nor using the data for purposes other than this research, for which the respondents have given permission.

Therefore, the moral foundations are based on the express, informed consent of the respondents, which was obtained for both the confidentiality and anonymity components of research ethics.

The procedures and risks associated with the research were outlined to the participants prior to participating via an introduction to the research topic, procedures, and the purpose of the interviews and questionnaire, merely after which their involvement in research was encouraged. Participant confidentiality is extremely important for individuals and organisations. Also, the interviews and the questionnaires were limited to the research topic only. The confidentiality of the participant and company names was ensured for the participants to feel comfortable disclosing sensitive information. Significantly, the researcher created the ethical approval forms for this research prior to the data collection phase. These forms were approved by the Research Governance and Ethics Committee at Strathclyde University. All the participants were officially invited and presented with a consent form for their consideration. Each participant's full acceptance was required before engaging in the research. The ethical approvals are included in Appendix G.

4.12 Pilot Study

A pilot study is a small-scale test of an interview or questionnaire to reduce the probability of respondents encountering difficulties when answering the questions, as well as anticipating data-recording difficulties (Saunders et al., 2009). Similarly, pilot testing is regarded the data collection methods on usual respondents before managing the main study (Simmons, 2006). Therefore, the exclusion of probable difficulties led the researcher to pilot test the questionnaire for the reasons outlined above. Also, this research used self-administration for both the interview survey and the questionnaire survey. The significance of a pilot study to the research due absence of interaction with respondents regarding misperception if any.

The semi-structured interview questions and the questionnaire survey were pilot tested prior to their use for collecting data after being ethically approved. Accordingly, the semi-structured interview questions were revised by a small sample of a number of current academics at Strathclyde University, as well as practitioners in the Saudi construction industry, who were contacted via email. A few wording and typo comments were noted and fixed. Furthermore, the pilot testing of the self-administered questionnaire required the reviewing of seven factors prior to distribution (Bryman and Bill, 2007): 1) the length of the entire questionnaire to completion; 2) the clarity of the instructions; 3) the clarity of the questions; 4) the ease of answering the questions; 5) the omission of any major topic; 6) the clarity of the layout; and 7) other comments. Therefore, the questionnaire survey questions were also pilot tested on a small sample of present construction practitioners of PBSC in office developments. Initially, the questionnaire was distributed to five construction practitioners with experience in questionnaire design. The purpose of the questionnaire and the research topic were clarified by the researcher to obtain valuable feedback. Furthermore, the participants were asked about layout, clarity of content, number of questions, and duration of the questionnaire. It was suggested that the introduction to the survey should include both Arabic and English text. Also, there should be images of PBSC to explain each type of application. These images were duly added. Numbers were suggested to be added to the choices for questions 1-A, 1-B, and 1-C. For Question 3, it was suggested that each type should include one written example to clarify that in Arabic. Also, it was suggested to remove the postal address due its inapplicability. All the comments (wordings and typo) from this feedback were fully considered.

4.13 Population

The population for this study included two categories: consultants and contractors in the building sector of the Saudi construction industry. Saudi Arabia consists of 13 provinces, of which Riyadh, Makkah, and Eastern are the top three provinces. Based on the SCE 2017 national membership list, registered architects/engineers of the major three provinces comprise almost 80% of the total population of the 13 provinces (see Table 4-9).

Table 4-9 Provinces of Saudi Arabia – No. of consultants in registered firms

No.	Region	Engineering Consulting Office	Professional Engineering Saudi Company	SUM
1	Al Baha	14	1	15
2	Al Jawf	21	0	21
3	N Borders	16	4	20
4	Ar Riyadh	799	86	885
5	Eastern	446	47	493
6	Al Qasim	71	10	81
7	Al Madinah	174	8	182
8	Tabuk	29	2	31
9	Jazan	57	8	65
10	Hail	30	4	34
11	Asir	83	7	90
12	Makkah	781	44	825
13	Najran	25	1	26
Total		2546	222	2768
SUM of three main regions		2026	177	2203
% of SUM /3 main to 13		80%	80%	

Since this study mostly concentrates on a technical aspect of PBSC in design and construction processes, this study only focuses on the top three provinces due to the higher percentage of contractor availability and time limitation. Also, based on the SCA 2017 national membership list and the MOMRA, the registered contractors and specialised contractors of the major three provinces are populated.

4.14 Sample Frame

The target group of participants for this study was consultants and contractors. Consultants are classified according to the SCE into, 1) professional engineering Saudi company (PESC), and 2) engineering consulting offices (ECO); whereas, contractors are classified into, 1) general contractors, and 2) specialised contractors. Table 4-10 and Table 4-11 illustrate the classes of consultant and contractor participants in this study. Both the consultants and contractors are currently operating in the Riyadh, Jeddah, or Eastern provinces. The survey targeted all consultants and contractors regardless of whether they used PBSC.

Consultants: The sampling frame for consultants was the SCE 2017 national membership list in the three provinces of Riyadh, Makkah, and Eastern, which contain 2026 ECO and 177 PESC. The population was 2203, from which 338 (sample) consultants were randomly selected, with the same percentage of firms from each province.

Contractors: The sampling frame for contractors in this study was the MOMRA and the SCA 2017 national membership list in the three provinces of Riyadh, Makkah, and Eastern, which contain 251 general contractors (1st, 2nd, and 3rd degree) and 1426 specialised subcontractors (1st, 2nd, and 3rd degree). The population was 1677, from which 323 (sample) contractors were randomly selected, with the same percentage of companies from each province.

This study used a stratified random sampling design to conduct the self-administrated survey. Two simple, random samples were nominated from the consultant and contractor groups.

The estimated total sample size for each group was determined using the following formula:

$n = N / [1 + N (e)^2]$, where e= 0.5 E.Q. 4.3

This study was designed on a 95% confidence level. For the precision level estimate, it was ±5%. Based on this calculation, the estimated total sample size was 338 for consultants and 323 for contractors. A sample size of 345 for consultants and 325 for contractors was used to the simplicity of study (Israel, 1992).

Table 4-10 Consultant population based on SCE data

Consultants				
Class	**Riyadh**	**Makkah**	**Eastern**	**Total**
PESC	86	44	47	177
ECO	799	781	446	2026
Total				**2203**

Table 4-11 Contractor population based on SCA data

Contractors				
Class	**Riyadh**	**Makkah**	**Eastern**	**Total**
G.C.	154	56	41	251
S.C.	483	478	465	1426
Total				**1677**

4.15 Validity and Reliability

Validity is defined by Saunders and Lewis (2015, pp.127-28) as the extent to which, 1) the data collection methods accurately measure what they were intended to measure (e.g. methodology, qualitative and quantitative, and analysis); and 2) the research findings concern what they profess to be about (e.g. discussion). Thus, the importance of validity and reliability is to provide quality assurance in research development, especially regarding data collection and analysis.

Data quality (validity and reliability) is essential for this research due to the employment of semi-structured interviews, a questionnaire survey, and case study methods.

4.16 Research Challenges

This research faced a number of challenges. First, there was a lack of any major Saudi-specific literature on the research topic. Second, this research is limited to 1st, 2nd, and 3rd degree contractors because they are the only ones fully and correctly listed in associations. Other degrees of contractors were unreachable due to missing or unavailable information. Furthermore, the unwillingness of some practitioners to contribute to the study was clear, especially when speaking about numbers. Moreover, regarding the time frame and response rate, there were noticeable limitations, particularly when some questionnaires were returned incomplete.

4.17 Summary

This chapter presented and justified the research philosophy, methodology rationale and strategy, and the research methods for data generation, collection, and analysis to meet the objectives and test the propositions. The qualitative and quantitative approaches employed different strategies and methods for data collection. For instance, the interviews (Phase I: Qualitative) were semi-structured and the researcher took field notes; whereas, the questionnaire (Phase II: Quantitative) used qualtrics.com for distribution.

These strategies and methods were used to best achieve the research aim and objectives. In addition, the ethical research issues were highlighted.

A mixed-methods approach (qualitative and quantitative) was employed to explore (exploratory sequential) the context of Saudi Arabia due to a shortage of literature regarding the application of PBSC in complex office developments. The data required were classified into primary and secondary data. The secondary data were obtained from the literature review. Several methods were employed for primary data collection and analysis, including semi-structured interviews, a questionnaire, and case studies for validity. Both the primary and secondary data were gathered to obtain a robust range of data to meet the research aim and objectives.

Chapter 4 discussed the exploratory mixed-methods (qualitative / quantitative) approach as a research design. A research plan that describes the data collection and analysis was provided. This research began with interviews (qualitative approach), and the findings were presented in the form of propositions (see Chapter 5). These propositions helped construct the questionnaire survey (quantitative approach). The consideration of sample size is in Section 4.14. The qualitative findings are presented in Chapter 5, and the results of the questionnaire survey and validation are presented in Chapter 6.

CHAPTER 5: ANALYSIS AND FINDINGS

5.1 Introduction

This chapter presents the findings of the qualitative data, which include the attitude towards using PBSC in complex office developments, the types of stakeholder influence regarding PBSC adoption decisions, and the types of contextual influence impacting PBSC adoption decisions. The qualitative results were gathered and framed by the TPB to provide direction. Through applying the methodology explained in Chapter 4, the findings were derived from the grounded theory analysis using Nvivo, and are presented in the form of propositions that can be examined further via a quantitative tool.

5.2 Interview Analysis

A semi-structured interview was designed in accordance with the TPB. After piloting the interview questions, they were translated into Arabic. The interviews were arranged either by meeting interviewees in the office or/and at onsite locations via phone. The interviewees were very familiar with the practice and had great knowledge about PBSC. Each interview began with a brief introduction of the research and its primary goals. All the interviews were audio-recorded and transcribed, then translated into English, and analysed based on constructivist grounded theory. All the interviews were read multiple times to analyse the script and extracting the themes according to the perceptions of the interviewees.

Context analysis applied grounded theory to analyse the transcriptions, while Nvivo software was used for coding. Level -1 coding involves sorting data to categorise codes and generate themes based on the relationship between codes, code frequencies, and meaning across codes. Level -2 coding includes focused coding, axial coding, and theoretical coding. Examining the initial codes was performed in conjunction with identifying relationships. Focused coding was applied to identify the most frequent or significant initial codes. Axial coding was used to identify the core category and related categories. Finally, theoretical coding was used to connect the core category and related categories to create a storyline to explain the phenomenon in terms of propositions.

5.3 Profile of Interviewees

This research aims to explore the intentions of consultants and contractors regarding using PBSC in complex office developments in Saudi Arabia. The purpose of this research is to improve project delivery. Technically, project delivery is related to stakeholders, such as consultants and contractors. The selection criteria for interviewees were outlined in the methodology chapter (Section 4.9.3). There was a total of 15 participants, with various positions and levels of experience. The participants interviewed in this study were eight consultants, five contractors, and two specialised contractors, all from the Riyadh, Jeddah, and Eastern regions of Saudi Arabia. The selection of the regions was based on those with the majority of prefabrication activity in Saudi Arabia. The interview questions are discussed in the methodology chapter (Section 4.9.2). The interview details are displayed in Table 5-2, in which the list of the participants is initialled to ensure confidentiality.

Grounded theory was used for the qualitative analysis (see Section 4.9.4). The results of the analysis are presented consistent with each of the theoretical components of the TPB model in Figure 3-1.

The analysis involves four sections. Section 1 has nine themes that express the benefits of using PBSC. Section 2 has eight themes that present the challenges to the use of PBSC.

Table 5-1 A snapshot of coding for the qualitative analysis using the grounded theory (Source: Author)

	Level – 1 coding		Level – 2 coding		
Interviewees	**Highlighted notes from transcripts 413**	**Initial coding**	**Sub-category**	**Core category**	**Theoretical model (Proposition)**
IV#1 - Contractor BS	I think with regard to the general picture of these techniques; for the client, it is a matter of preference, but for the contractor, it is quite related to profit. For example, if we assume that a project shall take up to two years to be implemented, and a year and a half of this duration will be dedicated for concrete works and wiring works, then the real work will take six months only. As a contractor, in the event of adopting offsite techniques, the works required to be done onsite shall be limited to the installation phase of the project, which is estimated to take six months. No doubt that using these techniques saves time and reduces the number of workers onsite. These two factors directly affect our profit as contractors.	Client preference Duration Adopting offsite Installation phase Contractor profit Reduces the number of workers onsite	Construction phase Cost-savings Material costs Labours costs	Construction cost	Preassembled building services components reduce construction cost
	I think that the costs are not an obstacle compared with the conventional method in which the costs are calculated in terms of the materials used, the workers hired, and the required project duration.	Costs calculation Materials, workers, duration			

Table 5-2 Interview Schedule (N=15)

Interviewee Identifier			Type	Interviewee Title	Location	Interview Type	Duration
Consultants		**EA**	Architect	Director	Jeddah, KSA	Phone	00:39:26
Consultants		**MA**	EE	Director	Riyadh, KSA	Office	00:34:35
Consultants		**OM**	ME	Senior Manager	Riyadh, KSA	Office	00:47:26
Consultants		**AC**	Accountant	Company Accountant	Riyadh, KSA	Office	00:33:48
Consultants		**AR**	Architect	Chief Executive Officer	Riyadh, KSA	Office	00:40:19
Consultants		**AM**	QCE	Manager	Dammam, KSA	Phone	00:49:56
Consultants		**SK**	Architect	Chief Operating Officer	Riyadh, KSA	Office	00:41:04
Consultants		**AS**	ME	Manager	Riyadh, KSA	On site	01:57:33
Contractors	General Contractors	**BS**	ME	Manager	Jeddah, KSA	On Site	01:55:44
Contractors	General Contractors	**MA**	EE	Director	Dammam, KSA	Phone	00:41:59
Contractors	General Contractors	**WS**	ME	Director	Riyadh, KSA	Phone	00:36:37
Contractors	General Contractors	**KS**	EE	Chief Operating Officer	Riyadh, KSA	Phone	00:50:11
Contractors	General Contractors	**AA**	ME	Director	Riyadh, KSA	Phone	00:39:38
Contractors	Specialised subs.	**MS**	ME	Senior Manager	Riyadh, KSA	Phone	00:47:43
Contractors	Specialised subs.	**SS**	EE	Chief Operating Officer	Jeddah, KSA	Phone	00:37:19

Section 3 has five themes regarding stakeholders who affect decision-making, while Section 4 has four themes regarding contextual factors influencing the adoption decisions for using PBSC. A total of 413 themes was calculated from all sources. The frequencies of theme are presented in Table 5-3.

The scale employed was developed as Low – Medium – High for qualitative findings. According to the percentage of frequencies, it appears that the percentages ranged between zero and six. Therefore, it was subjectively considered that the range for 'Low' is (0.0 < X < 2.0), 'Medium' is (2.1 < X < 4.0), and 'High' is (4.1 < X < 6.0 +).

Table 5-3 Theme generating for attitudes, SN, and PBC (Source: Author)

	Themes	Freq.	Thematic coding	Percentage	Scale
Benefits	Construction cost	19	CC	4.6%	High
	Overall project schedule	15	OPS	3.6%	Medium
	Construction waste	21	CW	5.1%	High
	Energy efficiency	22	EE	5.3%	High
	Higher quality	19	HQ	4.6%	High
	Coordination among parties	24	CAP	5.8%	High
	Ease construction process	13	ECP	3.1%	Medium
	Project design efficiency	4	PDE	1.0%	Low
	Safety performance	15	SP	3.6%	Medium
Challenges	Changes onsite	5	CO	1.2%	Low
	Design options	10	DO	2.4%	Medium
	Maintenance capability	16	MC	3.9%	Medium
	Preparatory requirements	17	PR	4.1%	High
	Image of low quality	4	ILQ	1.0%	Low
	Risk of processes	15	ROP	3.6%	Medium
	Transportation logistics	12	TL	2.9%	Medium
	Overall project cost	23	OPC	5.6%	High
Stakeholder Influence	Client influence	20	ONP	4.8%	High
	Consultant influence	16	CNI	3.9%	Medium
	Gov. regulators	39	GRI	9.4%	High
	Supplier influence	16	SI	3.9%	Medium
	Subs	8	SC	1.9%	Low
External Contextual Control	Manufacture competency	24	MC	5.8%	High
	Financial support	15	FS	3.6%	Medium
	Lack of skilled craft workers	13	SCW	3.1%	Medium
	Government regulations	8	MC	1.9%	Low
Total		413			

Objective two of the research is to assess the perception of consultants and contractors towards using PBSC in complex office developments in the framework of the TPB, including:

A) Attitudes: measuring benefit and challenge factors.

B) Subjective norms: measuring the influence of parties' factors.

C) Perceived behavioural control: measuring the influence of external contextual factors.

The descriptions are analysed by employing grounded theory through Nvivo. The descriptions and findings are both presented in the following sections.

Rationally, according to Briggs and Jago (2012), a proposition is what one believes, thinks, or means. Furthermore, a proposition is often defined as the semantic content, meaning, or compositional semantic values of declarative utterances or sentences and are primary bearers of truth or falsity. On the other hand, according to Macleod and Hockey (1989), 'A hypothesis is a statement or explanation that is suggested by knowledge or observation but has not, yet, been proved or disproved'. Nonetheless, this research applied an exploratory mixed-methods approach due to the lack of robust conceptual and empirical foundations for the topic under investigation. The exploratory mixed-methods approach began with a qualitative stage towards the goal to obtain insights before performing the quantitative survey. According to Creswell and Plano Clark (2007 p.77), researchers apply this research design to build on the findings of the qualitative phase by identifying factors, developing an instrument, or stating propositions for testing based on an emergent theory or framework. Also, much emphasis is focused on the qualitative data since the design was qualitatively originated. On the other hand, the TPB is designed to predict intention towards using PBSC in complex office developments; therefore, it depends on attitudes, SN, and PBC. Furthermore, grounded theory is employed in this research for qualitative data analysis to form findings into theories or propositions. Creswell and Plano Clark (2011), regarding theory development designs, highlight that qualitative findings play a more primary role and are used to develop propositions, and the secondary, quantitative phase tests or studies the quantitative results in more detail. Consequently, the term ‘propositions’ is adopted to motivate this research stream via a series of testable research propositions, which will, once tested, further describe the influence of consultants and contractors.

5.4 Attitudes Towards Using Preassembled Building Services Components

This section presents the findings regarding attitudes towards using PBSC in complex office developments in Saudi Arabia. Accordingly, the attitudes are presented in the forms of benefits and challenges, which are analysed and developed into propositions in the following section.

5.5 Findings – Benefits of Using Preassembled Building Services Components

Project Management Benefits

The project management benefits of using PBSC include, 1) improvement of product quality; 2) an increase in the speed of construction; and 3) a reduction in the construction cost. These findings confirm the findings/results of a number of earlier and recent studies.

Improve Product Quality

Consultants EA, MA, OM, AC, AR, AM, SK, and AS believed that international standards and codes play an important role in the quality process of PBSC. These consultants pointed out that the quality of preassembly is primarily the factor of technology adoption, as it undergoes high-quality tests and specifications. Accordingly, technical specifications and quality management guarantee the quality of PBSC as techniques. The consultants noted also the importance of the availability of skilled labour in the industrial sector and their influence on the quality issue of such technology.

> *Interviewee EA: Therefore, I think these offsite techniques are clearly based on international standards and that their designs are modernised on an international level. Therefore, naturally, they have better quality*.

Contractors BS, MN, WS, KS, AA, MS, and SS pointed to the quality of PBSC regarding both the technical specifications and final finishing of the product. These contractors believed that the quality issues of PBSC begins at the design stage, and then in the manufacturing and material selection stage. Technical specifications also play an important role in achieving the best quality, together with the experience in the implementation process, as factories enjoy a better level of employment than the construction sector.

> *Interviewee MS: Offsite building services techniques have a very high quality in comparison with the conventional methods, both in terms of the final finishes or the technical efficiency.*

Proposition Synthesis: Quality of product is one of the main targets in construction projects. Achieving high quality was reported as the third highest driver for using offsite construction in the UK (Pan et al., 2007). Furthermore, most failures to deliver a construction project are caused by a disagreement between stakeholders regarding quality. Poor communication, coordination between construction parties, and rework cause schedule delays in public projects in Saudi Arabia (Mahamid, 2013). Building services attach great importance to quality issues for most purposes as alignment or interchangeably with other systems. Quality of systems and components play a major role in the operation phase. Offsite construction provides a whole-life cost benefit to stakeholders involved in the construction process (Mostafa et al., 2012). However, failure to deliver qualified building services systems delays a construction project. Thus, preassembly can resolve many conflicts that may occur due to production being carried out in a controlled environment, where higher quality programmes are applied. In New Zealand, achieving high quality was ranked second as a benefit of using offsite construction (Scofield et al., 2009). Thus, the *quality of products is a highly significant variable* that can be achieved through the use of PBSC in complex office developments.

Increase Speed of Construction

Consultants EA, MA, OM, AR, AM, SK, and AS indicated that PBSC contribute to the timely completion of projects because of relevant involvement in the industrial sector. Factories are committed to completing PBSC according to the time and designs approved by the consultant. Specialisation plays an important role in the process of delivering products quickly due to the expertise that can be relied upon in the industrial sector. In principle, the industrial sector differs from the construction sector, in which factories produce components with an industrial sense, which ensures minimum production delays. Thus, projects can be achieved quickly.

According to contractors BS, MN, KS, AA, and SS, PBSC help contractors acquire more projects and benefit from in-house employment in other projects. This is done to adapt to the stage of production by avoiding having idle workers. Therefore, factories complete all products in a timely manner in line with consultant and client approval. Installation onsite is carried out by the general contractor as a small part of the timetable of the project. Skilled labour is an important element in overcoming tasks that overlap and delay project delivery.

Proposition Synthesis: Construction projects are often scheduled for completion according to the requirements of stakeholders. Projects are delayed for many reasons, such as failure to meet the standards for building services or approval by the supervising engineer. Saudi practices diverge from international standards, and foreign companies face difficulties regarding the causes of these deviations and the proper ways to handle them (Mitra and Tan, 2012). The preparatory phase requires more time to convey the client's requirements into designs. The testing phase of building services is important because a project falters in the event of a defect. However, industrial concepts assure that manufacturers produce components within the scheduled time and with zero defects. The process and programme of OSM are generally significant drivers for onsite construction time reduction (Blismas and Wakefield, 2009). Accordingly, time reduction is regarded as the most important theme for decision factors for OSM in the UK (Elnaas et al., 2014). Hence, *enhancing the speed of construction is a significant variable* that can be achieved through PBSC in complex office developments.

Reduce Construction Cost

Consultants MA, OM, AC, AM, SK, and AS believed that major savings in construction costs can be achieved by reducing the completion time of a project. These time reductions are estimated as cost-savings and are calculated in the project duration for the interest of the consultant. Additionally, the use of PBSC in complex office developments reduces the supervision tasks of the consultant and shifts their supervision to the production process. This abundance is of average significance for the consultant and is developed over time in the case of more standardised applications.

> *Interviewee SK: Speaking of cost-saving, of course, when there is a reduction in the timetable of the project, there will be a reduction in costs as well as the number of workers will be reduced and the works implemented on site will be less than in the conventional method. All these reductions save some costs. However, the first beneficiaries of these cost-savings are the contractor and the consultant.*

Construction costs were considered the most important factor for contractors BS, MN, AA, MS, and SS. Such savings are obtained through reducing the number of labourers employed onsite, as well as savings in purchase orders and coordination between labourers and staff, which requires larger manpower. The use of PBSC in complex office developments allows general contractors to work on more projects with the certainty of completing works within the specified period. Thus, contractors only carry out installation work onsite. Therefore, PBSC are highly significant for reducing construction costs.

Proposition Synthesis: The cost-savings in the construction phase are generated by the reduction in the schedule and the number of labourers involved onsite. The main benefits of using preassembly are obtained through indirect cost-savings and non-cost value-adding items (Blismas et al., 2006). Therefore, general contractors are the main beneficiary of such savings. Blismas and Wakefield (2009) highlight that preassembled construction provides lower site-related costs for general contractors and earlier income generation for clients. However, the main economic benefits of OSP are generally associated with labour and material savings (Zhai et al., 2014). These savings include the use of standardised PBSC and modules. Time reduction in a given project results in labour reduction for the general contractors as well as the time required by the consultant to supervise works onsite. Offsite construction reduces the amount of labour needed in the construction process in Saudi Arabia (Aburas, 2011). All the time savings lead to construction cost-savings, and the owner always benefits from the early completion of a project in the US, where reducing construction cost was ranked third by general contractors in terms of the benefits of offsite construction (Lu and Liska, 2008). Thus, *saving on construction costs is a very significant variable* that can be achieved via the use of PBSC in complex office developments.

Site Management Benefits

The site management benefits of using PBSC include, 1) reduction of construction waste, 2) facilitation of tasks, and 3) enhancement of coordination among parties. These findings confirm the findings/results of a number of earlier and recent studies.

Reduce Construction Waste

Consultants EA, MA, AM, and SK believed that the production process of PBSC is better managed than the conventional method. They noted also that design plays an important role in production in terms of material savings. Factories operate according to an industrial environment that is keen to provide resources through modern technologies. They believed that quality management, as a concept, is effectively applied at an advanced level in the industrial environment and that resources are used in the best way possible.

Contractors BS, KS, AA, and SS noted that one of the objectives of PBSC is to be highly efficient, and that it is dependent on accurate designs that inspire high quality to ensure multiple dimensions related to the project, including reducing production waste. International standards and codes also play an important role in the production process and, thus, the percentage of waste is far less than in the traditional process. This aspect is particularly true as factories are based on advanced administrative procedures, and some have quality certificates, such as ISO 14,001 and ISO 9001. Also, factories have to follow an industrial standard, which manages waste well.

Proposition Synthesis: Construction waste is an environmental issue that is part of a contractor's responsibility. Consultants can develop better design solutions that construction waste is part of. Tam et al. (2014) state that low-waste construction technologies have been supported for years, including designs for reducing foundation sizes, designs for reusing and for using modular building designs, and prefabricated components. During the construction phase, manufacturers take the place of contractors in producing PBSC with more efficient ways of waste control and then transporting them for final installation. Blismas and Wakefield (2009) highlight that the OSM could provide waste minimisation and better engineering for the construction industry. Waste management, quality management, quality assurance, and other management procedures play major roles in the industrial sector. In this regard, Goulding et al. (2012) report that reducing site waste is one of the key benefits of manufactured construction. Therefore, the *reduction of construction waste is a very significant variable* that can be achieved through the use of PBSC in complex office developments.

Facilitate Tasks

Consultants OM, AC, AR, MA, and AS believed that the construction sector has the desire to shift towards the use of modern building techniques, including PBSC. Preassembly can achieve project success in terms of quality, time, and cost by facilitating operations among stakeholders. The consultants believed also that the global trend is to invest in modern materials, components, devices, and equipment, which are all modern industrial methods that facilitate both the operation and the installation of processes of the construction phase. Furthermore, PBSC reduce the redundancy and overlap of tasks because they are based on pre-processing at the highest level.

Contractors MN, WS, AA, and MS noted that the manufacturing process relieves contractor burdens throughout the manufacturing stage.

Preassembled building services components do not require contractors to provide employment at this stage, as this is only needed during the installation stage. Also, these techniques do not require many approvals, especially regarding samples and purchase orders. All these facilitations can be achieved through the use of PBSC. Therefore, the contractors generally believed that many financial benefits are gained when using preassembly in projects.

Proposition Synthesis: Construction tasks generally pass through a procedure that begins with approvals of designs, samples of materials, and purchase orders. Change orders apply when faults occur with client requirements. Assaf and Al-Hejji (2006) state that delays in Saudi Arabia's construction projects are often caused by changing orders from the client during construction. The construction process requires more effective strategies to perform successfully in building services. Dodgson et al. (2008) suggest that the corporate strategy for driving organisational competitiveness must include technological innovation management. Therefore, the preassembly method assures that coordination is entirely active between designers and both consultants and contractors, including manufacturers. Consequently, construction tasks can be better facilitated when early approvals are obtained with the schedule is accurately estimated. Steinhardt and Manley (2016) report that simplification of tasks is an advantage of using prefabrication in Australia. Therefore, the *facilitation of tasks is a significant variable* that can be achieved through the use of PBSC in complex office developments.

Enhance Coordination Among Parties

According to consultants EA, AR, MA, SK, and AS, coordination among stakeholders begins at the design stage, when the client's requirements are translated into a scheme. The scheme is then adopted at a certain stage of the production process to produce PBSC. The factory initiates the coordination process in case a difference appears in these schemes and is observed by the client, the consultant, or by the contractor. Furthermore, the factory is responsible also for the testing process and the time of delivery to the site.

From the point of view of contractors BS, MN, MS, and SS, coordinating the work of PBSC and architectural services in the design phase is the cornerstone of successful work. This coordination produces high-quality schemes and avoids any change orders that may occur later. The contractors also pointed to the need to consider all aspects of the project and their conformity with the requirements of the client at the design stage, which relies on the consultant. The contractors believed that the representative of factories should have an engineering background, instead of marketing, to avoid putting the project at risk.

Proposition Synthesis: Coordination among stakeholders is a key issue to deliver a project on time. Mahamid (2013) notes that communication between parties is very important for the success of a project in Saudi Arabia. Consultants can mentor such coordination through the use of better strategies, in which a client's requirements are the starting point. Zhang et al. (2014) state that the building system depends on a well-coordinated development, in which designers (architects and engineers) work together in offsite construction technology. During the manufacturing phase, consultants communicate with factories' designers to enhance coordination and avoid conflicts. Halman et al. (2008) note that the use of prefabrication improves stakeholder cooperation in construction projects. During the construction phase, contractors are supervised by consultants for final installation tasks. Such coordination reduces faults in construction projects. Steinhardt and Manley (2016) note that the use of prefabrication has improved the coordination of staff and tasks in Australia. Accordingly, *coordination among parties is a significant variable* that can be achieved through the use of PBSC in complex office developments.

Sustainability Benefits

The sustainability benefits of using the PBSC include, 1) enhancement of health and safety, 2) enhancement of design efficiency, and 3) improvement of energy efficiency. These findings confirm the findings/results of a number of earlier and recent studies.

Enhance Health and Safety

Consultants MA, OM, AC, AM, SK, and AS stated that PBSC provide the best solutions in terms of health and safety. Labourers' health and safety increases due to the completion of the manufacturing process outside the project site and in a factory environment that is better governed by health and safety requirements. The consultants believed also that factories are fully equipped to deal with injuries and accidents. Factories have monitoring programmes and regular maintenance of equipment, and, therefore, the consultants thought that preassembly enhances health and safety on construction projects.

> *Interviewee MA: In addition, in terms of building services, offsite techniques enhance the health of the end consumer by providing him with a highly efficient product, especially the Pods.*

Contractors MN, KS, MS, and SS believed that reducing the number of workers onsite reduces the risk of injury during work. They believed also that safety standards in factories are better because they are subject to strict supervision. Factories have many safety standards designed to facilitate movement within the factory, especially on production lines; thus, reducing the vulnerability of workers to injury. Therefore, PBSC enhances health and safety during the construction phase as well as the operational phase, when they are at a better quality level for client and end-users.

> *Interviewee WS: In fact, safety and security depend on the number of workers; the fewer workers employed to work onsite, the less the risks become. In using preassembled building services components, the number of workers onsite is reduced, which boosts the safety level, and this is one of the long-sought targets.*

Proposition Synthesis: Projects involve risks, including labourer injuries. Project management seeks to improve health and safety on construction projects. Mostafa et al. (2016) state that the social benefits of using offsite construction improve safety and work conditions and workforce stabilisation. In traditional methods of construction, the projects differ in their nature and workers need to move between various locations within the site to perform the same job. In contrast, in offsite construction, the locations are different in nature; each worker in the factory is assigned a station within an industrial environment designed for a specific purpose of the manufacturing and production line. Blismas and Wakefield (2009) point out that offsite construction reduces labour/trade living expenses in remote areas. Industrial environments comply with health and safety standards and are equipped with emergency tools, such as fire systems and first aid. Outsourcing building services products promotes health and safety, especially when mechanical systems require testing and an electricity supply. Blismas and Wakefield (2009) note that offsite construction provides more efficient designs that reduce the need for high health and safety monitoring. Thus, *enhancing health and safety is a significant variable* that can be achieved through the use of PBSC in complex office developments.

Enhance Design Efficiency

Consultants EA and AS believed that PBSC adopt international standards and codes to increase its efficiency and facilitate its application. These international standards and codes play an essential role in the design process to optimise the use of spaces and materials. Consequently, the outputs of these designs are high quality to provide the client's basic requirements. Design efficiency reduces the probability of change orders during the construction phase.

From the point of view of contractors WS and MS, the efficiency of the design can be achieved through the use of PBSC, since these techniques follow international standards of quality in design. They believed also that these international standards facilitate maintenance after installation due to the availability of semi-standard spare parts. The contractors preferred to use PBSC as they comply with international standards, which leads to completing projects in a shorter time. Furthermore, they noted the advantages of quality assurance testing and quality management at the design stage.

> *Interviewee MS: The factories follow international standards regarding designs. Factories have quality assurance and quality control and also follow the international health and safety standards.*

Proposition Synthesis: Generally, design efficiency is an important requirement in construction projects. Designs of building services are often preliminarily approved in construction projects, while final approval is subsequently made with the general contractor following the approval of the specialised contractors. Samuelsson Brown et al. (2003) state that the final decision to work offsite on a project is left to the M&E contractor or the consultant in M&E applications. In the case of preassembly, these stages are bypassed; direct coordination between the consultant and the factory ensures the efficiency of the final designs. Blismas et al. (2006) reviewed the identification of OSP by Egan (1998) and state that standardisation, codes, and OSP play a major role in design efficiency and improving construction processes. The manufacturing environment ensures that quality assurance and quality management are applied to components as well as to designs. Blismas and Wakefield (2009) state that offsite construction provides more efficient designs and specifications. Thus, *enhancing design efficiency is a significant variable* that can be achieved through the use of PBSC in complex office developments.

Improve Energy Efficiency

Consultants AC, AR, MA, SK, and AS believed that PBSC play an important role in energy conservation due to the advanced applicability of international standards, specifications, and codes. Preassembled building services components require energy. Therefore, the consultants believed that the Government has a very important role to play in terms of energy management at a national level. This role can be positively reflected in the industrial process in all aspects, including the production of PBSC. Maintenance and operation are also part of that objective.

Contractors BS, MN, WS, and KS believed that PBSC reduce energy consumption, which is an important part of the client's requirements. The contractors stated also that energy-saving designs have been developed according to standard specifications and codes, in which energy-saving is a segment of the high quality associated with such a technology. The contractors talked positively about the adoption of preassembly designs to the applications of heating and cooling load calculations and in power distribution compared with the conventional operation.

Proposition Synthesis: Energy efficiency is one of the most important aspects offered by preassembly. Standardisations and codes play an important role in enhancing the efficiency of preassembly. The main three significant principles of industrialisation are standardisation, prefabrication, and systems building (Mostafa et al. (2016). Consultants are involved in the design process to adapt and optimise preassembly. Blismas and Wakefield (2009) highlight that the energy efficiency of buildings is improved by the design and performance testing of panels. The industrial sector is responsible for conveying innovations into the construction sector. Manufacturing values efficiently influence preassembly components in designs, materials, and standardisation alignment. Zhai et al. (2014b) identified energy consumption and the promotion of the uptake of green building technologies as environmental factors driving the use of OSP. Therefore, *improving energy efficiency is a significant variable* that can be achieved through the use of PBSC in complex office developments.

A summary of propositions that represent the benefits of using PBSC in complex office developments is provided in Table 5-4.

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Table 5-4 Summary of propositions (benefits) (Source: Author)

		Propositions	Statement – Perceived Behavioural Control
Benefits	Project Management Benefits	***Proposition 1***	The use of preassembled building services components increases product quality in complex office developments.
		Proposition 2	The use of preassembled building services components improves the speed of construction in complex office developments.
		Proposition 3	The use of preassembled building services components reduces the construction cost in complex office developments.
	Site Management Benefits	***Proposition 4***	The use of preassembled building services components reduces the construction waste in complex office developments.
		Proposition 5	The use of preassembled building services components improves coordination among parties in complex office developments.
		Proposition 6	The use of preassembled building services components simplifies construction tasks in complex office developments.
		Propositions	**Statement – Perceived Behavioural Control**
	Sustainability Benefits	***Proposition 7***	The use of preassembled building services components improves energy efficiency in complex office developments.
		Proposition 8	The use of preassembled building services components improves workplace safety in complex office developments.
		Proposition 9	The use of preassembled building services components increases the project design efficiency in complex office developments.

5.5.1 *Findings – Challenges of Using Preassembled Building Services Components*

Cost Implication Challenges

The cost implication challenges of using PBSC include, 1) an increase in the overall project cost, and 2) an increase due to maintenance complexity. These findings confirm the findings/results in a number of earlier and recent studies.

Increased Overall Project Cost

Consultants EA, MA, SK, and AS pointed out that the use of PBSC in construction projects increases overall costs. This aspect was cited as one of the main reasons for project failure in Saudi Arabia (i.e. being unable to complete projects at the estimated costs). It is believed also that building services are the most important elements of a complex project and, thus, require higher costs. Preassembly is performed offsite, which increases the process cost and, subsequently, increases the cost of the project. Designs, being customised, were also mentioned as being more expensive than standard designs.

Contractors WS, KS, AA, and MS noted that customised designs are more expensive than standardised designs. In general, building services are usually expensive, but PBSC are even more expensive. Modern technologies are often expensive for a certain period. Although the quality of preassembly increases prices to meet client requirements, it was noted that the production of building services in large quantities would eventually lower the prices of products. The contractors identified several reasons behind the high prices of preassembly. Outsourcing and task scheduling were the most important reasons, since it is difficult to store components in factories or onsite.

Proposition Synthesis: In most construction projects, building services are usually high in cost. These costs are mostly related to customised units of PBSC and modules. The variety of choices available to designers is often due to the expansion in the cost and complexity of building services systems (Francis et al., 2013). Preassembly is part of modern technology and is inspired by the manufacturing industry. Preassembly building services are highly cost-effective due to their high quality and industrial production method. Goodier and Gibb (2007) claim that the awareness level regarding the overall project cost-savings due to offsite implementation has increased. However, preassembly can increase overall project costs. The overall project costs of PBSC affect the client budget. Zhai et al. (2014) report that the overall costs of preassembly are a barrier in China. Therefore, *overall project cost is a significant variable* that can be a challenge to the use of PBSC in complex office developments.

Increased Maintenance

Consultants EA, MA, OM, and AS highlighted the high cost of maintenance contracts in Saudi Arabia. Preassembled building service components are highly expensive, and design also plays an important role in subsequent maintenance. The consultants noted that the entire mechanical or electrical systems may sometimes change, which all entails very high costs. Some PBSC provided by contractors include a maintenance programme within the contract, such as HVAC and elevators. Standardisation plays a role in reducing maintenance when standardised spare parts are available. The lack of skilled labour for the necessary maintenance work also plays an important role in this matter.

Contractors BS, MN, MS, and SS pointed to a weak maintenance process in the Saudi market, including PBSC. They noted also that preassembly systems contain a guidance manual when they are ready to deliver to site and guarantees and maintenance contracts. Maintenance of preassembly was considered very costly by contractors. In the case of partly standardised modules and preassembly, maintenance can be easy with the availability of spare parts from local suppliers. Some preassembly systems are covered with after-sales service, which includes comprehensive maintenance in the case of standardised products.

Proposition Synthesis: High maintenance costs are generally part of projects regardless of the method of implementation. The high cost of building services leads to higher maintenance costs, especially in the case of customised designs. Preassembled building services components might require a change of the entire system in some cases. Standardisation supports the production of spare parts in quantities and, thus, reduces the high maintenance costs. Jaillon and Poon (2010) demonstrated that variations in architectural design are less frequent when offsite processes are adopted. Maintenance considerations are also noted as being very important during the preparation stage due to their extreme impact on the operational phase. Pan and Gibb (2009) conclude that their study results emphasise the importance of integrating the concept of maintenance into early design stages. They note also how a shortage in the preassembly's production capability causes high costs of products and, therefore, expensive maintenance. Zhai et al. (2014) report that complexity of maintenance is part of the architectural performance that hinders the use of offsite construction in China. Therefore, the *maintenance is a significant variable* that can be a challenge to the use of PBSC in complex office developments.

Process Challenges

The process challenges of using PBSC include, 1) limitation of making changes onsite, 2) increase in transport, and 3) more preparatory requirements. These findings confirm the findings/results in a number of earlier and recent studies.

Limited Changes Onsite

Consultants EA, AR, and AS believed that it is difficult to change the work of PBSC in the implementation phase. This issue is mainly due to the fact that these technologies do not allow for change orders as their design is initially approved in accordance with the factory. Factories are committed to many project orders. Execution of these preassembly works takes much time, which affects the plant's potential and production lines. Therefore, it is not easy to make any changes after implementation. The cost of altering onsite is often expensive, because the client's requirements are not met. Changes result in a high increase in the project cost.

From the point of view of contractors AA and MS, it was believed that the preparation stage is very important and directly related to all problems that may be encountered during the implementation stage. Preassembled building services components are highly standardised, and clients are expected to understand this. Contractors often define change orders as designers misunderstanding the client's requirements. Therefore, change orders onsite during the installation stage are complicated if there is a failure to meet the requirements of the client. The contractors pointed to inconsistency between the client's desires and the consultant's ability to convey these desires into designs in the initial stages of the project.

Proposition Synthesis: Construction works onsite are subject to modifications or reworking due to either the client's unwillingness or mistakes during the work. Pan et al. (2007) report that the perceived inability to early freeze the design hinders the utilisation of offsite. In building services preassembly, the consultant and the factory work in parallel to meet the client's requirements and, thus, reduce the risk of client dissatisfaction and design errors.

Implementing any amendment to preassembly onsite is difficult due to its effect on the cost and the schedule of the project. Blismas and Wakefield (2009) highlight that making changes onsite during the construction phase is difficult when using preassembly; thus, reducing the use of preassembly. However, a contractor deals with only one project; whereas, a factory deals with many projects at the same time, which may cause extra waiting times for the reordering of preassembly components. Lu and Liska (2008) reported that offsite construction limits the ability to make changes onsite in the USA. Thus, *onsite changes is a significant variable* that can be a challenge to the use of PBSC in complex office developments.

Transportation Logistics

Consultants EA, MA, MA, SK, and AS believed that the transport of PBSC is a challenge, especially for large sizes, such as Unipods. Regarding large volumes, the importance of module designs was mentioned in terms of resizing preassembly for transporting to be finally installed on site. Modules were discussed as proper solutions. Transport should be well scheduled with the tasks onsite so that components are not kept onsite, where damage may occur. The consultants were aware of the need to rely on adopting a transport strategy approved by the Traffic Department, especially during peak hours. It was pointed out also that transport issues of preassembly are often the factory's responsibility.

According to BS, AA, MS, and SS, transport is a hindrance due to certain characteristics of PBSC, such as large forms that are difficult to transport in conventional ways. Also, oversized preassembly is sometimes difficult to fit onsite when there are missed measurements for structural dimensions. At other times, it is difficult to avoid cracking at the installation stage. Location and accessibility to a construction site are also key requirements in the preparation phase to assess the best method of preassembly delivery. Transport was noted as a responsibility of either the manufacturers or suppliers in most construction contracts. The manufacturer might transport components to the construction site to avoid storing them in a plant, but onsite storing is still inappropriate due to damage. Thus, the contractors believed that this problem may be solved with time.

Proposition Synthesis: The transport of preassembly building services was noted as an important step in a construction project. Zhai et al. (2014) highlight that transport is a logistical yet critical problem directly affecting the OSP supply chain in China. Transport is affected by the size of the products and, therefore, it is important to consider the transfer of products in the preparation stage. Blismas and Wakefield (2009) state that the transport of large components is limited due to the mass of items, road widths, bridge load capacities, and transport curfews. It is important also to consider peak hours and traffic, especially when the project is located in a busy area. Therefore, certain consideration should be taken within the preparation stage regarding the delivery of products to the construction site. Scofield et al. (2009) report that transport and site specifics are ranked as the second barrier in the use of offsite construction in New Zealand. Thus, *transport logistics is a significant variable* that can be a challenge to the use of PBSC in complex office developments.

More Preparatory Requirements

Consultants EA, MA, OM, AC, SK, and AS noted that the preparatory stage requires much coordination among parties when using PBSC. Early considerations reduce later disagreements in a construction project. The consultants summarised the problems during the preparation phase as a weakness of project overview, which include both the scope of work and weakness of design details. Therefore, these problems must be resolved before the design's approval and the production of preassembly in a factory. However, the preparation phase requires more time than the conventional method. Ultimately, the consultants believed that the preparation stage is difficult; it requires a large number of tasks, consistency, and linking different schemes of the preassembly plans in a short time.

Contractors BS, MN, AA, MS, and SS believed that the preparation stage is the foundation of either the success or the failure of a project. One of the weaknesses of the preparatory stage is the shortage of specialised designers of PBSC in the construction industry. The preparatory stage is primarily based on the client's requirements that are conveyed into the designs and scope of the work. Unresolved weakness in designs or scope of work have adverse consequences if approved to move to the next stage. The contractors pointed to a large number of building systems and works that need high concentration in the preparation stage.

Proposition Synthesis: The preparatory stage plays an important role in the success of construction projects. Goodier and Gibb (2005) discuss the preparatory stage with specific reference to the inability to freeze the design early on and the length of lead-in time in the initial stage of offsite construction. Preassembly building services components contain many technical designs and require precision and coordination between consultants and manufacturers. Building services designs are interchangeably related to architectural designs. Therefore, consistency of designs requires high coordination among stakeholders. The preparation phase of preassembly takes longer than the traditional implementation of projects. Pan et al. (2007) identified the long lead-in time as a significant barrier to the extensive uptake of offsite construction in the UK. Additionally, the shortage of specialised designers of preassembly increases the time required for preparation. Zhai et al. (2014) report that the preparatory stage is a challenge of using offsite construction in China. Thus, the *preparation phase is a significant variable* that can be a challenge to the use of PBSC in complex office developments.

Product Challenges

The product challenges of using PBSC include, 1) reduction of design flexibility, 2) an increase in risk, and 3) having an image of low quality. These findings confirm the findings/results in a number of earlier and recent studies.

Reduced Flexibility of Design

Consultants EA, AC, AR, and AS pointed to the design restriction as a result of complying with international standards and codes that limit the client’s choices when customised architectural designs are applied. Thus, building services designs are affected by customised architectural designs. Standardisation is an essence of PBSC. Many project failures are caused by a misunderstanding between the consultant and the client regarding the requirements, as well as the consultant's inability to transform the requirements into a design correctly. Compliance with standards in traditional projects or modern techniques may encounter the same problems. International standards and codes are advanced design solutions, but the client's understanding of these solutions is an issue for consultants.

Contractors BS, MN, and WS believed that the design stage is very important to achieve the client’s requirements through modern designs. Preassembled building services components highly comply with international standards and codes. The client’s understanding of such technology and solutions, at the levels of implementation and operation, is very important to avoid change orders during the implementation phase. The contractors noted much construction work being redone due to design errors or designers’ lack of experience with certain techniques. Preassembled building services components require designers to be highly efficient and accurate. The manufacturing process for PBSC negatively affects the budget and schedule of a project when client requirements are incorrectly evaluated.

Proposition Synthesis: Standards and codes limit the flexibility of designs and they may not necessarily meet the client's architectural aspirations. Goulding et al. (2012) claim that manufacturing standardisation clashes with the flexibility of designs. However, in building services, standardisation plays an important role in fulfilling the client's aspirations because of its importance in the operational phase, including easy maintenance and the availability of spare parts. Pan and Gibb (2009) conclude that the GRP modules had the smallest number of recorded maintenance problems in comparison with in-situ bathrooms. The preassembly industry is determined to find suitable solutions, such as modules, in which additional parts are available to avoid the excess of uniformity of standards. Therefore, preassembly needs to be well explained to clients to realise the outcomes of such components. Nadim and Goulding (2010) report that insufficient design flexibility is a perceived problem regarding the use of offsite construction. Therefore, *design inflexibility is a significant variable* that can be a challenge to the use of PBSC in complex office developments.

Increased Risk

Consultants EA, MA, OM, and AS believed that the risk of using PBSC is limited to the preparation stage, which may cause the failure of a project in the event of an error in designs or scope of work. Also, failure to meet the client's requirements highly jeopardies the budget and schedule of a project. The consultants noted also that preassembly has better quality than other methods, without noting any technical risks of using preassembly that may affect end-users. The consultants mentioned the importance of risk assessment in all phases of preparation, manufacturing, and implementation. They pointed out that risk is expensive in the event of errors while using PBSC, as well as supplier problems in delivering products on time due to certain difficulties inside factories.

According to KS, AA, MS, and SS, the risk of using PBSC has many aspects; the most important of which is the industry's ability to understand the construction process in the construction sector. The preparatory phase plays an important role in reducing project-related risks; in some projects, the client prefers certain products with certain specifications. This may lead to some risks related to project schedule, in which having a specific supply is one of the most high-risk scenarios. Additionally, the contractors mentioned a number of risks related to project management and coordination among building systems.

Proposition Synthesis: The risk of preassembly building services was noted by both consultants and contractors as an important factor that must be assessed throughout the duration of a construction project. Risk does not occur often within products, but this may not be the case when using preassembled components due to many aspects, such as less skilled labour or dealing with new construction processes. Zhai et al. (2014) highlight that risk, with reference to suppliers, includes ‘loss of factory production slot/production capacity’, ‘suppliers failing to deliver on time’, and ‘manufacturer insolvency’.

Therefore, risk is better managed and contained in the preparatory stage of a construction project. Steinhardt and Manley (2016) state that the risks in adopting new processes are a great disadvantage of using prefabrication in Australia. Therefore, *increased risk is a significant variable* that can be a challenge to the use of PBSC in complex office developments.

Low-Quality Image

Consultants EA and MA noted that PBSC are produced with the highest levels of quality, but other consultants did not mention that preassembly products have a low-quality image. It was noted also that the client's choice for such techniques often indicates that preassembly occupies a high degree of acceptance. Clients positively evaluate preassembly as high-quality products due to high cost. The consultants indicated that preassembly is often concealed by finished work and, thus, is hidden from the end-users.

Contractors BS and MN noted that clients accept PBSC because of the high interrelation to the project's technical work, for which many failures occur in the application of conventional methods. The contractors pointed out that preassembly is concealed by decorative works; whereas, other prefabrications are exposed to users. Therefore, PBSC can be judged mainly by quality, but this is limited to the functionality and efficiency of these technologies.

Proposition Synthesis: Preassembly may not necessarily find acceptance in terms of finishes. Blismas and Wakefield (2009) state that negative cultural perceptions remain an important constraint regarding OSM products. However, preassembly building services are technically designed; therefore, they operate much better than traditional building services. Zhai et al. (2014) state that, according to Jaillon and Poon (2010), the variations in architectural design are less frequent when offsite processes are adopted. Furthermore, preassembly building services are high-quality components and well accepted by most clients. Pan and Gibb (2009) claim that the maintenance of offsite modules is less complex than in-situ bathrooms. On the other hand, preassembly building services are covered with decorations in projects and, therefore, cannot be confirmed as having a low-quality image. Mostafa et al.

(2016) reports that negative perception is a barrier to using offsite construction, according to several earlier studies. Therefore, *low-quality image is a very significant variable* that can be a challenge to the use of PBSC in complex office developments.

A summary of the propositions that represent challenges is provided in Table 5-5.

Table 5-5 Summary of propositions (challenges) (Source: Author)

		Propositions	Statement – Attitude
Challenges	Cost Implication Challenges	***Proposition 10***	The use of preassembled building services components increases the overall project cost in complex office developments.
		Proposition 11	Maintenance capability limits the use of preassembled building services components in complex office developments.
	Process Challenges	***Proposition 12***	The use of preassembled building services components limits the ability to make changes onsite in complex office developments.
		Proposition 13	Transport restraints limit the use of preassembled building services components in complex office developments.
		Proposition 14	Preparatory requirements limit the use of preassembled building services components in complex office developments.
		Propositions	**Statement – Attitude**
	Product Challenges	***Proposition 15***	The use of preassembled building services components reduces the flexibility of designs in complex office developments.
		Proposition 16	The use of preassembled building services components increases risk in complex office developments.
		Proposition 17	Clients' negative perception of preassembled building services components limits their use in complex office developments.

5.6 Findings – Stakeholders Influence the Use of Preassembled Building Services Components

Consultants

Consultants EA, MA, OM, AC, SK, and AS referred to the role of the consultant in the decision-making process when using PBSC in projects. This role is limited to working as a technical adviser for the client or as a representative of the client in the event of total authorisation from the client, especially in government projects. It was noted that the decision-maker is the client, while the consultant plays an important role in understanding the client's requirements and trying to meet them through designs, scope of work, and scheduling a project. Additionally, the consultants highlighted the role of the consultant in the supervision of the project and the importance of this role for the success of the project and conformity to the scope of work.

Contractors BS, MN, WS, MS, and SS noted the role of a consultant in the advisory process to select appropriate systems for a construction project, including PBSC. The consultant's role is to achieve the client's requirements in terms of designs and specifications. It was mentioned also that consultants are involved in providing clients with financial advice to meet the requirements of a project. Additionally, consultants are sometimes delegated to lead the works instead of the client in some government projects. The role of the consultant is limited to the technical aspects of the project in the preparation stage, including building services systems. Consultants may supervise the project if approved by the client.

> *Interviewee SS: The consultant is responsible for submitting his technical opinion. That is the only way he can affect the decision. But, the client is the one who makes the final decision whether to use these techniques or not. However, this is not the case if the consultant represents the client. In such a case, the consultant has the same authority as the client as stipulated in the contract.*

Proposition Synthesis: Consultants are often responsible for the technical side of the project. Their responsibilities includes designs, the scope of work, sample selection, etc. The client may assign the project's task to the consultant at times. Alsuliman (2014) states that the parties involved at the design stage in Saudi public construction projects are two main stakeholders: the public client and the design consultant. The consultants supervise the projects and ensure that the work is carried out according to the scope of work and approve the work once completed. Almazyad (2009) points out that the design consultants are responsible for delivering design quality that seeks the best possible satisfaction for client requirements and expectations. The consultants recommend to the client the type of building services system as well as the best execution method. The consultants were open to building techniques and had a desire to use preassembly in projects. Steinhardt and Manley (2016) note that architects slightly influence the decision regarding using prefabrication in Australia. Therefore, the *consultant is a significant variable* that can influence the use of PBSC in complex office developments.

Clients

Consultants EA, AC, AR, MA, SK, and AS noted that the client often decides whether to use PBSC in a project. Clients control the project budget and decision approval. Consultants might take over governmental project control in some cases, depending on the contract system. It was noted also that preassembly provides better consistency for the building services requirements of the client, especially regarding quality and time. The lack of client perception regarding preassembly might lead to redoing certain works because of standardisations. Clients are usually looking for lower prices, but preassembly does not offer competitive prices. In many cases, high prices cause a reluctance to use such technologies.

> *Interviewee MA: The client plays the most prominent role in the process of deciding whether to adopt these preassembled building services components or not – whether in terms of technical matters such as the designs or the financial matters such as project costs*.

Contractors BS, MN, AA, MS, and SS discussed the client as decision-maker regarding using PBSC. Client expectations must be achieved by any means of construction, including preassembly. The importance of the consultant's opinion to the client was mentioned, but the final decision remains the clients regarding whether to use preassembly. The consultants were technically mentioned regarding meeting the client's requirements in the designs and scope of work. They highlighted the responsibility of the consultant to explain the advantages of preassembly to the client and the technicality that can be added to the construction sector.

> *Interviewee AA: The client is the one who pays the value of preassembled building services components, and if they do not meet the client's expectations, it is very difficult for the consultant to adopt*

them without the client's consent. Here, we are talking about the Government as a client.

Proposition Synthesis: The client controls the project budget. The client has the right to choose the appropriate execution method for the project budget at her/his discretion. Alsuliman (2014) highlights that the public client is the main stakeholder in the design stage in Saudi public construction projects. Building services are a technical part of a construction project. Consequently, the client may need specialist advice, but the choice remains the client's. Preassembly is a strategic option for the client if the consultant can match it to the client's budget. Lu and Liska (2008) note that product quality improvement results from engaging the client in pre-project planning through to the conceptual design phase to minimise the possibility of onsite changes. The client controls the finance but may have a technical department that serves as a consultant. Scofield et al. (2009) point out the client's influence in the use of offsite methods in construction projects. Thus, the *client is a significant variable* that can be influential when using PBSC in complex office developments.

Government Regulators

Consultants EA, MA, OM, AC, and AS believed that the role of government bodies, particularly municipalities, is very important in adopting PBSC more fully with the current building codes. Other government agencies, such as the Ministry of Commerce and Industry, and related entities, such as the Saudi Electricity Company and the National Water Company, also play important roles in the promotion of preassembly through institutional and systematic support. The consultants pointed to the importance of the role of the Government and decision-makers in supporting the use of building services technologies in government projects, which will enhance their future use in private sector projects.

Contractors BS, AA, MS and SS highlighted the role of government regulators in using PBSC. They noted also the Government's efforts to promote the principles of energy rationalisation and support measures that can generally strengthen sustainability in public and private projects. The contractors noted the role of the government regulator in supporting modern technologies in the construction sector and in keeping pace with global development in this field. They referred to the level of building services technologies in the Saudi market and the need for much reinforcement from the Government for approvals on governmental projects. This enhancement includes facilitating the process of supporting industrial facilities and providing facilities for this sector.

Proposition Synthesis: Government regulators have a major influence on the use of preassembly. Blismas and Wakefield (2009) report that regulatory constraints are expected to limit the level of OSM use in Australia, similar to the UK and the US. Licensing for the preassembly industry requires government approval as a first step. The municipality's approval of preassembly systems, including building services, is controlled by government regulators. Also, most of the projects are owned by the Government and, therefore, the use of preassembly can be promoted through these projects. Almutairi (2015) states that the participants in his study agreed to adopt OCT if the resources were available, including regulatory resources to monitor the industry and enforce outcomes that meet social needs. The Government supports the rationalisation of energy and water, which is a characteristic of the essence of preassembly and, therefore, should be promoted. Steinhardt and Manley (2016) claim that the Government and regulatory bodies influence the decision regarding using prefabrication in Australia. Hence, the *government regulator is a significant variable* that can influence the use of PBSC in complex office developments.

Suppliers

Consultants AR, MA, SK, and AS pointed to the role of suppliers in the process of influencing the use of PBSC. From the point of view of the consultants, the role of the suppliers is limited to marketing preassembly services to consultants to enhance the importance and quality of preassembly for public buildings and private enterprises and striving to compete with the prices of traditional systems.

Contractors BS, AA, MS, and SS noted the role of suppliers in raising awareness of PBSC in the construction sector. The contractors believed that it is important for suppliers to transfer innovation to the construction sector as well as the ability to feed the needs of the Saudi market with the appropriate quantities of technology. The contractors noted that there is a technical relationship between the suppliers and the subcontractors regarding PBSC. This technical relationship is important to gain client trust and provide a good impression to the construction sector.

Proposition Synthesis: Suppliers have a major role in the marketing of preassembly building services, and they connect the factories and the consultants. Pan et al. (2007) state that cooperation between house-builders and manufacturers and suppliers is weak in many cases. Suppliers market PBSC; some are locally made, others are imported. The supplier has a variety of components to sell; whereas, the factory often produces specific components and, thus, does not have the know-how regarding other products. Blismas and Wakefield (2009) state that OSM requires specific skills and that it is the OSM supplier’s duty to train their own contractors. Therefore, suppliers can analyse the market sales of preassembly. The supplier has the ability to provide manufacturers with best-selling products. Steinhardt and Manley (2016) investigated the influence of suppliers on the use of prefabrication methods in Australia. Thus, *suppliers are a significant variable* that can influence the use of PBSC in complex office developments.

Subcontractors

Consultants EA, MA, OM, and AC believed that the role of the subcontractor is secondary, because they follow the general contractors regarding the use of PBSC. It was noted that the subcontractor's contractual relationship is unclear in terms of decision-making; whereas, the general contractor plays a key role in the event of adopting preassembly in construction projects. Subcontractors influence the technical side of preassembly. This influence includes the quality provided and enhancing preassembly's use in the future. With respect to the nature of construction project contracts, the general contractor is not obliged to use certain techniques if an alternative is available. This aspect is stipulated in the procurement regulations of the Kingdom of Saudi Arabia.

Contractors BS, AA, MN, and SS referred to the role played by the subcontractor to provide better services when PBSC are used. This role is not influential in the decision-making process for adopting preassembly, but remains limited to the relationship between the general contractor and the subcontractor. The contractors pointed to the convergence of the role played by the subcontractors and suppliers through the marketing policies and the provision of techniques with good technical capabilities. They further pointed out the risks posed by the adoption of certain techniques based on very few subcontractors, as they might cause delays to construction projects.

Proposition Synthesis: The specialised subcontractor is key to completing the construction work in a technically correct manner. Almutairi (2015) states that the final key player in the process of innovation is the subcontractor. Specialised subcontractors' relationships with factories are often good, and, therefore, they have sufficient knowledge to provide general contractors with the needs of the project at the bidding stage. The specialised subcontractor is generally responsible for installation onsite; yet, sometimes, general contractors also perform this task. Goodier and Gibb (2007) note that many of the M&E services in UK building projects are installed by specialised subcontractors. The quality of the final installation is also the responsibility of the specialised subcontractor. The task of specialised subcontractors is technical at the stage of implementation, but they may make some recommendations to the general contractor regarding the preference of certain preassembly components. Steinhardt and Manley (2016) investigated the influence of subcontractors regarding using the prefabrication methods in Australia. Therefore, *subcontractors are a significant variable* that can influence the use of PBSC in complex office developments.

A summary of propositions that represent stakeholder influence is shown in Table 5-6.

Table 5-6 Summary of SN (stakeholder influence) (Source: Author)

	Propositions	Statement – Subjective Norm
Stakeholders	***Proposition 18***	Consultants influence the decision on use of preassembled building services components in complex office developments.
	Proposition 19	Clients influence the decision on use of preassembled building services components in complex office developments.
	Proposition 20	Suppliers influence the decision on use of preassembled building services components in complex office developments.
	Proposition 21	Subcontractors influence the decision on use of preassembled building services components in complex office developments.
	Proposition 22	Local building regulators influence the decision on use of preassembled building services components in complex office developments.

5.7 Findings – External Contextual Influence on the Decision to Use Preassembled Building Services Components

Finance Support

Consultants EA, MA, OM, AC, and AR noted that financial support largely controls the use of PBSC. Preassembly facilities are high cost because technology manufacturing plants require financial support. The issue of licensing these factories is also very important for obtaining financial support. Therefore, the consultants believed that financial support is very important through the banking sector, which is subject to government decisions; thus, creating more producers and breaking the monopoly. There is an urgent need to work on a programme that supports the production plants of PBSC.

Contractors BS, MN, WS, and SS regarded the financial support provided by the Government as the first source for industrial projects. The contractors believed that there is a great need for financial support for the PBSC industry due to the shortage of factories and, thus, expensive products. Financing preassembly plants is costly. The contractors, therefore, referred to the need for the Government to financially support the Ministry of Industry to meet all industrial requirements. The Government should support local products also; thus, enhancing the competition between local and foreign producers by increasing the number of factories in the kingdom. More factories locally will generate active price competition, and since government projects accept the lowest prices, a competitive environment between modern and traditional technologies can be created.

Proposition Synthesis: Financial support plays an important role in serving the industry by creating an appropriate number of preassembly factories. Lu and Liska (2008) report that banking or other financing institutions are ranked as the third largest challenge for using offsite construction in the US. Preassembly factories are high in cost and often exceed the financial ability of traders and investors. Therefore, there is a need for support from the banking sector to help establish preassembly factories. Additionally, Goodier and Gibb (2007) claim that obtaining finance limits supplier ability to expand the use of offsite techniques. The banking sector is controlled by the Government; therefore, the Government is a supporter of the preassembly industry. In addition to bank support, the use of offsite techniques requires government approval, such as licensing and industrial location. Blismas and Wakefield (2009) report that obtaining finance for OSM in Australia is difficult. Therefore, *financial support is a significant variable* that can control the use of PBSC in complex office developments.

Government Regulations

Consultants EA, MA, OM, and AS believed that the application of PBSC depends on the support of government systems for these technologies. Government support takes several forms; the most important of which is providing the necessary facilities to support investment in the industry. The presence of a larger number of factories producing these technologies would create competition for supplying government projects at competitive prices. The Saudi contracts system depends on the lowest bidder, and the contractor is not required to produce a particular product but is expected to perform according to the agreed specifications on the approved scope of work. Moreover, based on the contracts system, the contractor cannot be tied to a specific supplier.

Contractors BS, KS, AA, and SS noted that larger government projects with enormous budgets can accommodate the application of preassembled building techniques components. However, the organisation and government bodies play a significant role in either the adoption or rejection of these techniques. Therefore, the Government's support is essential to the success of preassembly, especially as prices are high compared with traditional methods, which are sometimes much cheaper. Investment in these technologies is difficult if there is no market to support their spread. Overall, government projects depend on the lowest price; thus, these technologies need a great deal of support.

Proposition Synthesis: Government regulations play a key role in promoting preassembly through several aspects; the most important of which is investment support. Blismas and Wakefield (2009) state that the regulatory constraints include qualifications, codes, and local regulations. Licensing to produce PBSC is also under government control. Municipalities have the right to allow the use of modern techniques in construction projects. Adopting preassembly in government projects enhances the spread of their use in construction projects. Alsuliman (2015) pointed out that the majority of construction projects apply traditional procurement methods in Saudi Arabia, which mainly depend on selecting the lowest price. Furthermore, the contracts system also prevents the adoption of specific techniques to promote competition. Thus, construction projects do not rely on preassembly because of the absence of competition between products. Zhai et al. (2014) state that regulations in China are inadequate regarding the use of OSP methods. Thus, *government regulation is a significant variable* that can control the use of PBSC in complex office developments.

Skilled Labour

Consultants EA, MA, OM, SK, and AS believed in the importance of skilled labourers in the production of PBSC. The consultants pointed out that the Saudi construction market is full of skilled labourers to accomplish building services in traditional ways, but has fewer numbers regarding preassembly. Therefore, the shortage in skilled labour availability automatically impedes the growth of preassembly in construction projects. The consultants noted that skilled workers are concentrated in the main cities of the Kingdom. They believed that Saudi Arabia's technical workforce is highly skilled, but the presence of skilled labour in major cities increases project costs in non-major cities.

Contractors BS, AA, MS, and SS thought that skilled labourers are widely available in the construction sector. Preassembled building services components require best practice to create transparency with clients and end-users. Skilled labourers in manufacturing plants are believed to be better than conventional skilled labourers in the construction sector, and are believed to play an important role in producing better quality products within a shorter time. The contractors referred to some government projects in which a request for certain products was made from a specific supplier or factory due to the presence of skilled labour and a good reputation. Generally, skilled labourers are more available in the contracting market than in the manufacturing market due to a shortage of preassembly plants.

Proposition Synthesis: Skilled labourers are available in the market to carry out construction tasks using traditional methods. Zhai et al. (2014) state that the high availability of cheap labour promoted labour-intensive housing construction in China. However, there is a shortage of preassembly factories, and, thus, a shortage of skilled labourers practising preassembly. Goodier and Gibb (2007) recognise that a skills shortage was the reason behind using offsite construction in southern England. Skilled labourers are an important part of the overall quality process in factories. Consequently, skilled labourers for producing PBSC are considered more qualified technically than skilled labourers with conventional methods. Steinhardt and Manley (2016) note that the current shortage of specific skills training in Australia with prefabrication experience was difficult to fund and administer without governmental support. In some projects, the client requests certain preassembly products due to the quality of the manufacturer's product and the efficiency of the products. Therefore, *lack of skilled labour is a very significant variable* that can control the use of PBSC in complex office developments.

Production Capacity

Consultants EA, MA, OM, AC, and AR believed that the ability to meet the market needs of PBSC depends on the capacity of production plants. The estimated production capacities are very low compared with the size of the market. The shortage of reasonable manufacturing capacity increases the risk of using preassembly. Consequently, consultants often prefer to use traditional methods to avoid the risk of poor production capacity of preassembly technologies. Low production capacity increases the time of the manufacturing stage due to high demand and poor production. Therefore, the consultants described a complex challenge that requires strategic plans to support preassembly technology industry and robust marketing with government projects, which eventually increases investment in the technology industry.

Contractors BS, AA, MS, and SS highlighted the lack of factories producing preassembly products, which causes a weakness in preassembly production. Production capacity cannot be increased without regulation support, funding support, and other requirements for success. There are some imported products used in construction projects, but the Saudi contracts system mainly supports local products. The production capacity of HVAC systems is effective, but other systems, such as fire systems and wiring, require reinforcement. The contractors pointed also to certain cases in which preassembly manufacturers were especially established to supply specific construction projects. An example of such cases includes the Social Insurance Housing project in Riyadh.

Proposition Synthesis: Preassembly production capacity is weak in the Saudi construction market. This weakness is a result of several factors; the most important of which is the small number of factories. Goodier and Gibb (2007) note that the manufacturing capacity limits suppliers from expanding. Government and financial support also play an important role in why there are so few producers. Steinhardt and Manley (2016) recognise the importance of governmental support in the funding and administering of prefabrication in Australia. Weak production capacity reduces the chances of winning bids in government projects because of the risks, such as technical faults in the factory. Alsuliman (2014) notes that the majority of Saudi construction projects were awarded to traditional procurement methods, which depend on the lowest price. Any manufacturing problem can weaken the level of client satisfaction with preassembly products. Zhai et al. (2014) point out that supplier capacity is related to risks such as 'loss of factory production slot/production capacity', 'suppliers failing to deliver on time', and 'manufacturer insolvency'. Therefore, *manufacturing capacity is a significant variable* that can control the use of PBSC in complex office developments.

A summary of propositions that represent external contextual control is in Table 5-7.

Table 5-7 Summary of PBC (external contextual control) (Source: Author)

	Propositions	Statement – Perceived Behavioural Control
External Contextual	***Proposition 23***	Easier financing impacts the use of preassembled building services components in complex office developments.
	Proposition 24	Governmental rules impact the use of preassembled building services components in complex office developments.
	Proposition 25	Manufacturing capacity impacts the use of preassembled building services components in complex office developments.
	Proposition 26	Skilled craft workers impact the use of preassembled building services components in complex office developments.

5.8 Summary

Chapter 5 addressed the analysis of the qualitative method findings. As mentioned previously, this research adopted the TPB model. First, the interviews were analysed using Nvivo and grounded theory. The profiles of the interviewees were addressed, and the participants selected as highly experienced practitioners in PBSC, based on pre-set criteria (Section 4.9.3). The interview questions are in Appendix B. The interview instrument included three questions based on the TPB as attitudes, SN, and PBC. The answers to these questions were given and recorded in Arabic, transcribed, and then translated into English. The English transcriptions were coded based on grounded theory and transformed into propositions (Table 5-4, Table 5-5, Tabel 5-6 and Table 5-7).

The findings from the interviews revealed that the attitudes towards PBSC include nine benefits and eight challenges. The benefits were classified into three categories: project management, site management, and sustainability benefits. Similarly, the challenges were classified into three categories: cost implication, process, and product challenges. Furthermore, five stakeholders and four external contextual controls were noted to influence the decision to use PBSC.

Chapter 5 presented the findings of the interviews that were constructed based on the TPB, as explained in Section 4.9.2. These findings were presented as propositions and discussed using the literature, then used to construct the questionnaire instrument. These propositions were seminal for the quantitative method of data collection, as explained in Section 4.9.5. The questionnaire survey generalised these findings (propositions) and then statistically analysed them (see Chapter 6). According to the methodology chapter, these propositions are assessed via a survey and validated through case studies, which are explained and discussed further in the following chapter.

CHAPTER 6: ANALYSIS AND DISCUSSION

6.1 Introduction

Chapter 6 presents the results of the statistical tests undertaken on the data collected from the survey. Statistics are deemed to be the art of knowledge that presents data into conclusions (Ross, 2004). Furthermore, this chapter addresses the responses to the questionnaires and discusses the outcomes and results. The descriptive analysis in Section A concerns the company information. Section B of the questionnaire measures the opinions regarding the applications of PBSC in complex office developments. A statistical analysis is provided to compare means between consultant and contractor responses. The reasons for not using PBSC are analysed also. Additionally, three case studies are analysed to further validate the results of the study.

This chapter focuses on a number of issues: descriptive statistics, the reliability of the questionnaire, the descriptive information, the type of PBSC (nature and extent), the opinions regarding using PBSC, as well as the reasons for not using PBSC. The opinion section of the questionnaire is based on the concept of the TPB. The opinions include direct and indirect measures of the attitudes towards using PBSC in complex office developments, the types of stakeholder influence regarding PBSC adoption decisions, and the types of contextual influence impacting PBSC adoption decisions.

6.2 Introduction to Quantitative Analysis and Discussion

This research explores the influence of consultants and contractors towards using PBSC in complex office developments in Saudi Arabia. The TPB was used as a means of predicting that influence and intention in terms of attitudes, stakeholder influence, and external contextual control (Section B of the questionnaire). The results are discussed in depth.

This section covers various elements, and each focuses on one aspect of the analysis process. Part 1 analyses data generated from the questionnaires to investigate the perceptions of implementing PBSC in complex office developments in Saudi Arabia. Part 2 explores the relative importance for consultants and contractors of a number of key factors that are examined in three groups based on the TPB: a) TPB attitudes, which measure process and technology factors; b) TPB SN, which measure the influence of stakeholder factors; and c) TPB PBC, which measures the influence of external contextual factors. Part 3 explores potential reasons for not using PBSC in complex office developments in the Saudi context.

Moreover, this section provides a descriptive analysis of the main characteristics of firms, using descriptive statistics (SPSS), and inferences are statistically drawn to achieve the main research objectives.

6.2.1 *The Reliability of the Questionnaire*

The consistency between answers on a given scale identifies reliability (e.g. to what extent the answers within a scale are consistent with each other) (Field, 2011). In this study, reliability (i.e. consistency) is measured using Cronbach's alpha. Cronbach's alpha uses one scale (e.g. factors related to PBSC including attitudes, stakeholder influence, and external contextual control) that encompasses 26 factors. These factors are 16 key attitudes, five key stakeholder influences, and four key external contextual controls. The SPSS reveals that there is almost 74% (0.735) consistency between answers when all 26 themes were employed simultaneously. Thus, the construct is considered reliable due to a reasonable consistency between answers, with a rating of more than 0.7 achieved. Furthermore, the test-retest for the indirect measures indicates that the correlation is significant at the 0.05 level (two-tailed) (Appendix C).

Cronbach's alpha	Items
0.735	26

6.3 Descriptive Analysis of the Questionnaire

The descriptive analysis labels the main features of the data in a quantitative (numeric) manner. The quantitative data are the recorded data that were provided in the several sections and subsections of the questionnaires.

Initially, the quantitative data were presented in either table format or charts and other graphics. Every data presentation presents numerical scores and percentages according to the associated categories as a summary of the specific grouping of data. This format allows the researcher to analytically describe and interpret data using descriptive statistical procedures (i.e. frequency, percentage, rank) in addition to the visual presentation of data (tables, charts, and graphics) in numbers and percentages.

The descriptive analysis presents each company's information (Section A of the questionnaire) regarding complex office developments in Saudi Arabia.

6.3.1 *Company Information*

This section presents the overall personal and company features provided by the respondents in the questionnaire. All respondents were required to answer the following sections: 1) their company type; 2) their profession; 3) location of their head office; 4) their years of experience in general; and 5) a guide question regarding whether they have ever applied PBSC in complex office developments.

6.3.2 *Type of Company*

Table 6-1 and Figure 6-1, below, reveal the responses to the company type (after removing the missing questionnaires) as follows: 51% of the participants were consultants, and 49% were contractors. The total number of responses was 258. The response rate was 38% consultants and 39% contractors.

Table 6-1 Type of company

	Initial	Respondents	Unusable	Net respondents
Consultants	338	154 (52%)	22	132 (51%)
Contractors	323	144 (48 %)	18	126 (49%)
Total	661	298 (100%)	40	258 (100%)

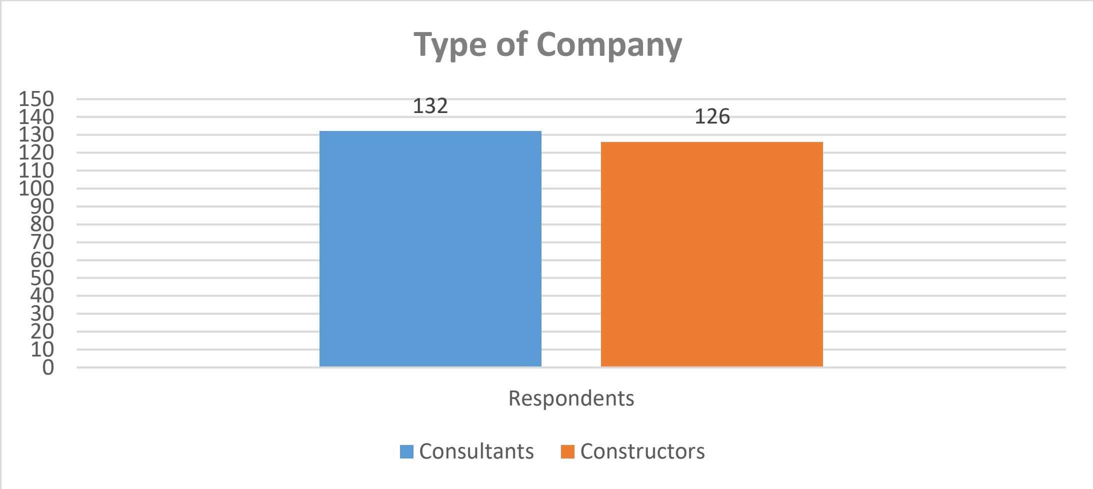

Figure 6-2 Type of company

6.3.3 *Participants' Professions*

Table 6-2 and Figure 6-3 below reveal that the participants' professions were as follows: the majority were electrical engineering (30% consultants and 19% contractors); then, mechanical engineering (17% consultants and 26% contractors); civil engineering (17% consultants and 14% contractors); project managers (9% consultants and 20% contractors); cost engineers (8% consultants and 13% contractors); and architects (15% consultants and 6% contractors).

Table 6-2 Participants' professions

Numerical								
	Arct	**EE**	**CE**	**ME**	**PM**	**CostE**	**Other**	**Total**
Consultants	20 (15%)	40 (30%)	23 (17%)	22 (17%)	12 (9%)	11 (8%)	0 (0%)	132
Contractors	8 (6%)	24 (19%)	18 (14%)	33 (26%)	25 (20%)	17 (13%)	1 (1%)	126

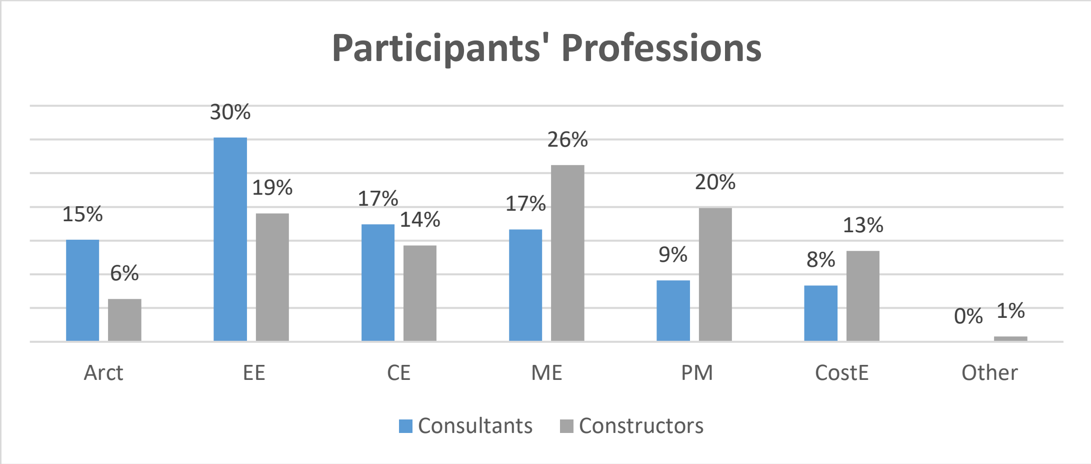

Figure 6-3 Participants' professions

6.3.4 *Location of Company*

Table 6-3 and Figure 6-4, below, reveal the company location of the respondents. The majority were located in Riyadh (40% consultants and 38% contractors); followed by Makkah (37% consultants and 32% contractors); and Eastern province (23% consultants and 38% contractors).

Table 6-3 Location of company

	Riyadh	**Makkah**	**Eastern**	Total
Consultants	53 (40%)	49 (37%)	30 (23%)	132
Contractors	48 (38%)	40 (32%)	38 (30%)	126

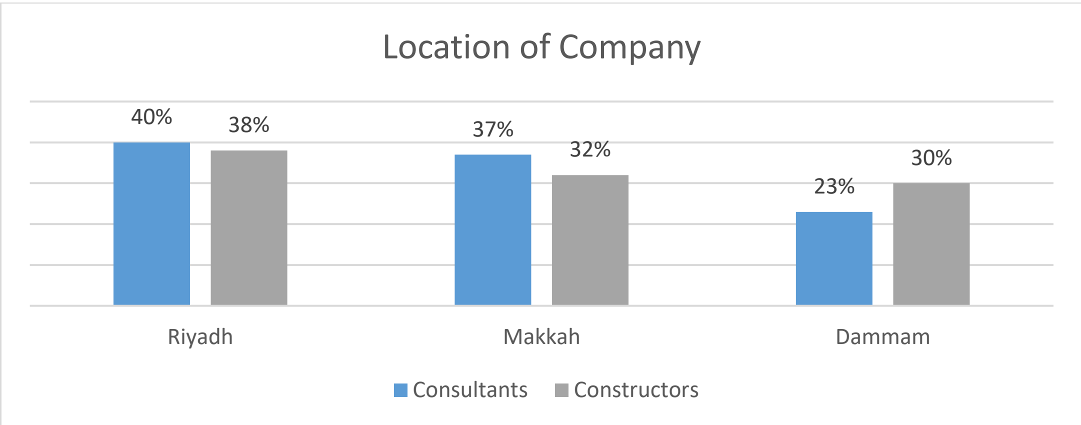

Figure 6-4 Location of company

6.3.5 *Years of Experience*

Table 6-4 and Figure 6-5, below, reveal that the respondents' years of experience are as follows: the majority had 10-15 years of experience (55% consultants and 55% contractors); followed by 15-20 years of experience (36% consultants and 41% contractors); and then more than 20 years of experience (9% consultants and 4% contractors).

Table 6-4 Years of experience

	10-15	15-20	20+	Total
Consultants	72 (55%)	48 (36%)	12 (9%)	132
Contractors	69 (54%)	52 (42%)	5 (4%)	126

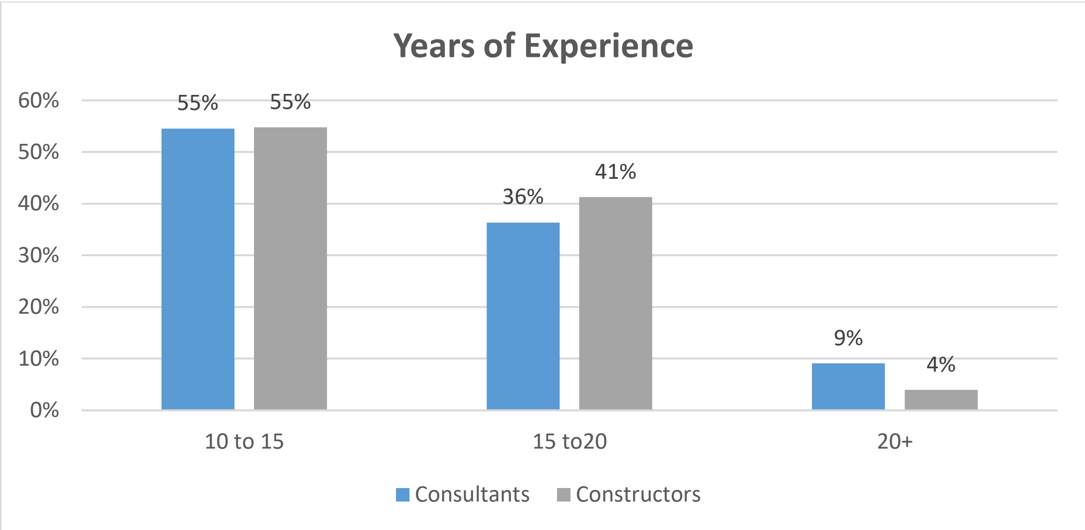

Figure 6-5 Years of experience

6.4 Objective 1: Explore the Current Nature and Extent of Utilisation of Preassembled Building Services Components

Objective 1 explores the current nature and extent of utilisation of PBSC in complex office developments. This objective was first discussed in the literature review and then explored using the questionnaire results. The analysis and discussion are presented next.

6.4.1 *Applications of Preassembled Building Services Components in Office Developments (Analysis RO: 1)*

The primary focus of this research is PBSC. Therefore, it was essential to indicate the participants experience by either a (yes) or a (no) regarding PBSC technology. Table 6-5 and Figure 6-6, below, reveal that the applications of PBSC in office developments among respondents are as follows: the majority were classified as non-practitioners of PBSC (77% consultants and 78% contractors); with practitioners of PBSC in office developments being 23% consultants and 22% contractors.

Table 6-5 PBSC Practitioners and non-practitioners

	Used PBSC	Not Used PBSC	Total
Consultants	31 (23%)	101 (77%)	132
Contractors	29 (22%)	97 (78%)	126

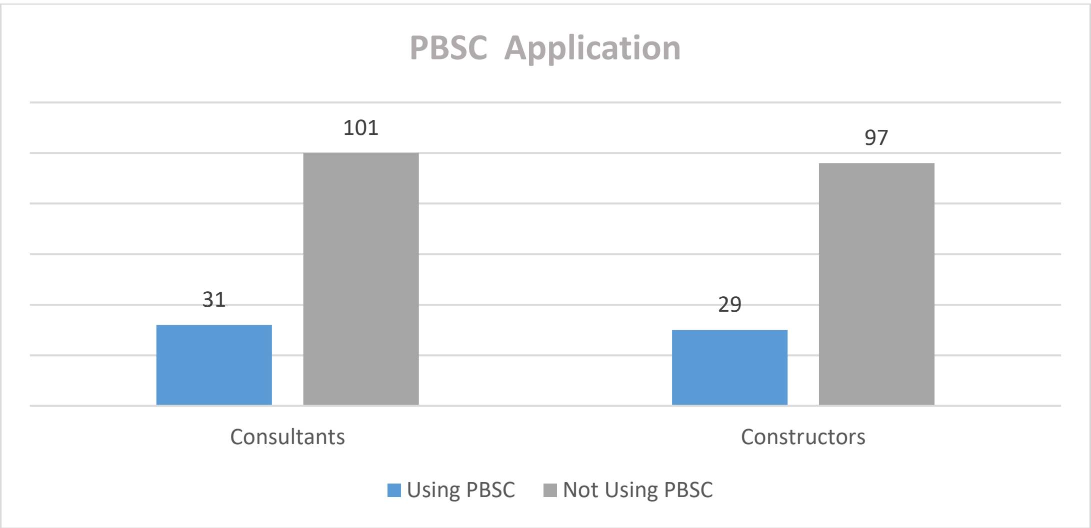

Figure 6-6 PBSC Practitioners and non-practitioners

6.4.2 *Opinion on Using Preassembled Building Services Components – Statistical Analysis (Analysis RO: 1)*

This section describes the opinions of the participants who applied PBSC in complex office developments in Saudi Arabia. The types of PBSC applications were queried to determine their levels. This section was divided into direct and indirect questions based on the concept of the TPB. The direct questions measured the three dimensions of the theory: attitude, SN, and the PBC (see Section 3.2). The indirect questions measured each predictor in terms of its likelihood and the outcome. More details of the analysis are presented in the following section regarding Part B of the questionnaire.

6.4.3 *Types of Preassembled Building Services Components Applications*

The participants were asked to label their level of application of PBSC in complex office developments in Saudi Arabia. The participants were given a scale of four levels to use. All applications are listed in the table, below. Table 6-6 and Figure 6-7 reveal that the types of PBSC application the respondents used are as follows: the majority used prefabricated horizontal/vertical distribution (81% consultants and 77% contractors); followed by terminal unit preassembly (69% consultants and 70% contractors); then, preassembled building services units/modules (66% consultants and 47% contractors); and finally, integrated services with modular buildings (13% consultants and 10% contractors).

Table 6-6 Types of PBSC application

Types of PBSC Application	Consultants	Contractors
Integrated services with modular buildings	4 (13%)	3 (10%)
Preassembled building services units/modules	21 (66%)	14 (47%)
Prefabricated horizontal / vertical distribution	26 (81%)	23 (77%)
Terminal unit preassembly	22 (69%)	21 (70%)
Total	**31**	**29**

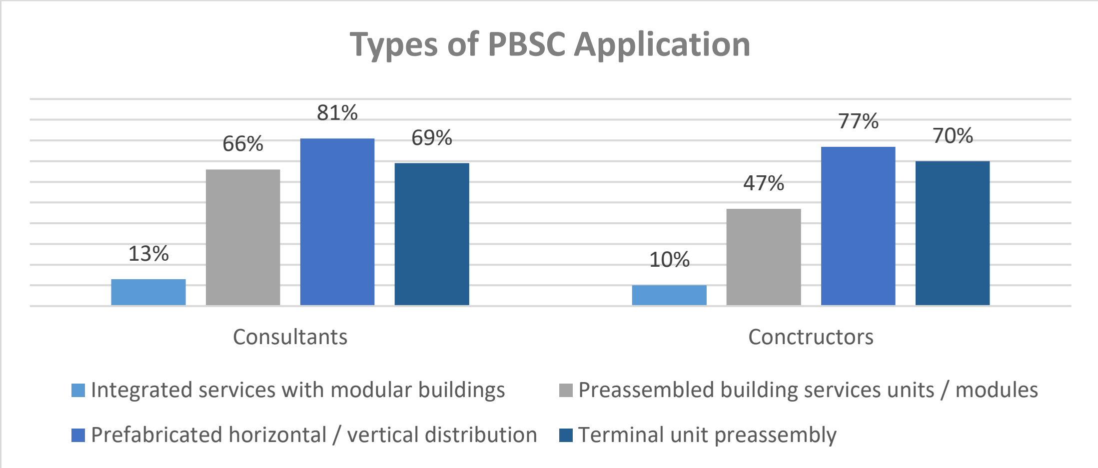

Figure 6-7 Types of PBSC application

6.4.4 *The Nature and Extent of the Preassembled Building Services Components Applications* (Discussion RO: 1)

The results of the questionnaire reveal that the level of applications of PBSC by both consultants and contractors is low; less than a quarter of respondents used PBSC in complex office developments. The majority of PBSC types were prefabricated horizontal/vertical distribution and terminal unit preassembly. The literature review also indicated that the application of preassembly is low (Pan, 2006; Lu, 2007; Zhai et al., 2014). This low performance implicitly including the PBSC applications, which is in relation to the main categories of 1) preassembly, 2) modular buildings, and 3) hybrid system. This finding reflects an earlier Buildoffsite market value study by Goodier and Gibb (2005), which notes that, in 2004, the preassembly market in the UK represented only 2.1% of the total value of the construction sector, including renovation. Additionally, the survey results of this research are consistent with an earlier research survey, by Pan (2007), of the top 100 UK house-builders, in which one-third (33%) of the responding firms confirmed that they had used preassembly, including complete modular building, kitchen pods and flat packs, toilet and bathroom pods and flat packs, and offsite plant rooms. Furthermore, this result agrees with the study of Lu (2008), which reports that the level of using OCT in the building sector in the US construction industry was low, being limited to preassembled trusses and precast concrete products.

Also, Blismas and Wakefield (2009) report that it was unsurprising to learn that OSM is not widespread, based on the interviews and workshops undertaken in the Australian context.

6.5 Objective 2: Assess the Perception of Consultants and Contractors Towards Using Preassembled Building Services Components

Objective 2 assesses the perception of consultants and contractors towards using PBSC in complex office developments in the framework of the TPB, including the following:

A) Attitudes: to measure benefit and challenge factors.

B) Subjective norm: to measure the influence of parties' factors.

C) Perceived behavioural control: to measure the influence of external contextual factors.

This objective was first highlighted in the literature review and then assessed using the interviews and the questionnaire results. Further discussion is presented next.

6.5.1 *Statistical Analysis (RO: 2 and 3)*

This part of the questionnaire focuses on the participants' opinions regarding the attitude towards using PBSC, which is associated with a general assessment of the benefits and challenges. Nine benefits and seven challenges were derived from the qualitative approach that needed to be measured by the participants. The TPB was applied. Each variable was measured regarding outcome and likelihood, and the participants were asked to rate their levels as either 'likely' or 'unlikely' and to indicate either a 'positive' or 'negative' outcome by means of a five-point Likert scale. Furthermore, the independent t-test, as a statistical analysis, was used to compare means among both consultants and contractors, to rank the variables, and to identify the significance of the relationship. The attitudes, stakeholder influence, and the external contextual control are analysed according to the recommendation of the TPB (see the manual and Appendix A) by Francis et al. (2006) under the following subheadings.

6.5.2 *Attitude Towards Using Preassembled Building Services Components in Complex Office Developments*

As discussed in the methodology (Chapter 4), the propositions that need to be tested in this study contain three units: 1) determining consultant responses to each proposition statement regarding using PBSC in complex office developments; 2) determining contractor responses to each proposition statement regarding using PBSC in complex office developments; and 3) comparing whether the responses of these two groups were significantly different from each other by using an independent samples t-Test assuming equal variances. The overall level of significance used in this study was 0.05.

Furthermore, the purpose is to achieve the third objective of the research, which is to examine the relationship between consultant and contractor perceptions regarding using PBSC in complex office developments in Saudi Arabia: *Did consultants and contractors perceive each benefit, challenge, stakeholder influence, or external contextual control significantly differently from each other at the 0.05 level of significance?.*

The procedure for analysing a proposition result is as follows: since [P] is greater than the significance level [$\alpha = 0.05$], we should not reject the null hypothesis of Levene's test. On the current evidence, we cannot reject that both consultants and contractors have equal variance regarding the tested variable, and vice versa.

Since the null hypothesis was not rejected, we need to check the last few columns in the upper row, which reveal no difference in means between consultants and contractors where [P] is greater than [$\alpha = 0.05$]. Therefore, we should not reject the null hypothesis t-Test. Consequently, we cannot reject that both consultants and contractors have equal means regarding the tested variable, and vice versa.

Project Management Benefits

The project management benefits of using PBSC include, 1) improvement of product quality; 2) increase in the speed of construction; 3) reduction of construction cost (Section 5.4.1). These results confirm the findings/results in a number of earlier and recent studies.

Examining Proposition Statement 1: The use of preassembled building services components increases product quality in complex office developments.

[P = 0.26] is greater than the significance level [α = 0.05] for Levene's test (Table 6-7), and [P = 0.437] is greater than [α = 0.05] for t-Test.

Table 6-7 Proposition t-Test for perceptions of quality of product

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Quality of Product	Equal variances assumed	1.27	0.26	-0.78	60.00	0.44	-0.11	0.14	-0.40	0.17
	Equal variances not assumed			-0.79	56.46	0.43	-0.11	0.14	-0.40	0.17

There was no significant difference in the scores of the consultants and contractors: t (60) = -0.783, p > .05. These results suggest that PBSC have no effect on the quality of product, indicating that, when using PBSC in complex office developments, the quality of product does not increase.

Table 6-8 Compare median for perceptions of quality of product

Increases quality of product		Statistics			
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	4.0	0.5	4.0	0.5

As Table 6-8 reveals, the median of consultants (*Mdn* = 4.0, *IQR* = 0.5) and of contractors (*Mdn* = 4.0, *IQR* = 0.5) indicates that both the consultants and contractors ‘highly agreed’ that the use of PBSC *increases product quality* in complex office developments. Furthermore, this study revealed that the quality of products is the perceived main benefit, as all of the participants in the interviews confirmed that they had used PBSC for quality purposes. Moreover, the highest survey result concerned the quality of the product. This result is consistent with the study by Almutairi (2015), which notes that the quality of preassembly in Saudi Arabia was a major benefit. Additionally, the improvement of product quality as a benefit was also emphasised in the studies of Parry et al. (2003), Gibb and Isack (2003), Goodier and Gibb (2004), Venables et al. (2004), Pan et al. (2007), Lu (2007), Goulding, et al. (2012), and Steinhardt and Manley (2016). Preassembly is produced under a high quality control (Arif and Egbu, 2010). The quality of the product in PBSC refers to the quality of design, the quality of production, and the use of means of compliance, such as regulatory codes by independent agencies. The quality of preassembly is improved through standardised design and professional supervision onsite, which leads to avoiding rework activities and change of orders (Tam et al., 2006; Goodier and Gibb, 2007). Furthermore, computer software (e.g. BIM) assists in confirming the alignment and precision of blueprints to maintain both preassembly and onsite quality of installation (Blismas, 2007; Russell et al., 2012).

Examining Proposition Statement 2: The use of preassembled building services components improves the speed of construction in complex office developments.

[P = 0.971] is greater than the significance level [α = 0.05] for Levene's test (Table 6-9), and [P = 0.083] is greater than [α = 0.05] for t-Test.

Table 6-9 Proposition t-Test for perceptions on the speed of construction

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Speed of Construction	Equal variances assumed	0.001	0.971	-1.761	60	0.083	-0.35	0.1988	-0.748	0.0476
	Equal variances not assumed			-1.758	59.178	0.084	-0.35	0.1991	-0.748	0.0484

There was no statistically significant difference in the scores of consultants and contractors: t (60) = -1.761, p > .05. These results suggest that PBSC make no difference in the relationship regarding the speed of construction when using PBSC in complex office developments.

Table 6-10 Compare median for perceptions of the speed of construction

Improve the speed of construction		Statistics			
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	4.0	1.0	4.0	1.0

As Table 6-10 reveals, the median of consultants (*Mdn* = 4.0, *IQR* = 1.0) and of contractors (*Mdn* = 4.0, *IQR* = 1.0) indicates that the consultants 'moderately agreed' and the contractors 'highly agreed' that the use of PBSC *increases the speed of construction* in complex office developments. These results confirm the finding of the study by Pan (2006), which notes that the top 100 house-builders in the UK used preassembly to increase the speed of construction. Also, Steinhardt and Manley (2016), in a study of Australian house-builders, state that prefabrication's ability to increase construction speed was clearly recognised by respondents, but this was not simply interpreted as reductions in overall project costs. Preassembly improves the speed of construction, which is one of the most significant benefits for the construction industry (Blismas, 2007; Arif and Egbu, 2010). Several studies (Blismas et al., 2005; Goodier and Gibb, 2007; Arif and Egbu, 2010) report that the reduction of work time is one of the main benefits of preassembly. Increasing the speed of construction is a main benefit highlighted in this present study from both the interviews findings and the survey results. This increase has many causes, such as relying on leading professionals in the industry sector and using repetitive designs. In complex office developments, the benefit of time reduction is very important. Extreme weather impacts conventional site work (Larsson and Simonsson, 2012); whereas, applying the preassembly method reduces the risks of delay in a construction project since such components are produced in a controlled environment (Manley et al., 2009). Productivity difficulties often occur because of the interfacing of many trades onsite (Blismas and Wakefield, 2009). Preassembly addresses this issue to reduce schedules and improve productivity (Manley et al., 2009).

Examining Proposition Statement 3: The use of preassembled building services components reduces construction cost in complex office developments.

[P = 0.741] is greater than the significance level [α = 0.05] for Levene's test (Table 6-11), and [P = 0.191] is greater than [α = 0.05] for t-Test.

Table 6-11 Proposition t-Test for perceptions on construction cost

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Construction Cost	Equal variances assumed	0.111	0.741	-1.322	60	0.191	-0.275	0.208	-0.691	0.1411
	Equal variances not assumed			-1.315	57.067	0.194	-0.275	0.2091	-0.694	0.1438

There was no statistically significant difference in the scores of consultants and of contractors: t (60) = -1.322, p > .05. These results suggest that PBSC make no difference to the relationship regarding construction cost in complex office developments.

Table 6-12 Compare median for perceptions of construction cost

Improve construction cost		Statistics			
N Valid	60	Consultants		Contractors	
		Mdn	*IQR*	*Mdn*	*IQR*
Missing	0	3.5	0.5	4.0	1.0

As Table 6-12 reveals, the median of consultants (*Mdn* = 3.5, *IQR* = 0.5) and of contractors (*Mdn* = 4.0, *IQR* = 1.0) indicates that the consultants 'moderately agreed' and the contractors 'highly agreed' that the use of PBSC *reduces construction cost* in complex office developments. Therefore, the reduction of construction cost, in this study, is the main benefit. This result is consistent with the study by Lu (2007) concerning general contractor and designer perceptions of using preassembly construction techniques in the US, which confirmed that the utilisation of preassembly construction techniques reduces construction cost. Construction cost refers to the expense of all labour, materials, equipment, and overheads (Lu, 2007). Additionally, the cost-savings are involved in every process of the preassembly, including the design, manufacturing, and construction. Furthermore, the material savings can occur during the manufacturing and procurement processes, as well as labour savings during the construction process (Larsson and Simonsson, 2012). Several studies (Johnson, 2007; Tam et al., 2006; CII, 2002) report that construction cost is one of the main benefits of preassembly. Javanifard et al. (2013) mainly refer to construction cost-savings through lowering the cost of preassembly labour. Moreover, construction cost-savings can take many forms, including the site overhead reduction, installation efficiencies, and the standardisation of design (Manley et al., 2009). The increase of craftworker productivity and reducing labour rates onsite also represent construction cost reductions (Elnaas et al., 2014).

Site Management Benefits

The site management benefits of using the PBSC include, 1) facilitation of tasks, 2) reduction of construction waste, and 3) enhancement of coordination among parties (see Section 5.4.1). These results confirm the findings/results in a number of earlier and recent studies.

Examining Proposition Statement 4: The use of preassembled building services components reduces construction waste in complex office developments.

[P = 0.105] is greater than the significance level [α = 0.05] for Levene's test (Table 6-13), and [P = 0.041] is less than [α = 0.05] for t-Test.

Table 6-13 Proposition t-Test for perceptions of construction waste

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Construction Waste	Equal variances assumed	2.706	0.105	-2.088	60	0.041	-0.46	0.2205	-0.902	-0.019
	Equal variances not assumed			-2.071	54.714	0.043	-0.46	0.2223	-0.906	-0.015

There was a statistically significant difference between the scores of consultants and of contractors: t (60) = -2.088, $p < .05$. These results suggest that PBSC do make a difference in the relationship regarding construction waste in complex office developments.

Table 6-14 Compare median for perceptions of construction waste

Reduce construction waste		Statistics			
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	3.5	0.5	4.0	1.0

As Table 6-14 reveals, the median of consultants (*Mdn* = 3.5, *IQR* = 0.5) and of contractors (*Mdn* = 4.0, *IQR* = 1.0) indicates that the consultants ‘moderately agreed’ and the contractors ‘highly agreed’ that the use of PBSC *reduces construction waste* in complex office developments. The reduction of construction waste benefits identified in this study were also highlighted in the studies of Blismas and Wakefield (2009), Jaillon et al. (2009), Nadim and

Goulding (2011), Goulding et al. (2012), Almutairi (2015), and Steinhardt and Manley (2016). In complex office developments, the reduction of construction waste plays an important role during the production phase in terms of material savings and increasing sustainability. Therefore, the result is consistent with the study by Almutairi (2015) in the Saudi context regarding offsite construction application, in which reducing construction waste is determined as a potential driver for the use of modular preassembly construction, together with the increase in value and appeal to the environmentalist lobby. The higher level of production control and design specifications allows manufacturing to reduce construction waste. Several researchers have discussed waste minimisation and higher energy performance as benefits of preassembly (McIntosh and Guthrie, 2008; Elnaas et al., 2009; Monahan and Powell, 2011). Similarly, an application such as BIM contributes to innovative design methods in preassembly (Banihashemi, 2012). The following can generate waste: 1) poor early involvement of project stakeholders; 2) uncertain allocation of responsibilities; 3) unsuccessful project coordination and communication; and 4) inconsistent procurement documentation (Gamage et al., 2009). Additionally, the construction industry is impacted by increasing demand for sustainable project performance through reducing onsite waste and cutting costs (Tseng, 2010). The enhancement of coordination among parties was also recognised in the studies by Kelly (2009), Almutairi (2015), and Steinhardt and Manley (2016).

Examining Proposition Statement 5: The use of preassembled building services components improves coordination among parties in complex office developments.

[P = 0.932] is greater than the significance level [α = 0.05] for Levene's test (Table 6-15), and [P = 0.578] is greater than [α = 0.05] for t-Test.

Table 6-15 Proposition t-Test for perceptions of coordination among parties

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Coordination of Staff	Equal variances assumed	0.007	0.932	-0.559	60	0.578	-0.102	0.1825	-0.467	0.2629
	Equal variances not assumed			-0.559	59.735	0.578	-0.102	0.1825	-0.467	0.263

There was no statistically significant difference between the scores of consultants and of contractors: t (60) = -0.559, p > .05. These results suggest that PBSC make no difference in the relationship regarding coordination among parties in complex office developments.

Table 6-16 Compare median for perceptions of coordination among parties

Improve coordination of staff		Statistics			
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	3.5	1.0	3.5	0.5

As Table 6-16 reveals, the median of consultants (*Mdn* = 3.5, *IQR* = 1.0) and of contractors (*Mdn* = 3.5, *IQR* = 0.5) indicates that both consultants and contractors ‘moderately agreed’ that the use of PBSC increases coordination among parties in complex office developments. This study reveals that the enhancement of coordination among parties is a benefit of using PBSC. This result is consistent with the study by Steinhardt and Manley (2016), which examined Australian house-builders’ attitudes regarding the ease of use of offsite construction, in which the improvement of coordination is considered a major benefit of offsite construction. This benefit is mainly due to the ability of a firm to either create a supportive industry network or to draw on internal resources. However, this result is inconsistent with the study by Almutairi (2015), which examines the argument by Kelly (2009) that states that delays in offsite construction projects are associated with the detailed design information required prior to the start of a project. Coordination includes a number of stakeholders: clients, architects, management consultants, and contractors. This inconsistency could be caused by the scope of the study; as this study focuses mainly on the use of PBSC as part of a construction project. Halman et al. (2008) state that effective competition among corporations requires meeting customer requirements by offering a variety of products. Coordination among stakeholders, as well as workforces with tasks, is enhanced by using preassembly (Steinhardt and Manley, 2016; Halman et al., 2008). Product variety management requires corporations to progressively reduce complexity and to invest in the design of a product, as well as manufacturing and marketing (Krishnan and Gupta, 2001). Additionally, the implementation of preassembly coordination requires improved design planning (Din et al., 2012). Significantly, module and component designs depend on the design team. Hence, designers should cooperate with contractors and suppliers (Halman et al., 2008). The construction industries require a transparent system that includes many interrelating stakeholders to influence innovation by sharing ideas, knowledge, and innovations (Chesbrough and Appleyard, 2007). Therefore, reliable transparency and cooperation among parties are key factors to improve innovation (Steinhardt and Manley, 2016).

Examining Proposition Statement 6: The use of preassembled building services components simplifies tasks in complex office developments.

[P = 0.080] is greater than the significance level [α = 0.05] for Levene's test (Table 6-17), and [P = 0.124] is greater than [α = 0.05] for t-Test

Table 6-17 Proposition t-test for perceptions of simplifying tasks

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Simplify Tasks	Equal variances assumed	3.179	0.08	-1.561	60	0.124	-0.24	0.1535	-0.547	0.0674
	Equal variances not assumed			-1.563	59.953	0.123	-0.24	0.1533	-0.546	0.0671

There was no statistically significant difference between the scores of consultants and contractors: t (60) = -1.561, p > .05. These results suggest that PBSC make no difference in the relationship regarding the simplification of tasks in complex office developments.

Table 6-18 Compare median for perceptions of simplifying tasks

Simplify tasks		Statistics			
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	3.5	1.0	3.5	0.5

As Table 6-18 reveals, the median of consultants (*Mdn* = 3.5, *IQR* = 1.0) and of contractors (*Mdn* = 3.5, *IQR* = 0.5) indicates that both the consultants and the contractors 'moderately agreed' that the use of PBSC *simplifies tasks* in complex office developments. This study indicates that the facilitation of tasks is a benefit of using PBSC. The simplification of tasks, as a benefit, is also highlighted in the studies of Lu (2007), Eastman and Sacks (2008), Lu and Korman (2010), and Steinhardt and Manley (2016). This result is consistent with the study by Lu (2007) regarding the US offsite construction industry, in which *onsite management efficiency* is recognised as a key benefit of offsite construction. Additionally, this result is consistent with the study by Steinhardt and Manley (2016) in the Australian context, in which house-builders' beliefs confirm that preassembly facilitates onsite tasks. Such simplification is believed to increase the speed of construction. Simplifying the installation tasks of modules onsite reduces the requirement for outside contractors and subcontractors (Pan and Sidwell, 2011; Poon et al., 2003). The level of staff management can also be reduced through such simplification (Roy et al., 2003). Consequently, the speed of construction can be increased due to onsite construction simplifications (Lu and Korman, 2010). Similarly, the incurrence of costs can be balanced by the reduced time necessary for onsite tasks (Aburas, 2011; Bildsten, 2011). The cost-saving due to *task simplification* takes the form of reducing the number of staff and costly onsite operations. Luo et al. (2005) report that the simplification of onsite construction tasks, as a benefit of preassembly, encourages the use of preassembly because of the increasing demand for skilled construction workers without a steady increase in supply. Consequently, contractors are responsible for the higher direct costs of material and labour, as well as for the costs of establishing a plant environment for preassembly even with insufficient legislation and funding (Lovell and Smith, 2010).

Sustainability Benefits

The sustainability benefits of using PBSC include, 1) enhancement of health and safety, 2) enhancement of design efficiency, and 3) improvement of energy efficiency in (see Section 5.4.1).

Examining Proposition Statement 7: The use of preassembled building services components improves the energy efficiency in complex office developments.

[P = 0.540] is greater than the significance level [α = 0.05] for Levene's test (Table 6-19), and [P = 0.489] is greater than [α = 0.05] for t-Test.

Table 6-19 Proposition t-test for perceptions of energy efficiency

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Energy Efficiency	Equal variances assumed	0.381	0.54	-0.697	60	0.489	-0.138	0.1973	-0.532	0.2572
	Equal variances not assumed			-0.693	57.235	0.491	-0.138	0.1983	-0.535	0.2596

There was no statistically significant difference between the scores of consultants and contractors: t (60) = -0.697, p > .05. These results suggest that PBSC make no difference in the relationship regarding the energy efficiency in complex office developments.

Table 6-20 Compare median for perceptions of energy efficiency

Improve energy efficiency		Statistics			
N Valid	60	Consultants		Contractors	
		Mdn	*IQR*	*Mdn*	*IQR*
Missing	0	3.5	1.0	3.5	1.0

As Table 6-20 reveals, the median of consultants (*Mdn* = 3.5, *IQR* = 1.0) and of contractors (*Mdn* = 3.5, *IQR* = 1.0) indicates that both the consultants and the contractors 'moderately agreed' that the use of PBSC *enhances energy efficiency* in complex office developments. This is consistent with findings regarding sustainability benefits highlighted by Pan (2007), Blismas and Wakefield (2009), and Bildsten (2011). The study by Pan (2007), concerning the top 100 UK house-builders, confirms that 'energy efficiency' is a benefit of applying offsite construction in the UK. Standardisation and codes play an important role in achieving energy efficiency. The quality of the final product is inspected and assured much more by a manufacturer than in an onsite environment (Blismas and Wakefield, 2009). Thus, preassembly benefits the environment in terms of reducing the use of materials in construction, reducing the water used for constructing a typical house, and reducing energy consumption (Manley et al., 2009; Elnaas et al., 2014). Furthermore, onsite assembly must meet the necessary standards for the product to perform as designed (Manley et al., 2009).

Examining Proposition Statement 8: The use of preassembled building services components improves workplace safety in complex office developments.

[P = 0.021] is less than the significance level [α = 0.05] for Levene's test (Table 6-21), and [P = 0.809] is greater than [α = 0.05] for the t-Test.

Table 6-21 Proposition t-Test for perceptions of workplace safety

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Workplace Safety	Equal variances assumed	5.627	0.021	0.246	60	0.806	0.05	0.203	-0.356	0.4561
	Equal variances not assumed			0.243	49.446	0.809	0.05	0.2057	-0.363	0.4633

There was no statistically significant difference between the scores of consultants and contractors: t (60) = 0.243, p > .05. These results suggest that PBSC make no difference in the relationship regarding workplace safety in complex office developments.

Table 6-22 Compare median for perceptions of workplace safety

Improve workplace safety		Statistics			
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	4.0	0.5	4.0	1.25

As Table 6-22 reveals, the median of consultants (*Mdn* = 4.0, *IQR* = 0.5) and of contractors (*Mdn* = 4.0, *IQR* = 1.25) indicates that both the consultants and the contractors 'highly agreed' that the use of PBSC *improves workplace safety* in complex office developments. The enhancement of health and safety, identified in this research as a benefit, is also recognised by Blismas and Wakefield (2009), Nadim and Goulding (2011), Goulding, et al. (2012), and Almutairi (2015). However, in complex office developments, the enhancement of health and safety is essential for the production and installation phases (vertical issues) in terms of labourer safety. This result is consistent with the study by Almutairi (2015), which investigated offsite construction application in the Saudi context. In the study, the enhancement of health and safety is examined and identified as a potential benefit when using offsite construction, in addition to increasing the value and the appeal to the environmentalist lobby. Similarly, the enhancement of health and safety is consistent with the study by

Lu (2007), which examined the American context and found that the respondents ‘slightly agreed’ with safety performance as a benefit when using OCT. Moreover, onsite safety is enhanced by preassembly via minimising the exposure of labourers to heights, severe weather, onsite working time, and hazardous operations (Blismas and Wakefield, 2009; Larsson and Simonsson, 2012). Furthermore, a manufacturer is a controlled environment that protrects labourers from hazardous extremes (Blismas, 2007) and provides extra working space.

Examining Proposition Statement 9: The use of preassembled building services components increases the project design efficiency in complex office developments.

[P = 0.132] is greater than the significance level [α = 0.05] for Levene's test (Table 6-23), and [P = 0.442] is greater than [α = 0.05] for the t-Test.

Table 6-23 Proposition t-Test for perceptions of project design efficiency

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Design Efficiency	Equal variances assumed	2.327	0.132	-0.774	60	0.442	-0.144	0.1857	-0.515	0.2276
	Equal variances not assumed			-0.779	59.364	0.439	-0.144	0.1846	-0.513	0.2256

There was no statistically significant difference between the scores of consultants and contractors: t (60) = -0.774, p > .05. These results suggest that PBSC make no difference in the relationship regarding the design efficiency in complex office developments.

Table 6-24 Compare median for perceptions of project design efficiency

Improve design efficiency		Statistics			
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	3.5	0.5	4.0	1.0

As Table 6-24 reveals, the median of consultants (*Mdn* = 3.5, *IQR* = 0.5) and of contractors (*Mdn* = 4.0, *IQR* = 1.0) indicates that the consultants 'moderately agreed' and the contractors 'highly agreed' that the use of PBSC *enhances design efficiency* in complex office developments. The result of this study indicates that the enhancement of design efficiency is recognised as a sustainable benefit, which is in line with Lu (2007), in his study of the American offsite industry. This result is consistent also with Almutairi (2015) regarding the Saudi context, which confirms that the use of offsite construction increases design efficiency. The ideal design and well-managed coordination and installation of the manufacturing process enhance the design efficiency of preassembly (Johnson, 2007; Larsson and Simonsson, 2012). Standardisation and codes also play important roles in achieving design efficiency. Additionally, software such as BIM contributes to innovative design methods in preassembly (Banihashemi, 2012). Consequently, design efficiency contributes to reducing onsite construction time, reducing noise, and reducing waste produced onsite, which are all considered means of mitigating negative environmental impacts (Blismas and Wakefield, 2009).

Challenges of Using Preassembled Building Services Components

The challenges to the consultants and contractors who use PBSC, which are explored in Section 5.4.2, are supported by previous studies, such as Goodier and Gibb (2004), Pan et al. (2007), Halman, et al. (2008), Blismas and Wakefield (2009), Nadim and Goulding (2011), Goulding, et al. (2012), Almutairi (2015), and Steinhardt and Manley (2016). In this research, these challenges were identified via semi-structured interviews and a questionnaire, and are confirmed via the case studies. These challenges are classified into three categories: cost implication, process, and product. Both the consultants and the contractors agreed on the challenge factors (propositions), except for '*low-quality image*', which they disagreed on. The findings and results present an understanding of consultant and contractor attitudes towards the challenges that prevent the application of PBSC in complex office developments, and they contextualise the challenges for organisational contexts.

The challenges that hinder the use of PBSC applications in complex office developments were identified in two phases: the semi-structured interviews (Section 5.4.2) and the questionnaire. The results from the two phases were combined to explore the significant challenges to the use of PBSC associated with specific activities within complex office developments and the studied context. The results of this study reveal that the challenges in the Saudi context are as follows: 1) increase in the overall project cost; 2) increase in risk; 3) reduction in the flexibility of designs; 4) the need for extra preparation work; 5) limitation in making changes to the work onsite; 6) increase in transport logistics; and 7) increase in maintenance. However, it is important to note that neither the consultants nor the contractors supported the challenge (proposition) stating that PBSC 'has an low-quality image'.

Cost Implication Challenges

The cost implication challenges of using the PBSC include, 1) increase in the overall project cost, and 2) increase of maintenance complexity (see Section 5.4.2).

Examining Proposition Statement 10: The use of preassembled building services components increases the overall project cost in complex office developments.

[P = 0.935] is greater than the significance level [α = 0.05] for Levene's test (Table 6-25), and [P = 0.992] is greater than [α = 0.05] for the t-Test.

Table 6-25 Proposition t-Test for perceptions of the overall project cost

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper
Overall Project Cost	Equal variances assumed	0.007	0.935	-0.01	60	0.992	-0.002	0.206	-0.414	0.41
	Equal variances not assumed			-0.01	59.557	0.992	-0.002	0.2062	-0.415	0.4104

There was no statistically significant difference between the scores of consultants and contractors: t (60) = -0.010, p > .05. These results suggest that PBSC make no difference in the relationship regarding overall project cost in complex office developments.

Table 6-26 Compare median for perceptions of the overall project cost

Increase in overall project cost		Statistics			
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	3.5	1.0	3.5	0.75

As Table 6-26 reveals, the median of consultants (*Mdn* = 3.5, *IQR* = 1.0) and of contractors (*Mdn* = 3.5, *IQR* = 0.75) indicates that both the consultants and the contractors ‘moderately agreed’ that the use of PBSC *increases the overall project cost* in complex office developments. This finding is consistent with the study by Almutairi (2015), which revealed that the use of offsite construction increases overall project cost. However, this result is inconsistent with the study conducted by Lu (2007), in which the results indicate that both the general contractors and architects were against the idea that the use of preassembly increases overall project cost. The financial performance of preassembly remains a controversial issue (Zhai et al., 2013). Similarly, Pan et al. (2007) state that the financial performance of preassembly matters for the construction industry’s perception. Furthermore, Jaillon and Poon (2008) note that the overall cost of preassembled high-rise buildings is about 20% higher than the overall costs of the conventional onsite process. In addition, Blismas and Wakefield (2009) state that the perception of higher capital and initial cost is a significant challenge to improving the use of preassembly. Zhai et al. (2014) explain that the overall cost of preassembly is often associated with higher initial costs, higher capital costs, and a longer capital payback period. This aspect is particularly important, as the decision-making process relies on the economic parameters when selecting the optimal construction method (Elnaas, 2015).

Examining Proposition Statement 11: The use of preassembled building services components increases the need for maintenance in complex office developments.

[P = 0.863] is greater than the significance level [α = 0.05] for Levene's test (Table 6-27), and [P = 0.769] is greater than [α = 0.05] for the t-Test.

Table 6-27 Proposition t-Test for perceptions of need for maintenance

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Needs for Maintenance	Equal variances assumed	0.03	0.863	0.294	60	0.769	0.05	0.1698	-0.29	0.3897
	Equal variances not assumed			0.294	59.824	0.769	0.05	0.1698	-0.29	0.3896

There was no statistically significant difference between the scores of consultants and contractors: t (60) = -0.294, p > .05. These results suggest that PBSC make no difference in the relationship regarding the need for maintenance in complex office developments.

Table 6-28 Compare median for perceptions of need for maintenance

Maintenance capability limitation			Statistics		
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	3.5	0.5	3.5	0.75

As Table 6-28 reveals, the median of consultants (*Mdn* = 3.5, *IQR* = 0.5) and of contractors (*Mdn* = 3.5, *IQR* = 0.75) indicates that both the consultants and the contractors ‘moderately agreed’ that the maintenance capability limits the use of PBSC in complex office developments. The challenge of increased need for maintenance is consistent with the results of a study by Zhai et al. (2013), in which major maintenance risks and defects were noticed regarding bathroom maintenance. Wet areas are critical in terms of increased maintenance (Ramly et al., 2006). This issue is especially important when noting that wet areas cover around 10% of the gross building floor but correspond to 35% to 50% of the total annual maintenance cost of a building (Chew and De Silva, 2003). Thus, the procurement method is important when considering the whole-life cost for preassembly (Gardiner and Theobald, 2005). Since the maintenance cost of using preassembly is unclear, the decision to use preassembly and the realisation of preassembly technology are largely influenced by the lack of perception of maintenance cost (Pan et al., 2008).

Process Challenges

The process challenges of using PBSC include, 1) limitation of making changes onsite, 2) increase in transport, and 3) extra preparatory requirements (see Section 5.4.2).

Examining Proposition Statement 12: The use of preassembled building services components limits making changes to work onsite in complex office developments.

[P = 0.107] is greater than the significance level [α = 0.05] for Levene's test (Table 6-29), and [P = 0.421] is greater than [α = 0.05] for t-Test.

Table 6-29 Proposition t-Test for perceptions of making changes to work onsite

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Changes Onsite	Equal variances assumed	2.68	0.107	-0.811	60	0.421	-0.169	0.2082	-0.585	0.2477
	Equal variances not assumed			-0.804	54.977	0.425	-0.169	0.2098	-0.589	0.2518

There was no statistically significant difference in the scores of consultants and of contractors: t (60) = -0.811, p > .05. These results suggest that PBSC make no difference in the relationship regarding making changes onsite in complex office developments.

Table 6-30 Compare median for perceptions of making changes to work onsite

Limit the ability to make changes onsite		Statistics			
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	3.5	1.0	3.5	1.0

As Table 6-30 reveals, the median of consultants (*Mdn* = 3.5, *IQR* = 1.0) and of contractors (*Mdn* = 3.5, *IQR* = 1.0) indicates that both the consultants and the contractors 'moderately agreed' that the use of PBSC *limits making changes on site* in complex office developments. This finding is consistent with Lu (2007) and Almutiri (2015). The implementation of preassembly in construction is essentially founded on standardised, modularised, and repetitive designs during the early stage of the project (Goodier and Gibb, 2007). Making changes onsite during the construction phase is not possible when using preassembly, which reduces the use of the method (Blismas, 2007; Blismas and Wakefield, 2009). Similarly, many arguments state that a wider application of preassembly in the housing construction industry is prevented due to the high standardisation and repetitiveness of the processes involved (Arif and Egbu, 2010; Blismas et al., 2005; Blismas et al., 2006). Additionally, modular buildings require a well-defined scope of work prior to the project planning phase as a form of preassembly (Manley et al., 2009).

Examining Proposition Statement 13: The use of preassembled building services components increases transport logistics in complex office developments.

[P = 0.411] is greater than the significance level [α = 0.05] for Levene's test (Table 6-31) and [P = 0.270] is greater than [α = 0.05] for t-test.

Table 6-31 Proposition t-Test for perceptions of transport logistics

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Transportation Logistics	Equal variances assumed	0.687	0.411	-1.113	60	0.27	-0.227	0.2041	-0.635	0.1811
	Equal variances not assumed			-1.12	59.005	0.267	-0.227	0.2028	-0.633	0.1787

There was no statistically significant difference in the scores of consultants and of contractors: t (60) = -1.113, p > .05. These results suggest that PBSC make no difference in the relationship regarding the transport logistics in complex office developments.

Table 6-32 Compare median for perceptions of transport logistics

Transport limitations		Statistics			
N Valid	60	Consultants		Contractors	
		Mdn	*IQR*	*Mdn*	*IQR*
Missing	0	3.5	0.5	3.5	1.0

As Table 6-32 reveals, the median of consultants (*Mdn* = 3.5, *IQR* = 0.5) and of contractors (*Mdn* = 3.5, *IQR* = 1.0) indicates that both the consultants and the contractors 'moderately agreed' that *transport logistics restrain* the use of PBSC in complex office developments. This result agrees with Steinhardt and Manley (2016). Similarly, Goulding et al. (2014) state that transport is a logistically serious problem influencing the preassembly construction supply chain. The transport challenge includes limitations of size and weight and constraints of width and height due to the techniques and routes that transport uses during transit (Manley et al., 2009). The size of the modular building or preassembly components is often limited to 12-14 feet in width and 50-55 feet in length (Larsson and Simonsson, 2012). Similarly, the weight is limited by the capacity of lifting equipment; typically, between 10 to 30 tonnes, while the highway limit depends on the lifting capacity of the crane (Blismas and Wakefield, 2009).

Examining Proposition Statement 14: The use of preassembled building services components requires more preparation work in complex office developments.

[P = 0.291] is greater than the significance level [α = 0.05] for Levene's test (Table 6-33), and [P = 0.211] is greater than [α = 0.05] for the t-Test.

Table 6-28 Proposition t-Test for perceptions of preparation work

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Preparation Work	Equal variances assumed	1.135	0.291	-1.264	60	0.211	-0.229	0.1813	-0.592	0.1335
	Equal variances not assumed			-1.27	59.683	0.209	-0.229	0.1805	-0.59	0.1319

There was no statistically significant difference between the scores of consultants and contractors: t (60) = -1.264, p > .05. These results suggest that PBSC make no difference in the relationship regarding preparation work in complex office developments.

Table 6-34 Compare median for perceptions of preparation work

Need more preparatory work		Statistics			
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	3.5	1.0	3.5	0.5

As Table 6-34 shows, the median of consultants (*Mdn* = 3.5, *IQR* = 1.0) and of contractors (*Mdn* = 3.5, *IQR* = 0.5) indicates that both the consultants and the contractors ‘moderately agreed’ that the use of PBSC *requires more preparation work* in complex office developments. Such preparation work is a challenge that is consistent with the findings of Pan (2007) and Zhai et al. (2014). Preassembly construction requires more time in the preparation phase with reference to the early design and the length of lead-in time (Zhai et al. 2014). Preassembly requires long preparation and detailed planning at the preparation phase of the project to precisely, 1) describe the architectural design; 2) check the availability of labourers and preassembly components; 3) coordinate between different stakeholders; 4) plan transport accessibility; and 5) provide technological solutions and other related features (Zhai, et al., 2014). Therefore, extended lead-in time is identified in many studies as a challenge to the uptake of preassembly (Venables et al., 2004; Goodier and Gibb, 2005; Pan et al., 2007).

Product Challenges

The product challenges of using PBSC include, 1) reduction of design flexibility, 2) increase in risk, and 3) having a low-quality image (see Section 5.4.2).

Examining Proposition Statement 15: The use of preassembled building services components reduces the flexibility of designs in complex office developments.

[P = 0.543] is greater than the significance level [α = 0.05] for Levene's test (Table 6-35), and [P = 0.764] is greater than [α = 0.05] for t-test.

Table 6-35 Proposition t-Test for perceptions of flexibility of designs

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Flexibility of Designs	Equal variances assumed	0.374	0.543	0.301	60	0.764	0.0563	0.1868	-0.317	0.4299
	Equal variances not assumed			0.3	58.511	0.765	0.0563	0.1874	-0.319	0.4313

There was no statistically significant difference between the scores of consultants and contractors: t (60) = 0.301, p > .05. These results suggest that PBSC make no difference regarding the flexibility of designs in complex office developments.

Table 6-36 Compare median for perceptions of flexibility of designs

Reduces the flexibility of designs		Statistics			
N Valid	60	Consultants		Contractors	
		Mdn	*IQR*	*Mdn*	*IQR*
Missing	0	3.5	1.0	3.5	1.0

As Table 6-36 reveals, the median of consultants (*Mdn* = 3.5, *IQR* = 1.0) and of contractors (*Mdn* = 3.5, *IQR* = 1.0) indicates that both the consultants and the contractors 'moderately agreed' that the use of PBSC *reduces the flexibility of design* in complex office developments. This finding is consistent with Almutiri (2015), who explains how this consequently limits making changes onsite. The *design flexibility* factor includes the entire design process and the flexibility of using the system to complete the process (Pan, 2007). Zhai et al. (2013) argue that the standardisation and extreme repetitiveness of processes contribute to preventing a broader application of offsite construction. Reducing the flexibility of design is one of the key challenges in the use of preassembly (Almutairi, 2015). On the other hand, standardisation plays a significant role that contributes towards reducing construction costs (Graing, 2000). Furthermore, the use of standard elements, components, or modules assists in reducing overhead costs, as they are sometimes shared across a number of construction projects. Reduction in cost results also from fewer tasks, lower resources required for building sites, and less dependency on skilled workers (Khalili and Chua, 2013). Edge (2002) found that home-buyers are not resistant to new forms of preassembly, but are somewhat resistant to new building materials. Moreover, inspiration from manufacturing industries can be realised in the construction industry, with standardisation being promoted through preassembly (CIB, 2010; Elnass, 2014:49).

Examining Proposition Statement 16: The use of preassembled building services components increases risk in complex office developments.

[P = 0.234] is greater than the significance level [α = 0.05] for Levene's test (Table 6-37), and [P = 0.069] is greater than [α = 0.05] for the t-Test.

Table 6-37 Proposition t-Test for perceptions of risk

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Increase Risk	Equal variances assumed	1.446	0.234	-1.854	60	0.069	-0.415	0.2236	-0.862	0.0326
	Equal variances not assumed			-1.848	58.245	0.07	-0.415	0.2244	-0.864	0.0345

There was no statistically significant difference between the scores of consultants and of contractors: t (60) = -1.854, p > .05. These results suggest that PBSC make no difference in the relationship regarding risk increasing in complex office developments.

Table 6-38 Compare median for perceptions of risk

Increase risk		Statistics			
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	3.5	0.5	4.0	0.75

As Table 6-38 reveals, the median of consultants (*Mdn* = 3.5, *IQR* = 0.5) and of contractors (*Mdn* = 4.0, *IQR* = 0.75) indicates that the consultants 'moderately agreed' and the contractors 'highly agreed' that the use of PBSC *increases the risk* in complex office developments. In this study, the increase in risk is documented as a challenge, which is consistent with Pan (2007). Risk allocation can occur with various aspects, including standardisation of processes and risk management (Pan, 2007); supplier capacity (Zhai et al., 2013); lack of awareness to avoid risk (Almutairi, 2015); and a supportive industry network (Steinhardt and Manley, 2016). Also, commitment to innovation involves risk to the construction industry (Loosemore, 2014). The risks of using preassembly methods include design changes during the project (NAO, 2005); maintenance (Pan et al., 2008); and new construction methods (Steinhardt and Manley, 2016). A number of studies (Gibb et al. 2003; McKay, 2010) have examined the health-and-safety risks associated with preassembly. Blismas and Wakefield (2009) report other forms of risk, such as the high-risk of involvement in regional and international supply chains, and the risk of installation, which includes crane utilisation, high winds, and hook-time availability.

Examining Proposition Statement 17: The use of preassembled building services components has a low-quality image in complex office developments.

[P = 0.648] is greater than the significance level [α = 0.05] for Levene's test Table 6-39), and [P = 0.288] is greater than [α = 0.05] for the t-Test.

Table 6-39 Proposition t-Test for perceptions of image of low quality

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Image of Poor Quality	Equal variances assumed	0.211	0.648	-1.072	60	0.288	-0.3	0.2799	-0.86	0.2599
	Equal variances not assumed			-1.074	60	0.287	-0.3	0.2793	-0.859	0.2587

There was no statistically significant difference between the scores of consultants and contractors: t (60) = -1.072, p > .05. These results suggest that PBSC make no difference in the relationship regarding a low-quality image in complex office developments.

Table 6-40 Compare median for perceptions of low-quality image

Low-quality Image		Statistics			
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	2.5	1.0	2.5	1.0

As Table 6-40 shows, the median of consultants (*Mdn* = 2.5, *IQR* = 1.0) and of contractors (*Mdn* = 2.5, *IQR* = 1.0) indicates that both the consultants and the contractors 'slightly disagreed' that the use of PBSC *has a low-quality* in complex office developments. This result is consistent with Lu and Liska (2008), who found that architects and engineers did not support the idea that client perceptions of offsite techniques negatively impacted their use. However, this result is not in line with Pan (2006) and Almutairi (2015). Manley et al. (2009) state that preassembly is mostly perceived as a complex technology compared with traditional construction culture. The negative perceptions of preassembly include lack of governmental support, client resistance and disbelief, lack of available standards and codes, and lack of confidence in the industry (Goodier and Gibb, 2007; Blismas, 2007; Blismas and Wakefield, 2009; Manley et al., 2009).

6.5.3 *Stakeholders Influence the Decision to Use Preassembled Building Services Components in Complex Office Developments*

This section analyses and discusses the results regarding stakeholder influence on the decision to use PBSC applications in complex office developments, based on the perceptions of both the consultants and the contractors. The findings of the semi-structured interviews (Section 5.5) identified the stakeholders who influence decisions regarding the use of PBSC applications in complex office developments. The survey results revealed that consultant and contractor perceptions significantly confirm the influence of stakeholders on using PBSC. These stakeholders include, 1) the client, 2) the consultants, 3) the government regulators, and 4) the suppliers. However, the consultants and the contractors did not agree with the proposition (SN) that 'the subcontractors' influence decision-making. Stakeholder influence on decision-making is now analysed and discussed.

Examining Proposition Statement 18: Consultants influence the decision on the use of preassembled building services components in complex office developments.

[P = 0.811] is greater than the significance level [α = 0.05] for Levene's test (Table 6-41), and [P = 0.071] is greater than [α = 0.05] for the t-Test.

Table 6-41 Proposition t-Test for perceptions of consultants' influence

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Consultant	Equal variances assumed	0.058	0.811	-1.84	60	0.071	-0.329	0.1789	-0.687	0.0287
	Equal variances not assumed			-1.875	46.872	0.067	-0.329	0.1755	-0.682	0.024

There was no statistically significant difference between the scores of consultants and contractors: t (60) = -1.840, p > .05. These results suggest that PBSC make no difference in the relationship regarding the influence of consultants in complex office developments.

Table 6-42 Compare median for perceptions of consultants' influence

Consultant influence			Statistics		
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	4.0	0.75	4.0	0.5

As Table 6-42 reveals, the median of consultants (*Mdn* = 4.0, *IQR* = 0.75) and of contractors (*Mdn* = 4.0, *IQR* = 0.5) indicates that the consultants 'moderately agreed' and the contractors 'highly agreed' that *consultants influence* the decision to use PBSC in complex office developments. This result is consistent with Elnaas (2015), who found that respondents 'highly agreed' with the consultant's major role in the decision to use preassembly in the UK context. Zha et al. (2008) state that, in the early design phases, the design decisions in the construction industry are evaluated by a number of decision-support systems, which are usually used by consultants. Whether in the UK or worldwide, achieving a high, sustainable performance for buildings is a goal for the AEC professional (Zanni et al., 2013). Elnaas (2015, p.158) reports that consultants have a significant influence on decision-making regarding using preassembly in the UK context.

Examining Proposition Statement 19: Clients influence the decision to use preassembled building services components in complex office developments.

[P = 0.259] is greater than the significance level [α = 0.05] for Levene's test (Table 6-43), and [P = 0.006] is less than [α = 0.05] for the t-Test.

Table 6-43 Proposition t-Test for perceptions of clients' influence

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Owners	Equal variances assumed	1.3	0.259	-2.857	60	0.006	-0.433	0.1517	-0.737	-0.13
	Equal variances not assumed			-2.884	57.306	0.006	-0.433	0.1503	-0.734	-0.132

There was a statistically significant difference between the scores of consultants and of contractors: t (60) = -2.857, $p < .05$. These results suggest that PBSC do affect the relationship regarding the influence of the client in complex office developments.

Table 6-44 Compare median for perceptions of clients' influence

Client influence		Statistics			
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	4.0	0.5	4.5	0.5

As Table 6-44 reveals, the median of consultants (*Mdn* = 4.0, *IQR* = 0.5) and of contractors (*Mdn* = 4.5, *IQR* = 0.5) indicates that both the consultants and the contractors ‘highly agreed’ that the *client influences* the decision to use PBSC in complex office developments. This result is consistent with Elnaas (2015). Goodier and Gibb (2004) found that a market survey confirmed that the main challenge of using preassembly is clients and their advisers perceiving extra costs. Similar results were obtained by Birkbeck and Scoones (2005) in their study on the perceptions of the housebuilding sector. The value added by preassembly is unclear to clients; therefore, the perceived high cost hinders using preassembly technology (Lu 2007, p.22). However, the main reason that clients avoid using preassembly is their inability to determine the benefits that could be added to a project (Pasquire and Gibb, 2002). The decision to use preassembly in the UK is based on subjective suggestions rather than solid data (Lu 2007, p.23; Pasquire and Gibb, 2002).

Examining Proposition Statement 20: Governmental regulators influence the decision to use preassembled building services components in complex office developments.

[P = 0.016] is less than the significance level [α = 0.05] for Levene's test (Table 6-45), and [P = 0.022] is less than [α = 0.05] for the t-Test.

Table 6-45 Proposition t-Test for perceptions of governmental regulators’ influence

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Government and Regulators	Equal variances assumed	6.09	0.016	2.4	60	0.02	0.5688	0.237	0.0947	1.0428
	Equal variances not assumed			2.371	50.295	0.022	0.5688	0.2399	0.0869	1.0506

There was a statistically significant difference between the scores of consultants and contractors: t (60) = 2.371, $p < .05$. These results suggest that PBSC affect the relationship regarding the influence of regulators in complex office developments.

Table 6-46 Compare median for perceptions of governmental regulators' influence

Building regulator influence		Statistics			
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	4.0	1.0	3.5	1.0

As Table 6-46 shows, the median of consultants (*Mdn* = 4.0, *IQR* = 1.0) and of contractors (*Mdn* = 3.5, *IQR* = 1.0) indicates that the consultants 'highly agreed' and the contractors 'moderately agreed' that the *government regulators influence* the decision to use PBSC in complex office developments. This result is consistent with Almutairi (2015), but is not in line with Elnaas (2015), who found that governmental regulators have very little influence. The government regulatory policies and the procurement method play important roles in promoting change via the uptake of new construction technology (Goulding et al., 2014). In 2006, the Barker 33 Cross-Industry Group stated that investment in new techniques, such as preassembly construction, is struggling due to numerous alterations to building regulations and conflict within different sections of the regulations (McKay, 2010). Therefore, both the UK Government and the construction industry are jointly revisiting the regulations with a view to classifying a few aspects for the adoption of new preassembly products (Elnaas, 2014, pp.74-75).

Examining Proposition Statement 21: Suppliers influence the decision to use preassembled building services components in complex office developments.

[P = 0.023] is less than the significance level [α = 0.05] for Levene's test (Table 6-47), and [P = 0.088] is greater than [α = 0.05] for the t-Test.

Table 6-47 Proposition t-Test for perceptions of suppliers' influence

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Suppliers	Equal variances assumed	5.475	0.023	1.746	60	0.086	0.3667	0.21	-0.053	0.7867
	Equal variances not assumed			1.737	57.26	0.088	0.3667	0.2111	-0.056	0.7893

There was no statistically significant difference between the scores of consultants and contractors: t (60) = 1.737, p > .05. These results suggest that PBSC make no difference in the relationship regarding the influence of suppliers in complex office developments.

Table 6-48 Compare median for perceptions of suppliers' influence

Supplier influence			Statistics		
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	3.0	0.5	3.0	0.75

As Table 6-48 shows, the median of consultants (*Mdn* = 3.0, *IQR* = 0.5) and of contractors (*Mdn* = 3.0, *IQR* = 0.75) indicates that both the consultants and the contractors 'neither agreed nor disagreed' that suppliers influence the decision to use PBSC in complex office developments. Supplier influence (as a proposition) was not supported by either the consultants or the contractors, since the median is 3.0. This result is in line with Elnass (2015), who states that suppliers have little influence on the decision to use OSM as a strategy for the construction of housing projects. Housing Forum (2004) states that suppliers considered production capacity to be one of the main limiting factors to market demand (Pan et al., 2004).

Examining Proposition Statement 22: Subcontractors influence the decision to use preassembled building services components in complex office developments.

[P = 0.671] is greater than the significance level [α = 0.05] for Levene's test (Table 6-49), and [P = 0.115] is greater than [α = 0.05] for the t-Test.

Table 6-49 Proposition t-Test for perceptions of subcontractors' influence

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Subcontractors	Equal variances assumed	0.183	0.671	1.599	60	0.115	0.3771	0.2359	-0.095	0.8489
	Equal variances not assumed			1.602	59.997	0.114	0.3771	0.2354	-0.094	0.848

There was no statistically significant difference between the scores of consultants and contractors: t (60) = 1.599, p > .05. These results suggest that PBSC make no difference in the relationship regarding the influence of subcontractors in complex office developments.

Table 6-50 Compare median for perceptions of subcontractor influence

Subcontractor influence		Statistics			
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	3.0	0.5	3.0	1.0

As Table 6-50 reveals, the median of consultants (*Mdn* = 3.0, *IQR* = 0.5) and of contractors (*Mdn* = 3.0, *IQR* = 1.0) indicates that both the consultants and the contractors 'neither agreed nor disagreed' that subcontractors influence the decision to use PBSC in complex office developments. Subcontractor influence (as a proposition) is not supported by either the consultants or the contractors, since the median is 3.0. This result is consistent with Elnaas (2015), who found that subcontractor and supplier influence on the decision to use preassembly is very limited. However, this result is not in line with

Samuelsson Brown et al. (2003), who found that the final decision regarding whether to use offsite on a project is often left to the M&E contractor or consultant in M&E applications. Sexton et al. (2008) explain that subcontractors are not as technical as large construction firms, and often lack the scale of human, physical, intellectual, and financial resources to invest in innovation. A study conducted to investigate the perception of general contractors, architects, and engineers in the US regarding preassembly notes that onsite workers may not have the skills to adopt offsite preassembly technology (Lu and Liska, 2008). Additionally, Goh and Loosemore (2017) note that the implications regarding physical resources by subcontractors involves purchasing or renting new manufacturing equipment and facilities, transport technologies, and installation equipment, which are not necessarily required in the traditional construction processes. Therefore, applying preassembly by subcontractors requires the necessary social capital resource to develop new supply-and-demand-chain partnerships to protect the resources, connections, and desired knowledge to make preassembly work (Goh and Loosemore, 2017).

6.5.4 *External Influence on Decision to Use Preassembled Building Services Components in Complex Office Developments*

This section analyses and discusses the influential contexts that control the decision to use PBSC applications in complex office developments. The analyses and discussion are based on the perceptions of both the consultants and the contractors. The findings of the semi-structured interviews (Section 5.6) identified the influential contexts that control the decision to use PBSC applications in complex office developments in Saudi Arabia. The survey results revealed that the control of the influential contexts are significantly confirmed by both the consultants and the contractors. The influential contexts that control the decision to use the PBSC include, 1) financial support, 2) government regulations, 3) manufacturing capacity, and 4) skilled craft workers. The influential contexts that control decisions are now analysed and discussed.

Examining Proposition Statement 23: Easier financing impacts the use of preassembled building services components in complex office developments.

[P = 0.786] is greater than the significance level [α = 0.05] for Levene's test (Table 6-51), and [P = 0.479] is greater than [α = 0.05] for the t-Test.

Table 6-51 Proposition t-Test for perceptions of financial support

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Finance Support	Equal variances assumed	0.074	0.786	-0.712	60	0.479	-0.138	0.1932	-0.524	0.2489
	Equal variances not assumed			-0.723	51.436	0.473	-0.138	0.1903	-0.519	0.2444

There was no statistically significant difference between the scores of consultants and contractors: t (60) = -0.712, p > .05. These results suggest that PBSC make no difference in the relationship regarding financial support in complex office developments.

Table 6-52 Compare median for perceptions of financial support

Financial support impact		Statistics			
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	4.0	0.5	4.0	0.75

As Table 6-52 shows, the median of consultants (*Mdn* = 4.0, *IQR* = 0.5) and of contractors (*Mdn* = 4.0, *IQR* = 0.75) indicates that both the consultants and the contractors ‘highly agreed’ that *financial support impacts* the use of PBSC in complex office developments. This result reveals that financial support has the most control on the decision to use PBSC. This result is consistent with Steinhardt and Manley (2016), who identified a lack of support from the financial sector for preassembly technology. Ong (2004) notes that lenders often require an independent estimation for preassembly, as new construction methods, before promising their future loan value. Loan lenders are often demotivated from providing a loan either to build or buy property built using preassembly systems (Elnaas, 2014, pp.74-75). In addition, Barker (2003) states that investment in preassembled facilities includes plant, factories, and other construction approaches, which are associated with the industry's mitigation risk attitude, which prevents the use of preassembly (McKay, 2010).

Examining Proposition Statement 24: Government regulations impact the use of preassembled building services components in complex office developments.

[P = 0.844] is greater than the significance level [α = 0.05] for Levene's test (Table 6-53), and [P = 0.016] is less than [α = 0.05] for the t-Test.

Table 6-53 Proposition t-Test for perceptions of government regulations

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Government Regulations	Equal variances assumed	0.039	0.844	-0.039	60	0.016	-0.006	0.1588	-0.324	0.3113
	Equal variances not assumed			-0.039	58.061	0.021	-0.006	0.1594	-0.325	0.3128

There was a statistically significant difference between the scores of consultants and contractors: t (60) = -0.039, $p < .05$. These results suggest that PBSC make a difference in the relationship regarding the influence of government regulations in complex office developments.

Table 6-54 Compare median for perceptions of government regulations

Government regulation impact		Statistics			
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	4.0	0.5	4.0	0.5

As Table 6-54 reveals, the median of consultants (*Mdn* = 4.0, *IQR* = 0.5) and of contractors (*Mdn* = 4.0, *IQR* = 0.5) indicates that both the consultants and the contractors 'highly agreed' that *government regulations impact* the use of PBSC in complex office developments. This result agrees with Almutairi (2015), who found that local building regulations restrict the use of OCT. The lack of government policies was the main challenge of the study because of inadequate progress with the application of preassembly (Mao et al., 2011). Additionally, McKay (2010) notes that the use of cranes to handle heavy preassembled components is highly controlled by safety compliance issues. Previous studies report that building regulations are a barrier in terms of company strategy and client influence (Arif et al., 2012a). Pan (2007) states that the promotion of preassembly is influenced by the perceptions of benefits and challenges, which are controlled by regulatory factors and the broader market.

Examining Proposition Statement 25: Manufacturing capacity impacts the use of preassembled building services components in complex office developments.

[P = 0.043] is less than the significance level [α = 0.05] for Levene's test (Table 6-55) and [P = 0.110] is greater than [α = 0.05] for the t-Test.

Table 6-55 Proposition t-Test for perceptions of manufacturing capacity

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Manufacturing Capacity	Equal variances assumed	4.265	0.043	1.609	60	0.113	0.2417	0.1502	-0.059	0.5422
	Equal variances not assumed			1.622	57.839	0.11	0.2417	0.149	-0.057	0.5399

There was no statistically significant difference between the scores of consultants and contractors: t (60) = 1.622, p > .05. These results suggest that PBSC make no difference in the relationship regarding manufacturing capacity in complex office developments.

Table 6-56 Compare median for perceptions of manufacturing capacity

Manufacturing capacity impacts		Statistics			
N Valid	60	Consultants		Contractors	
		Mdn	*IQR*	*Mdn*	*IQR*
Missing	0	3.5	1.0	3.5	0.75

As Table 6-56 reveals, the median of consultants (*Mdn* = 3.5, *IQR* = 1.0) and of contractors (*Mdn* = 3.5, *IQR* = 0.75) indicates that both the consultants and the contractors 'moderately agreed' that *manufacturing capacity impacts* the use of PBSC in complex office developments. This result is consistent with Pan (2007), who notes that manufacturing capacity is a barrier to the use of OCT. Zhai et al. (2013) report that the capacity of preassembly was highlighted in the building prefabrication process to overcome the challenges of sustainability in the construction industry. Housing Forum (2004) states that suppliers considered production capacity to be one of the main limiting factors of market demand (Pan et al., 2004). Additionally, specialised contractors involved in creating preassembly components are subject to business failure when maintaining the traditional strategy of building companies; the inability to pledge full utilisation of factory capacity significantly increases the costs of preassembly (Saxon, 2017).

Examining Proposition Statement 26: Skilled craft workers impact the use of preassembled building services components in complex office developments.

[P = 0.122] is greater than the significance level [α = 0.05] for Levene's test (Table 6-57) and [P = 0.245] is greater than [α = 0.05] for the t-Test.

Table 6-57 Proposition t-Test for perceptions of skilled workers

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Skilled craft Workers	Equal variances assumed	2.463	0.122	1.174	60	0.245	0.7438	0.6336	-0.524	2.0111
	Equal variances not assumed			1.209	34.298	0.235	0.7438	0.6151	-0.506	1.9933

There was no statistically significant difference between the scores of consultants and contractors: t (60) = 1.174, p > .05. These results suggest that PBSC make no difference in the relationship regarding skilled craft workers in complex office developments.

Table 6-58 Compare median for perceptions of skilled workers

Skilled craft worker impact		Statistics			
N		Consultants		Contractors	
Valid	60	*Mdn*	*IQR*	*Mdn*	*IQR*
Missing	0	3.5	0.5	3.5	1.0

As Table 6-58 shows, the median of consultants (*Mdn* = 3.5, *IQR* = 0.5) and of contractors (*Mdn* = 3.5, *IQR* = 1.0) indicates that both the consultants and the contractors ‘moderately agreed’ that *skilled craft workers impact* the use of PBSC in complex office developments. This result agrees with Steinhardt and Manley (2016), who identified the current lack of specific skilled trades with prefabrication knowledge as affecting the use of preassembly. The lack of skilled workers is often related to several ranges of technological change, mainly within developments in preassembly (McKay, 2010). Saxon (2017) states that the challenge occurs when companies are incapable of affording advanced training or research and development. However, preassembly is considered by some to be a more constructive choice currently because of the shortage of skilled labour and the increased labour cost (Luo, 2008). Similarly, the CITB (2002) state that some challenges hinder the construction industry from fulfilling its skills requirements, including competition from other industries, a lack of training, and the gap in the labour force. Luo (2008) notes that the prospects for skilled labour employment demand continue to grow above the industry average. However, the availability of skilled labourers, such as sheet metal workers, electricians, and HVAC mechanics, is decreasing.

A summary of the results of the propositions based on independent t-Tests in this section is in Table 6-59 below.

Table 6-59 Summary of results

Proposition Statement – Attitude	Consultant Perception	Contractor Perception	diff.
The use of PBSC increases **product quality** in complex office developments.	Highly Agree	Highly Agree	No
The use of PBSC improves the **speed of construction** in complex office developments.	Moderately Agree	Highly Agree	No
The use of PBSC reduces the **construction cost** in complex office developments.	Moderately Agree	highly Agree	No
The use of PBSC reduces the **construction waste** in complex office developments.	Moderately Agree	highly Agree	Yes
The use of PBSC improves the **energy efficiency** in complex office developments.	Moderately Agree	Moderately Agree	No
The use of PBSC improves **workplace safety** in complex office developments.	Moderately Agree	highly Agree	No
The use of PBSC improves **coordination among parties** in complex office developments.	Moderately Agree	Moderately Agree	No
The use of PBSC simplifies **construction tasks** in complex office developments.	Moderately Agree	Moderately Agree	No
The use of PBSC increases the **project design efficiency** in complex office developments.	Moderately Agree	highly Agree	No
The use of PBSC increases the **overall project cost** in complex office developments.	Moderately Agree	Moderately Agree	No
The use of PBSC reduces the **flexibility of designs** in complex office developments.	Moderately Agree	Moderately Agree	No
The use of PBSC limits the ability to make **changes to work onsite** in complex office developments.	Moderately Agree	Moderately Agree	No
Transport restraints limit the use of PBSC in complex office developments.	Moderately Agree	Moderately Agree	No
Maintenance capability limits the use of PBSC in complex office developments.	Moderately Agree	Slightly Agree	No
Preparatory requirements limit the use of PBSC in complex office developments.	Moderately Agree	Moderately Agree	No
The **poor-quality image** of PBSC limits their use in complex office developments.	Slightly Disagree	Slightly Disagree	No
The use of PBSC **increases risk** in complex office developments.	Slightly Agree	highly Agree	No
Proposition Statement – Subjective Norms	**Consultants' Perception**	**Contractors' Perception**	**diff.**
Consultants influence the decision to use PBSC in complex office developments.	Moderately Agree	Highly Agree	No
Clients influence the decision to use PBSC in complex office developments.	Highly Agree	Highly Agree	Yes
Governmental regulators influence the decision to use PBSC in complex office developments.	Moderately Agree	Highly Agree	Yes
Subcontractors influence the decision to use PBSC in complex office developments.	Neutral	Neutral	No

Suppliers influence the decision to use PBSC in complex office developments.	Neutral	Neutral	No
Proposition Statement – Perceived Behaviour Control	**Consultants' Perception**	**Contractors' Perception**	**diff.**
Easier financing impacts the use of PBSC in complex office developments.	Highly Agree	Highly Agree	No
Governmental rules impact the use of PBSC in complex office developments.	Highly Agree	Highly Agree	Yes
Manufacturing capacity impacts the use of PBSC in complex office developments.	Moderately Agree	Slightly Agree	No
Skilled craft workers impact the use of PBSC in complex office developments.	Moderately Agree	Slightly Agree	No

6.5.5 *Results Summary (RO: 2)*

The purpose of this section to achieve the second research objective, which is to identify the benefits, challenges, stakeholder influence, and external contextual control (attitude, SN, and PBC), as well as highlighting the top three of each element. The analysis revealed that the benefits of using PBSC in complex office developments include increasing product quality, improving the speed of construction, improving workplace safety, improving energy efficiency, increasing project design efficiency, reducing construction waste, reducing construction cost, improving coordination of staff and tasks, and simplifying tasks. On the other hand, the challenges of using PBSC in complex office developments include increasing the overall project cost, increasing risk, reducing design flexibility, requiring more preparation work, increasing transport logistics, and increasing the need for maintenance. However, neither the consultants nor the contractors supported the proposition that PBSC 'have a low-quality image'.

The analysis further revealed that the stakeholders who largely influence the decision to use PBSC in complex office developments include clients, consultants, government, and regulators. Moreover, neither the consultants nor the contractors supported the proposition that subcontractors influence the decision to use PBSC. The analysis revealed also that the external contextual controls of the decision to use PBSC in complex office developments include financial support, government regulations, manufacturing capacity, and the shortage of skilled labour. The ranking of these propositions is illustrated in Table 6-60.

The following paragraphs list the top three benefits that motivate the use of PBSC in complex office developments in Saudi Arabia, as well as the challenges that prevent their use, according to the responses obtained from the consultants and the contractors.

1) Top three benefits according to consultants

Based on the consultant responses, the top three benefits of using PBSC in complex office developments in Saudi Arabia are ranked as follows: 1) to increase the quality of product; 2) to improve the speed of construction and to improve workplace safety; and 3) to increase project design efficiency.

2) Top three challenges according to consultants

Based on consultant responses, the top three challenges to using PBSC in complex office developments in Saudi Arabia are ranked as follows: 1) reduces the flexibility of designs; 2) increases overall project cost and limits making changes to work onsite; and 3) requires more preparation work.

3) Top three benefits according to contractors

Based on the contractor responses, the top three motivations to use PBSC in complex office developments in Saudi Arabia are as follows: 1) increases the quality of the product; 2) improves the speed of construction; and 3) reduces construction costs.

4) Top three challenges according to contractors

Based on the contractor responses, the top three challenges to the use of PBSC in complex office developments in Saudi Arabia are as follows: 1) limits making changes to work onsite; 2) requires more preparation work; and 3) increases transport logistics and increases risk.

5) Top three stakeholder influence on decisions, according to consultants: 1) client, 2) government regulators, and 3) consultants.

6) Top three stakeholder influence on decisions, according to contractors: 1) client, 2) consultants, and 3) government regulators.

7) Top three contextual controls on decisions, according to consultants: 1) governmental regulations, 2) financial support, and 3) skilled workers.

8) Top three contextual controls on decision-making, according to contractors: 1) financial support, 2) governmental regulations, and 3) manufacturing capacity. Table 6-60 summarises the results of this section.

Table 6-60 Summary of median and ranking

Variables		*Mdn*	Consultants			Contractors		
			No		Rank	No		Rank
			>	≤		>	≤	
Benefits	Increase the quality of product	4	10	21	1	9	20	1
	Improve the speed of construction	4	6	25	2	8	21	2
	Improve workplace safety	4	6	25	2	0	29	4
	Improve energy efficiency	3.5	9	22	6	14	15	6
	Increase design efficiency	4	4	27	3	0	29	4
	Reduce construction waste	3.5	5	26	8	17	12	5
	Reduce construction cost	4	0	31	4	5	24	3
	Improve staff coordination	3.5	8	23	7	11	18	8
	Simplify tasks	3.5	12	19	5	13	16	7
Challenges	Increase overall project cost	3.5	10	21	2	3	26	5
	Increase risk	3.5	2	29	6	6	23	3
	Reduce the flexibility of designs	3.5	13	18	1	4	25	4
	Require more preparation work	3.5	9	22	3	8	21	2
	Limit making changes onsite	3.5	10	21	2	9	20	1
	Increase transport logistics	3.5	7	24	4	6	23	3
	Increase need for maintenance	3.5	3	28	5	2	27	6
	Image of low-quality outcome	2.5	12	19		10	19	
Stakeholder Influence								
SN	Consultant	4	6	25	3	14	15	2
	Client	4	11	20	1	16	13	1
	Government and regulators	4	10	21	2	3	26	3
	Suppliers	3	6	25		5	24	
	Subcontractors	3	7	24		4	25	
External Contextual Control								
PBC	Financial support	4	8	23	2	10	19	1
	Government regulations	4	10	21	1	9	20	2
	Manufacturing capacity	3.5	8	23	4	10	19	3
	Skilled craft workers	3.5	12	19	3	6	23	4

6.6 Objective 3: Examine the Relationship Between Consultant and Contractor Perceptions

Objective 3 is to examine the relationship between consultant and contractor perceptions regarding the use of PBSC in complex office developments. This objective was first discussed in the literature review and methodology (4.10), and then examined using the questionnaire results via a t-Test. The analysis results are summarised in Table 6-59 and the discussion is presented in the following section.

6.6.1 *The Relationship Between Consultant and Contractor Perceptions Towards Using Preassembled Building Services Components (RO: 3 Discussion)*

This section discusses the analysis of the t-Test regarding consultant and contractor perceptions towards the use of PBSC in complex office developments in the Saudi context. The results of the t-Test identified in this study are in line with Lu (2007). The t-Test revealed that the results of all attitudes, including both the benefits and the challenges, are insignificant, except the variable related to reducing construction waste. This result is not consistent with Lu (2007), however, who examined the impact of using OCT to reduce construction operations in the US. This inconsistency could be due to the different context. Similarly, the t-Test revealed that the results of SN are all insignificant, except the one related to the influence of the client and the government regulators on the decision to use PBSC. The result of 'the client influence on the decision' is in line with Lu (2007), who notes that clients' negative perceptions limit the use of OCT. However, in Lu's study, government regulators were not examined. The t-Test revealed also that the results of PBC are not significant, except the variable related to the government regulations' control regarding the use of PBSC. Again, this result is inconsistent with Lu (2007), who examined the restriction of local building regulations on the use of OCT in the US. This inconsistency could be because of Lu's (2007) study being in a different context.

6.7 Objective 4: Determine Consultant and Contractor Intentions to Use Preassembled Building Services Components

Objective 4 is to determine consultant and contractor intentions to use PBSC in complex office developments (statistically). This objective was first mentioned in the literature review of the TPB and investigated using the questionnaire results. The analysis and discussion are presented in the following sections.

6.7.1 *Opinion Regarding Upgrading the Level of Preassembled Building Services Components – Intention (RO: 4)*

This part of the questionnaire was statistically analysed using the ordinal regression model for those direct questions concerning practitioner intentions to use PBSC. All the participants were asked to express their opinions about the three direct dimensions of the TPB, which were presented in a scale between 1 and 5 (i.e. from 'strongly disagree' to 'strongly agree'). A statistical analysis of the responses revealed that all three direct questions were significant, where p is ≤ 0.05. Table 6-61, below, reveals that the intentions of both consultants and contractors are significant regarding using PBSC in complex office developments.

Pseudo R-Square

Cox and Snell	.645
Nagelkerke	.797
McFadden	.624

Pseudo R-Square indicates that only 0.79 of Y can be explained by X.

Table 6-61 Intention to use PBSC (direct)

							95% Confidence Interval	
		Estimate	**Std. Error**	**Wald**	**Df**	**Sig.**	**Lower Bound**	**Upper Bound**
Threshold	[Intention-Q3 0.0]	4.886	.792	38.06	1	.000	3.333	6.438
	[Intention-Q3 1.0]	7.487	1.048	51.01	1	.000	5.432	9.541
	[Intention-Q3 2.0]	8.916	1.099	65.81	1	.000	6.762	11.07
	[Intention-Q3 3.0]	9.048	1.103	67.23	1	.000	6.885	11.21
Location	**Worthwhile**	1.819	.614	8.78	1	.003	.616	3.022
	Supported by most parties	.636	.419	2.30	1	.029	-1.457	.186
	Easy to do	.876	.438	4.002	1	.045	.018	1.734

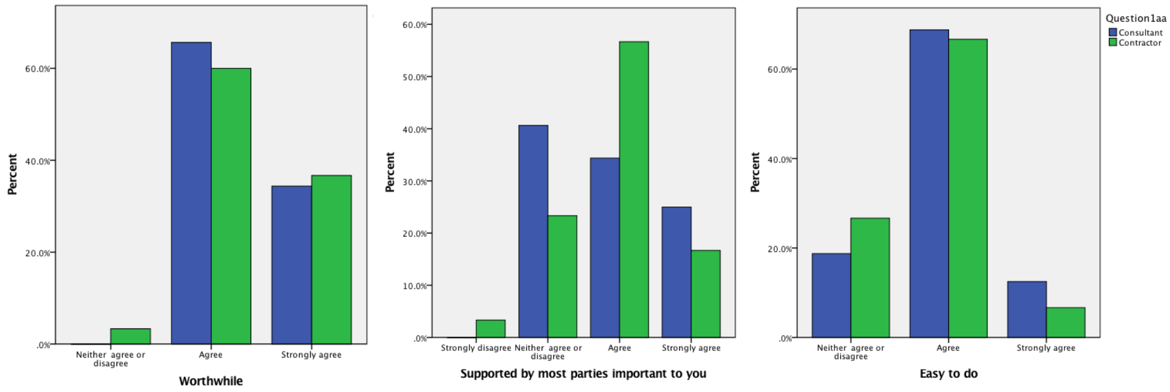

Figure 6-7 Intention to use PBSC (direct)

The ordinal regression model was used. Here, Y is a dependent variable expressed by (0, 1, 2, 3, 4) instated of (-∞, +∞).

Y=$\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_2$

X1= (Worthwhile), β=1.819, P=0.003 --- significant since it is ≤ 0.05

X2= (Supported by most parties), β=.636, P=0.029 --- significant since it is ≤ 0.05

X3 = (Easy to do), β=876, P=0.045 --- significant since it is ≤ 0.05

Threshold:

Y= (0, 1, 2, 3, 4)

(-∞, 4.886) – (4.886, 7.487) – (7.487, 8.916) – (8.916, 9.048) - (9.048, +∞)

For example;

Where β_1=1.819

Assume x_1=3

Therefore, Y = 3 x 1.819 = 5.457, which is = 2

The results of the above analysis are based on the theoretical components of the TPB in Chapter 3, Figure 3-1. The literature review noted these beliefs in a different manner. However, these beliefs were not examined using a similar theoretical framework. The TPB represents a well-validated set of structured beliefs that assist in interpreting the relationships between beliefs (Steinhardt and Manley, 2016). The results from this study include the examination of the three direct measures: 1) attitude, 2) SN, and 3) PBC. Therefore, the results of this research reveal that both the consultants and the contractors have a significant intention to use PBSC in complex office developments in Saudi Arabia. This result is consistent with Almutairi (2015, p.205), who found a good level of satisfaction among participants regarding the use of OCT in the Saudi context. However, this result is not in line with Pan (2006, p.150), who notes that a large number of leading house-builders in the UK were not satisfied with the performance of offsite-MMC.

6.7.2 *Indirect and Direct Intention Questions Regarding Using Preassembled Building Services Components*

This part of the analysis was statistically analysed using the ordinal regression model for predicting internal intentions based on practitioner responses regarding the use of PBSC, which were obtained through direct and indirect questions in the three sections of the PBT in accordance with Francis (2004). This was done to predict the practitioners' intentions by mapping the significance of all indirect questions to each of the three direct questions. Therefore, a statistical analysis was performed on the responses. The indirect questions indicate a significance, where p is ≤ 0.05. Table 6-62 reveals that indirect attitudes and indirect PBC are both significant for predicting direct attitudes, where $p = 0.047$ and $p = 0.028$, respectively; however, indirect SN are not significant. Also, Table 6-63 reveals that both indirect attitudes and indirect PBC are significant for predicting direct SN, where $p = 0.002$ and $p = 0.025$, respectively; however, indirect SN are not significant. Table 6-64 reveals that there is no significance regarding prediction of direct PBC from indirect questions.

Table 6-62 Both indirect attitudes and indirect PBC are significant for predicting direct attitude

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[Attitude_a = 3.00]	3.432	2.486	1.905	1	0.167	-1.44	8.31
	[Attitude_a = 4.00]	8.687	2.508	11.99	1	0.001	3.77	13.6
Location	Indirect_attitude	0.012	0.006	3.939	1	0.047	0	0.02
	Indirect_Subjective_norm	0.027	0.02	1.858	1	0.173	-0.01	0.07
	Indirect_PBC	0.062	0.028	4.809	1	0.028	0.007	0.12

Table 6-63 Both indirect attitudes and indirect PBC are significant for predicting direct SN

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[CPB_c = 3.00]	1.569	1.961	0.64	1	0.424	-2.28	5.41
	[CPB_c = 4.00]	5.243	2.123	6.098	1	0.014	1.082	9.4
Location	Indirect_attitude	0.001	0.006	0.045	1	0.832	-0.01	0.01
	Indirect_Subjective_norm	0.017	0.013	1.55	1	0.213	-0.01	0.04
	Indirect_PBC	0.026	0.026	1.044	1	0.307	-0.02	0.08

Table 6-64 There are no significant variables for predicting direct PBC

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence	
							Lower Bound	Upper Bound
Threshold	[SN_b = 1.00]	2.439	2.128	1.314	1	0.252	-1.73	6.61
	[SN_b = 3.00]	6.124	1.971	9.65	1	0.002	2.26	9.99
	[SN_b = 4.00]	8.587	2.155	15.88	1	0	4.364	12.8
Location	Indirect_attitude	0.018	0.006	9.795	1	0.002	0.007	0.03
	Indirect_Subjective_norm	-2.85E-05	0.012	0	1	0.998	-0.02	0.02
	Indirect_PBC	0.054	0.024	5.019	1	0.025	0.007	0.1

Francis et al. (2004) instructed how to measure the regression of indirect determinants to predict the direct determinants in order to examine their influence. This result reveals that both indirect attitudes and indirect PBC are significant for predicting direct attitude. Furthermore, indirect attitudes and indirect PBC are both significant for predicting direct SN. However, direct PBC is not significantly predicted by the other three indirect determinants. These results are unique in terms of statistics treatment and data entry. Thus, they cannot be compared to the literature reviewed in this study, nor can they be compared to the work of Steinhardt and Manley (2016) because of the difference in the approach method (qualitative method).

6.8 Objective 5: Determine the Reasons Why Preassembled Building Services Components Were Not Being Used

Objective 5 is to determine the reasons why PBSC were not being used by consultants and contractors (non-practitioners) in complex office developments. This objective was first highlighted in the literature review and then investigated using the interviews and questionnaire results. The analysis and discussion are presented in the following section.

6.8.1 *Reasons for Not Using Preassembled Building Services Components (RO: 5 Analysis and Discussion)*

This section presents the data analysis of the reasons that prevent non-practitioners of preassembly from using PBSC in complex office developments (both consultants and contractors). The data were analysed using the t-Test to compare the mean of both the consultants and the contractors. The data analysis reveals no significance in the results between consultants and contractors, apart from the following three factors: increase in overall project cost, increase in risk, and increase in transport logistics.

Moreover, this section discusses the perceptions of consultants and contractors who have not practised preassembly to reveal their reasons for not using PBSC applications in complex office developments. The survey results agree with Goodier and Gibb (2004), Venables et al. (2004), Pan et al. (2006), Lu (2007), Goulding et al. (2012), and Almutairi (2015). According to the survey results, and the results of the above studies, the reasons that prevent the use of PBSC by consultants and contractors who have not practised preassembly include, 1) the increase in the overall project cost; 2) the reduction in design flexibility; 3) the lack of governmental support; and 4) the manufacturing capacity. Also, the respondents did not support other propositions, such as the increase in risk; the need for more preparation work; the limitations in making changes to work onsite; the increase in transport logistics; the increase of required maintenance; the lack of financial support; the low-quality image; the shortage of skilled craft workers; and the lack of products in the market. The reasons that prevent the use of PBSC by consultants and contractors are now analysed and discussed.

After following the same procedure of analysis for the t-Test, Table 6-65 reveals that only three variables displayed significant differences between consultant and contractor responses: 1) the increase of overall project cost; 2) the increase of risk and 3) the increase of transport logistics.

[$P = 0.037$] is less than the significance level [$\alpha = 0.05$] for Levene's test (Table 6-65), and [$P = 0.016$] is less than [$\alpha = 0.05$] for the t-Test. Thus, there was a statistically significant difference in the scores of consultants and of contractors: $t(198) = -1.620$, $p < .05$. These results suggest that PBSC affect the relationship regarding overall construction cost in complex office developments.

The median of consultants (Mdn = 4.0, IQR = 0.5) and of contractors (Mdn = 4.0, IQR = 1.0) indicates that both the consultants and the contractors ‘highly agreed’ that the use of PBSC increases the overall project cost in complex office developments. Therefore, the increase in overall project cost is the main reason preventing practitioners from using the PBSC. This result agrees with Blismas and Wakefield (2009), who note that OSM is considered a more expensive option in the Australian context. Similarly, Zhai et al. (2014) state that the overall cost of preassembly often includes higher initial costs, higher capital costs, and a longer capital payback period.

[P = 0.012] is less than the significance level [α = 0.05] for Levene's test (Table 6-65), and [P = 0.036] is less than [α = 0.05] for the t-Test. Thus, there was a statistically significant difference in the scores of consultants and of contractors: t (198) = -2.113, $p < .05$. These results suggest that PBSC affect the relationship regarding risk increasing in complex office developments.

The median of consultants (Mdn = 4.0, IQR = 1.0) and of contractors (Mdn = 4, IQR = 1.0) indicates that both the consultants and the contractors 'moderately agreed' that the use of PBSC *increases the risk* in complex office developments. Furthermore, the increase in risk is documented as a reason preventing the use of PBSC, which is consistent with Pan (2007). The risks of using preassembly include design changes during the project (NAO, 2005); risk of maintenance (Pan et al. 2008); and risk of new construction methods (Steinhardt and Manley, 2016). The results regarding the need for more preparation work and the inability to make changes to work onsite are in line with Zhai et al. (2013), who found that both these reasons prevent the use of OCT in the Chinese context.

[P = 0.001] is less than the significance level [α = 0.05] for Levene's test (Table 6-65), and [P = 0.010] is less than [α = 0.05] for the t-Test. Thus, there was a statistically significant difference in the scores of consultants and of contractors: t (198) = -2.615, $p < .05$. These results suggest that PBSC affect the relationship regarding increased transport logistics in complex office developments.

The median of consultants (Mdn = 4.0, IQR = 1.0) and of contractors (Mdn = 4.0, IQR = 1.0) indicates that both the consultants and the contractors 'moderately agreed' that the use of PBSC increases transport logistics in complex office developments. This finding, as a reason for preventing the use of PBSC, is consistent with Steinhardt and Manley (2016). The transport challenge includes limitations of size and weight and constraints of width and height that are required for the technique and path of transporting components (Manley et al., 2009).

In addition, the reduction of design flexibility is confirmed by this study as a second reason that prevents the use of PBSC, which is consistent with Pan (2007). According to Almutairi (2015), preassembly hinders making changes in designs, which is a key challenge. However, standardisation plays a significant role in contributing towards a reduction in real construction costs (Graing, 2000).

Financial support is the third reason that hinders the use of PBSC. This result agrees with Steinhardt and Manley (2016). According to McKay (2010), investment in preassembled facilities, including factories, plant, and other construction approaches, in conjunction with the industry's mitigation risk attitude has prevented the application of preassembly construction techniques. Similarly, the lack of governmental support is confirmed by this study, which also prevents the use of PBSC. This result is consistent with Almutairi (2015). Mao et al. (2011) found the lack of government policies was the main challenge due to inadequate progress with the application of preassembly. Making changes onsite during the construction phase is not possible with preassembly, which consequently reduces its use (Blismas, 2007; Blismas and Wakefield, 2009).

The results reveal that lack of products is not a reason that hinders the use of PBSC. This result is consistent with Pan (2007). Therefore, the inability to pledge full utilisation of factory capacity causes large costs for preassembly (Saxon, 2017). Moreover, this study reveals that skilled craft workers are a reason that prevents the use of PBSC. This result is in line with Steinhardt and Manley (2016) from the consultant point of view, but is inconsistent with the contractor point of view. The problem of skilled labour is related to several technological changes, mainly within developments in preassembly (McKay 2010). Saxon (2017) states that this challenge occurs when companies are incapable of affording high training or research and development.

The challenge of the increased need for maintenance is consistent with Zhai, et al. (2013), in addition to the result of having a low-quality image from the consultants perspective, but, again, is inconsistent with that of the contractors.

The issue of major maintenance risks being related to a high number of defects was unclear regarding bathroom maintenance. Therefore, wet areas are critical in terms of increased maintenance (Ramly et al., 2006). The negative perceptions of preassembly include lack of governmental support, lack of available codes and standards, client disbelief and resistance, and lack of confidence within the industry regarding preassembled construction (Blismas, 2007; Blismas and Wakefield, 2009; Goodier and Gibb, 2007; Manley et al., 2009).

Table 6-65 Proposition t-Test for perceptions of reasons for not using PBSC

		Levene's Test for Equality of Variances		t-Test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Increase overall project cost	Equal variances assumed	4.429	0.037	-1.62	198	0.017	-0.1349	0.08324	-0.299	0.0293
	Equal variances not assumed			-1.619	193.21	0.016	-0.1349	0.08328	-0.2991	0.0294
Increase risk	Equal variances assumed	6.406	0.012	-2.113	198	0.036	-0.1809	0.08562	-0.3497	-0.012
	Equal variances not assumed			-2.11	191.13	0.036	-0.1809	0.08571	-0.3499	-0.0118
Reduce the flexibility of designs	Equal variances assumed	0.179	0.673	-0.469	198	0.64	-0.0424	0.09045	-0.2208	0.136
	Equal variances not assumed			-0.468	192.32	0.64	-0.0424	0.09052	-0.2209	0.1362
More preparation work	Equal variances assumed	2.862	0.092	-1.787	198	0.075	-0.151	0.08448	-0.3176	0.0156
	Equal variances not assumed			-1.787	193.71	0.076	-0.151	0.0845	-0.3177	0.0157
Limit making changes to work onsite	Equal variances assumed	2.526	0.114	1.828	198	0.069	0.15558	0.08512	-0.0123	0.3235
	Equal variances not assumed			1.829	193.82	0.069	0.15558	0.08508	-0.0122	0.3234
Increase transport logistics	Equal variances assumed	12.01	0.001	-2.621	198	0.009	-0.2318	0.08845	-0.4063	-0.0574
	Equal variances not assumed			-2.615	185.17	0.01	-0.2318	0.08863	-0.4067	-0.0569
Increase need for maintenance	Equal variances assumed	3.778	0.053	1.023	198	0.308	0.08674	0.08482	-0.0805	0.254
	Equal variances not assumed			1.023	193.74	0.307	0.08674	0.08477	-0.0804	0.2539
Poor-quality image	Equal variances assumed	0.867	0.353	1.179	198	0.24	0.12288	0.10419	-0.0826	0.3284
	Equal variances not assumed			1.178	191.95	0.24	0.12288	0.10428	-0.0828	0.3286
Shortage of skilled craft workers	Equal variances assumed	0.856	0.356	0.582	198	0.561	0.06081	0.10447	-0.1452	0.2669
	Equal variances not assumed			0.581	186.1	0.562	0.06081	0.10467	-0.1457	0.2673
Lack of governmental support	Equal variances assumed	0.107	0.744	-0.269	198	0.788	-0.0211	0.0786	-0.1762	0.1339
	Equal variances not assumed			-0.269	193.44	0.788	-0.0211	0.07863	-0.1762	0.134
Lack of financial support	Equal variances assumed	0.477	0.491	-0.141	198	0.888	-0.0113	0.07977	-0.1686	0.1461
	Equal variances not assumed			-0.141	193.6	0.888	-0.0113	0.07972	-0.1685	0.146
Lack of products in the market	Equal variances assumed	2.01	0.158	0.686	198	0.493	0.06873	0.10014	-0.1288	0.2662
	Equal variances not assumed			0.685	189.77	0.494	0.06873	0.10027	-0.1291	0.2665

6.8.2 *Summary of Results for Reasons (RO: 5 Discussion)*

The purpose of the data analysis is to identify the reasons that hinder non-practitioners of preassembly from using PBSC in complex office developments. The analysis revealed that, according to consultants and contractors, the reasons for not using PBSC in complex office developments include increased overall project cost, reduced flexibility of designs, lack of governmental support, and lack of manufacturing capacity. The respondents were neutral to the other factors. The ranking for these propositions is illustrated in Table 6-66.

.Based on the responses of consultants (non-practitioners), the top three reasons that hinder the use of PBSC in complex office developments in Saudi Arabia are as follows: 1) increase in the overall project cost; 2) reduction in design flexibility and the government regulations; and 3) lack of manufacturing capacity.

Based on the responses of contractors (non-practitioners), the top three reasons that hinder the use of PBSC in complex office developments in Saudi Arabia are as follows: 1) increase in the overall project cost, 2) reduced design flexibility, and 3) lack of manufacturing capacity.

Table 6-66 Compare mean regarding perceptions of reasons for not using PBSC

Variables		*Mdn*	Consultants No >	Consultants No ≤	Consultants Rank	Contractors No >	Contractors No ≤	Contractors Rank
Reasons	Increase overall project cost	4	16	83	1	26	70	1
	Increase risk	3	28	71		45	51	
	Reduce the flexibility of designs	4	3	96	2	4	92	2
	Require more preparation work	3	44	55		48	48	
	Limit making changes to work onsite	3	48	51		32	64	
	Increase transport logistics	3	29	70		48	48	
	Increase need for maintenance	3	32	67		30	66	
	Low-quality image	3	35	64		21	75	
	Financial support	3	38	61		22	74	
	Government regulations	4	0	99	3	2	94	4
	Manufacturing capacity	4	3	96	2	3	93	3
	Skilled craft workers	3	8	91		9	87	

6.9 Case Studies (External Validity)

This section presents the analysis and discussion of the case studies. Three case studies were investigated to validate the results of this study. Case Study 1 represents a consultant firm, Case Study 2 represents a general contractor company, and Case Study 3 represents a specialised subcontractor. The consultants and contractors were interviewed at the project site and answered structured questions in the form of a matrix and closed questions to convey the results of this research into a real-world case study. The participants (consultants and contractors) were architects, project managers, and senior mechanical, electrical, and civil engineers. For practicality, the evaluation procedure used Microsoft Excel, pairwise comparison, occurrence indices, and frequency indices.

The results of this research are presented in the model of TPB, which involves three predictors for the intention: attitudes (benefits and challenges), SN (stakeholder influence), and PBC (external contextual control). Accordingly, the three case studies were evaluated using the matrix for pairwise comparison, occurrence indices, and frequency indices. The results of the case studies confirmed the attitudes, the SN, and the PBC regarding the use of PBSC in complex office developments in the Saudi Arabian context.

Three firms were selected (represented by consultant, a general contractor, and a specialised subcontractor) that employ PBSC in their projects to validate the outcome model (results) of this study, which is Phase 3 of the research. Therefore, each firm provided a case study that includes applications of PBSC. The case study selection was based on certain criteria, which were presented in the methodology chapter (Section 4.9.10). All the participants in this validation section were part of the decision-making processes for construction strategy in their firms. More details of these case studies are now discussed.

6.9.1 *Case Study 1*

Case Study 1, CP-D, is a new complex office development presented by a consultant. The gross floor area is approximately 65,000 m^2 (basement excluded), which contains offices space, a 400-seat theatre, food areas, a fitness centre, and a swimming pool on the top floor. The underground area consists of three full basement levels that accommodate car parking, provision functions, central plant, and equipment zones. The client (a government body) intends to employ 35% of the project for their own use, while renting the remaining office spaces. The client requirements included a high-performance solar control system, including external fins with perforated panels for shading and enhancing the thermal efficiency. Thus, the shading devices are orientated to optimise the use of an HVAC system to reduce energy costs. Moreover, wireless communication and fibre optics are provided as well as a photovoltaic system on the roof of the tower to promote electrical power.

The evaluation process of the project outcomes involves a project manager (contractor), a senior electrical engineer (specialised contractor), and a mechanical engineer (consultant). The project data were reviewed to promote the evaluation of the results. The critical objective is to provide a high-performance solar control system, high-quality building services systems, an environmental and sustainable building, as well as a healthy and safe environment for the end-users. In addition, the project needs to meet the completion date, as the client plans to profit from renting the remaining office spaces.

The client requirements revealed that the main concern is to provide a highly sustainable project that can meet recent legislation updates by the Government regarding energy-saving and avoid high-cost energy consumption. These requirements cover the end-users' health and safety, which meet high standards for workspaces and ensure the building is highly classified in the real estate market. The project completion is a critical factor in terms of time to market the project and make the most profit possible. Other indicators, both benefits and challenges, were evaluated, including design efficiency, cooperation, task performing, risk involvement, transport, and maintenance. The respondents indicated that the client plays a major role in influencing decision-making, followed by the consultant. However, meeting the government regulations was identified as the most important control for deciding to apply new technologies, including PBSC.

Figure 6-8 Equipment zone – inside ductwork (Source: Author)

During the discussion, the participants agreed with all the factors included on the evaluation sheet, except low-quality image, mainly because most PBSC are concealed. Also, the factor of stakeholder influence excluded the influence of subcontractors regarding decision-making, as in this project they were not part of the contractual agreement. Therefore, based on the discussion and the inclusion of the nine benefit factors, the evaluation process of the matrix demonstrates that the highly scored factors for benefits are as follows: quality (S1) and project schedule (S1), construction cost (S2), and energy efficiency (S3). The medium scored factors are workplace safety (S4) and construction tasks (S5). Finally, the low scored factors for benefits are construction waste (S6), coordination among parties (S7), and design efficiency (S7).

Based on the discussion and the inclusion of the eight challenge factors, the highest scored challenge factors are making changes onsite (S1), design flexibility (S2), and preparatory requirements (S3). The medium scored factors for challenges are overall project cost (S4) and transport (S4). Finally, the low-scored factors for challenges are risk involvement (S5) and maintenance capability (S5). The low-quality image factor failed in this evaluation. Case study CP-D provides evidence to validate the results of this study.

Tables 6-67 and 6-68 contain the data and results of the evaluation process and matrix.

Furthermore, based on the discussion and the inclusion of the five stakeholder influence factors, the client (S1) has the highest scored influence on decision-making, according to respondents, followed by the consultants (S2). However, the influence of governmental regulators is medium (S3), while the influence of suppliers is low (S4). The subcontractors factor failed in this evaluation.

Table 6-67 Matrix of pairwise comparison for CP-D case study

	Benefits	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
A	Quality of product	0								
B	Speed of construction	A	0							
C	Workplace safety	A	B	0						
D	Energy efficiency	D	B	D	0					
E	Design efficiency	A	B	C	D	0				
F	Construction waste	A	B	C	D	F	0			
G	Construction cost	A	B	G	G	G	G	0		
H	Coordination btw. parties	A	B	C	D	H	F	G	0	
I	Construction Tasks	A	B	C	I	E	I	G	I	0
	Challenges	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	
J	Overall project cost	0								
K	Risky	J	0							
L	Design flexibility	L	L	0						
M	Preparatory requirements	M	M	L	0					
N	Transport	J	N	L	M	0				
O	Maintenance capability	O	K	L	M	N	0			
P	Make changes onsite	P	P	P	P	P	P	0		
Q	Low-quality image	J	K	L	M	N	O	P	0	
	Stakeholders Influence	**R**	**S**	**T**	**U**	**V**				
R	Consultants	0								
S	Clients	S	0							
T	Governmental regulators	R	S	0						
U	Subcontractors	R	S	T	0					
V	Suppliers	R	S	T	V	0				
	Contextual Control	**W**	**X**	**Y**	**Z**					
W	Financial support	0								
X	Governmental regulations	W	0							
Y	Manufacturing capacity	W	X	0						
Z	Skilled craft workers	W	X	Z	0					

Additionally, based on the discussion and the inclusion of the four control factors, the only high contextual control is financing (S1). Government regulations have a medium control of behaviour (S2), while the control of skilled craft workers is low (S3). The 'manufacturing capacity' factor failed in this evaluation.

Overall, CP Development confirms all the results except the challenge factors of ‘low-quality image’, the ‘subcontractor’ as influencer stakeholder, and the ‘manufacturing capacity’ as an external contextual control factor. In addition, the evaluation matrix reveals that the highest three benefits are as follows: 1) improving the quality of the product and reducing the construction time; 2) reducing the construction cost; and 3) enhancing energy efficiency. On the other hand, the evaluation reveals that the highest three challenges are as follows: 1) making changes onsite; 2) reduction of design flexibility; and 3) requiring more preparation work. Similarly, the top influencer regarding the decision are as follows 1) client, 2) consultant, and 3) regulators, which were evaluated as a medium factor. The top external contextual controls are as follows: 1) financial support, 2) government regulation, and 3) skilled labour as a medium factor.

Table 6-68 Occurrence, frequency, and ranking for CP-D case study

	Indicator Code Benefits	Occurrence	Frequency (%)	Ranking (Ri) Score
A	Quality of product	7	78	S1
B	Speed of construction	7	78	S1
C	Workplace safety	4	44	S4
D	Energy efficiency	5	56	S3
E	Design efficiency	1	11	S7
F	Construction waste	2	22	S6
G	Construction cost	6	67	S2
H	Coordination among parties	1	11	S7
I	Construction tasks	3	33	S5
	Indicator Code Challenges	**Occurrence**	**Frequency (%)**	**Ranking (Ri)**
J	Overall project cost	3	38	S4
K	Risky	2	25	S5
L	Design flexibility	6	75	S2
M	Preparation requirements	5	63	S3
N	Transport	3	38	S4
O	Maintenance capability	2	25	S5
P	Make changes onsite	7	88	S1
Q	Low-quality image	0	0	0
	Indicator Code Stakeholder Influence	**Occurrence**	**Frequency (%)**	**Ranking (Ri)**
R	Consultants	3	60	S2
S	Clients	4	80	S1
T	Governmental regulators	2	40	S3
U	Subcontractors	0	0	0
V	Suppliers	1	20	S4
	Indicator Code Contextual Control	**Occurrence**	**Frequency (%)**	**Ranking (Ri)**
W	Financial support	3	75	S1
X	Governmental regulations	2	50	S2
Y	Manufacturing capacity	0	0	0
Z	Skilled craft workers	1	25	S3

6.9.2 *Case Study 2*

Case Study 2, GP-D, is a new complex office development (represented by a general contractor) with a gross floor area of approximately 54,200 m^2. The project includes offices, retail spaces, conference rooms, a lobby, a fitness centre, food catering, and car parking. The design goal was mainly to provide a cost-effective and energy-efficient mechanical strategy. According to the respondents (the project manager and two senior mechanical engineers), the client requirements in the project documents mainly included: 1) achieving the project in a cost-effective manner; 2) committing to the milestones and completing the project on time; 3) providing high-quality building services; and 4) minimising the operation cost. The consultants noted that the key challenges that accompany the project are the complexity of the designs, requiring more preparation time, and the inability to make changes onsite due to the complex designs and the fact that some components are already preassembled. These main challenges increase the chances of various risks to the project. Similarly, transport logistics were mentioned as a challenge, being subject to traffic law.

In addition, the client requirements concentrate on the predictability of cost and time, the quality of products, and the cost of operation. The department of construction management represents the client for this project. Furthermore, these requirements allow the client to decide on the systems and methods appropriate for the project. Figure 6.8 illustrates the outdoor system and ductwork. Other attitude indicators, such as construction waste and energy efficiency, must be met by different authorities (e.g. MOMRA). Similarly, the managerial indicators, such as coordination and construction tasks, are important for both the consultant and the contractor.

Therefore, the client, as well as the consultant on this project, influence the decision-making. The consultant represents the client in approving the specifications of the components. Consequently, the financing, authorities' regulations, and the skilled labourers are the contextual controls on the decisions regarding certain benefits. Furthermore, the procurement system, as a regulations reference, limits the use of innovative products if there are not enough competitors (at least three). Also, financing and skilled labourers are influenced by new and updated legislation by either Saudi Arabia's Monetary Authority (SAMA) or the Ministry of Labours (MOL).

Figure 6-8 Outdoor ductwork and air handling units (Source: Author)

During the discussion, the participants agreed on all the factors included on the evaluation sheet, except for 'low-quality image', because most PBSC are concealed. Also, the factor of stakeholder influence excludes the influence of subcontractors on decision-making, as they were not part of the contractual agreement. Case study GP-D provides evidence to validate the results of this study. Tables 6-69 and 6-70 display the data and results of the evaluation process and matrix.

Therefore, based on the discussion and the inclusion of the nine benefit factors, the evaluation matrix demonstrates that the high-scored factors for benefits are as follows: quality (S1), project schedule (S2), workplace safety (S2), construction cost (S3), and design efficiency (S3). The medium-scored factors for benefits are energy efficiency (S4) and construction waste (S4). Finally, the low-scored factors for benefits are coordination among parties (S5) and construction tasks (S5).

Table 6-69 Matrix of pairwise comparison for GP-D case study

Benefits		**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
A	Quality of product	0								
B	Speed of construction	A	0							
C	Workplace safety	A	C	0						
D	Energy efficiency	A	B	C	0					
E	Design efficiency	A	B	C	E	0				
F	Construction waste	A	B	C	F	E	0			
G	Construction cost	A	B	G	G	E	G	0		
H	Coordination btw. parties	A	B	C	D	E	F	G	0	
I	Construction Tasks	A	B	C	D	E	I	G	H	0
Challenges		**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	
J	Overall project cost	0								
K	Risk	J	0							
L	Design flexibility	L	L	0						
M	Preparation requirements	M	M	L	0					
N	Transport	J	N	L	N	0				
O	Maintenance capability	J	K	L	O	O	0			
P	Make changes onsite	P	K	P	P	P	P	0		
Q	Low-quality image	J	K	L	M	N	O	P	0	
Challenges		**R**	**S**	**T**	**U**	**V**				
R	Consultants	0								
S	Clients	S	0							
T	Governmental regulators	R	T	0						
U	Subcontractors	R	S	T	0					
V	Suppliers	R	S	V	V	0				
Challenges		**W**	**X**	**Y**	**Z**					
W	Financial support	0								
X	Governmental regulations	W	0							
Y	Manufacturing capacity	X	W	0						
Z	Skilled craft workers	X	Z	Y	0					

On the other hand, based on the discussion and the inclusion of the eight challenge factors, the highest-scored challenge factors are making changes onsite (S1) and design flexibility (S2). The only medium-scored factor is overall project cost (S3). The low-scored factors for challenges are risk involvement (S4), maintenance capability (S4), transport (S4), and preparation requirements (S4). The low-quality image factor failed in this evaluation.

Table 6-70 Occurrence, frequency, and ranking for GP-D case study

	Indicator Code Benefits	Occurrence	Frequency (%)	Ranking (Ri) Score
A	Quality of product	8	89	S1
B	Speed of construction	6	67	S2
C	Workplace safety	6	67	S2
D	Energy efficiency	2	22	S4
E	Design efficiency	5	56	S3
F	Construction waste	2	22	S4
G	Construction cost	5	56	S3
H	Coordination among parties	1	11	S5
I	Construction tasks	1	11	S5
	Indicator Code Challenges	**Occurrence**	**Frequency (%)**	**Ranking (Ri)**
J	Overall project cost	4	50	S3
K	Risk	3	38	S4
L	Design flexibility	6	75	S2
M	Preparation requirements	3	38	S4
N	Transport	3	38	S4
O	Maintenance capability	3	38	S4
P	Make changes onsite	6	88	S1
Q	Low-quality image	0	0	0
	Indicator Code Stakeholders Influence	**Occurrence**	**Frequency (%)**	**Ranking (Ri)**
R	Consultants	3	60	S1
S	Clients	3	60	S1
T	Governmental regulators	2	40	S2
U	Subcontractors	0	0	0
V	Suppliers	2	40	S2
	Indicator Code Contextual Control	**Occurrence**	**Frequency (%)**	**Ranking (Ri)**
W	Financial support	2	50	S1
X	Governmental regulations	2	50	S1
Y	Manufacturing capacity	1	25	S2
Z	Skilled craft workers	1	25	S2

Furthermore, based on the discussion and the inclusion of the five stakeholder influence factors, client (S1) and consultant (S1) scored the highest regarding decision-making, according to the respondents, followed by government regulators (S2) and suppliers (S2), who scored low influence. The subcontractors factor failed in this evaluation. Also, based on the discussion and the inclusion of the four contextual control factors, the highest scored are government regulations (S1) and financing (S1); whereas, the control of skilled craft workers (S2) and manufacturing capacity (S2) is low.

Overall, GP Development confirms all the results except the challenge factor ‘low-quality image’ and the ‘subcontractor’ as influencer stakeholder. The evaluation matrix reveals that the highest three benefits are as follows: 1) improving the quality of the product, 2) reducing the construction time, 2) enhancing work safety, and 3) enhancing design efficiency and 3) reducing construction cost. On the other hand, the evaluation reveals that the highest three challenges are 1) making changes onsite, 2) reducing design flexibility, and 3) increasing overall project cost. Similarly, the top influencers regarding the decision are 1) client, 1) consultant, followed by 2) regulators and 2) suppliers, who were less influential and evaluated as medium factors. Additionally, the top external contextual controls are 1) financial support, 1) government regulation, followed by 2) manufacturing capacity and 2) skilled labours, who were less influential and evaluated as medium factors.

6.9.3 *Case Study 3*

Case study 3, SP-D, is a new complex office development, and was represented by a specialised subcontractor. The project gross area is a 46,000m^2 site, strategically located in the intersection of beltways. The project includes two medium-rise office buildings (16 storeys), a lobby and gathering spaces, a business centre (which includes multipurpose halls, administration offices, meeting rooms, and a cafeteria with restaurant), shaded arcades within a green plaza, public areas, a food centre, and three levels of underground parking. The parking structure is naturally ventilated with the green plaza and is accessible from the basement of the office buildings.

The participants were a project manager and two senior electrical engineers who represented both the consultant and the contractors of the project. The client is a semi-governmental authority, and, as such, must apply the government procurement system. The client is represented by the consultant. The client requirements mainly focus on the project designs and the involvement of high-quality finishes for building services components to meet the optimum whole-life cost. The project completion date was noted as a major objective. In addition, the project was designed to meet the highest level of standards regarding applications.

The project objectives indicate that the project management dimension is essential in terms of quality, time, and cost. This quality is achieved by applying high-quality standardised designs of PBSC. Other benefits were discussed regarding health and safety, coordination, and managing site waste. The challenges were evaluated, including preparatory designs, making changes onsite, achieving the overall cost, and the transport of products to the site. Thus, the stakeholder influence is represented by the consultant on the project, followed by the client. Also, according to the respondents, the government regulations and financing exert the most contextual control on the project.

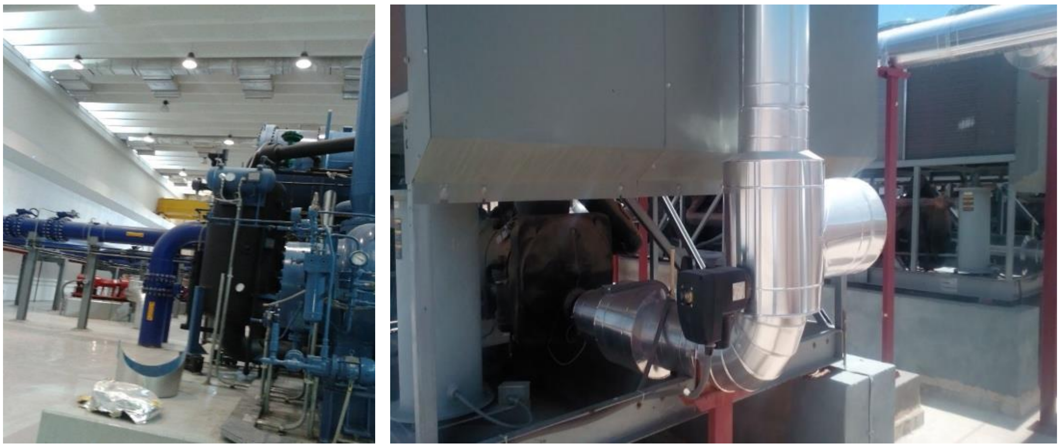

Figure 6-10 Mechanical area and air handling units (Source: Author)

During the discussion, the participants agreed on all factors included on the evaluation sheet, except ‘low-quality image’, because most PBSC are concealed. Also, the factor of ‘stakeholder influence’ was rejected because it excludes the influence of subcontractors regarding decision-making, as they were not part of the contractual agreement. Similarly, according to the respondents, the PBC factor of ‘manufacturing capacity’ failed due to the availability of PBSC on the Saudi construction market. Overall, SP-D provides evidence to validate the results of this study. Tables 6-71 and 6-72 list the data and results of the evaluation process and matrix.

Based on the discussion and the inclusion of the nine benefit factors, the evaluation matrix demonstrates that the highest-scored factors for benefits are quality (S1), project schedule (S2), design efficiency (S2), and construction cost (S3). The medium-scored factor is workplace safety (S4). Finally, the low-scored factors for benefits are construction waste (S5), coordination among parties (S5), energy efficiency (S5), and construction tasks (S5).

Table 6-71 Matrix of pairwise comparison for SP-D case study

	Benefits	A	B	C	D	E	F	G	H	I
A	Quality of product	0								
B	Speed of construction	A	0							
C	Workplace safety	A	C	0						
D	Energy efficiency	A	B	C	0					
E	Design efficiency	E	B	E	E	0				
F	Construction waste	A	B	F	F	E	0			
G	Construction cost	A	B	G	G	G	G	0		
H	Coordination btw. parties	A	B	C	D	E	H	H	0	
I	Construction tasks	A	B	C	D	E	G	I	I	0
	Challenges	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	
J	Overall project cost	0								
K	Risk	J	0							
L	Design flexibility	J	L	0						
M	Preparation requirements	M	M	M	0					
N	Transport	J	N	L	M	0				
O	Maintenance capability	J	O	N	M	N	0			
P	Make changes onsite	P	K	P	P	P	P	0		
Q	Low-quality image	J	K	L	M	N	O	P	0	
	Challenges	**R**	**S**	**T**	**U**	**V**				
R	Consultants	0								
S	Clients	R	0							
T	Governmental regulators	R	T	0						
U	Subcontractors	R	S	T	0					
V	Suppliers	R	S	T	V	0				
	Challenges	**W**	**X**	**Y**	**Z**					
W	Financial support	0								
X	Governmental regulations	X	0							
Y	Manufacturing capacity	W	X	0						
Z	Skilled craft workers	W	X	Z	0					

On the other hand, based on the discussion and the inclusion of the eight challenge factors, the highest-scored challenge factors are making changes onsite (S1), preparation requirements (S1), and overall project cost (S2). The medium-scored factors are transport (S3) and design flexibility (S4). Finally, the low-scored factors for challenges are risk involvement (S5) and maintenance capability (S5). The ‘low-quality image’ factor failed in this evaluation.

Table 6-72 Occurrence, frequency, and ranking for SP-D case study

	Indicator Code Benefits	Occurrence	Frequency (%)	Ranking (Ri) Score
A	Quality of product	7	78	S1
B	Speed of construction	6	67	S2
C	Workplace safety	4	44	S4
D	Energy efficiency	2	22	S5
E	Design efficiency	6	67	S2
F	Construction waste	2	22	S5
G	Construction cost	5	56	S3
H	Coordination among parties	2	22	S5
I	Construction tasks	2	22	S5
	Indicator Code Challenges	**Occurrence**	**Frequency (%)**	**Ranking (Ri)**
J	Overall project cost	5	63	S2
K	Risk	2	25	S5
L	Design flexibility	3	38	S4
M	Preparation requirements	6	75	S1
N	Transport	4	50	S3
O	Maintenance capability	2	25	S5
P	Make changes onsite	6	75	S1
Q	Low-quality image	0	0	0
	Indicator Code Stakeholder Influence	**Occurrence**	**Frequency (%)**	**Ranking (Ri)**
R	Consultants	4	80	S1
S	Clients	2	40	S3
T	Governmental regulators	3	60	S2
U	Subcontractors	0	0	0
V	Suppliers	1	20	S4
	Indicator Code Contextual Control	**Occurrence**	**Frequency (%)**	**Ranking (Ri)**
W	Financial support	2	50	S2
X	Governmental regulations	3	75	S1
Y	Manufacturing capacity	0	0	0
Z	Skilled craft workers	1	25	S3

Furthermore, based on the discussion and the inclusion of the five stakeholder influence factors, consultant (S1) scores the most influence regarding decision-making, according to the respondents, followed by government regulators (S2). Client influence (S3) is medium-scored, while supplier (S4) influence is low. The ‘subcontractors’ factor failed in this evaluation. Also, based on the discussion and the inclusion of the four control factors, ranked as high contextual control is government regulations (S1). Also, financing (S2) has medium control, while the control of skilled craft workers (S3) is low. The ‘manufacturing capacity’ factor failed in this evaluation.

Overall, SP Development confirms all the results, except the challenge factor of ‘low-quality image’, subcontractor as influential stakeholder, and ‘manufacturing capacity’ as an external contextual control factor. Furthermore, the evaluation matrix reveals that the highest three benefits are, 1) improving the quality of the product, 2) speeding the construction time, 2) enhancing design efficiency, and 3) reducing construction cost. The evaluation reveals that the highest three challenges are, 1) making changes onsite, 1) requiring more preparation work, 2) increasing the overall project cost, and 3) increasing transport logistics. Similarly, the top influencers regarding decision-making are 1) consultant, 2) regulators, and 3) client, who is less influential and evaluated as a medium factor. Finally, the top external contextual controls are 1) government regulation, 2) financial support, and 3) skilled labour, which was less influential and evaluated as a low factor.

6.9.4 *Cross-Section Analysis*

In a cross-case analysis, the researcher compares the data from one case study with another to identify key similarities and differences and to determine any patterns, trends, or relationships that emerge. Eisenhardt and Graebner (2007) explain that theories emerge and develop through the recognition of patterns of relationships among themes within and across interviews and their fundamental logical arguments. The cross-sectional analysis illustrates all the benefits in challenges in Figure 6-11, challenges in Figure 6-12, stakeholders' influence in Figure 6-13, and external contextual control in Figure 6-14.

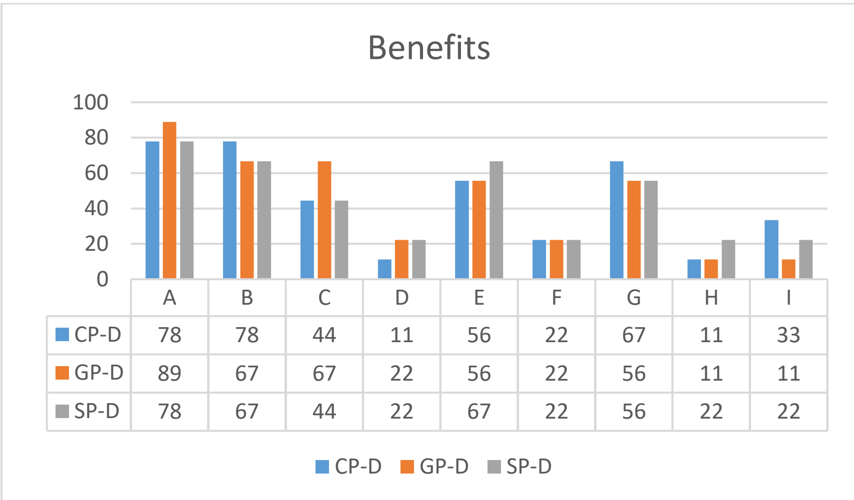

Figure 6-11 Benefits – cross-sectional

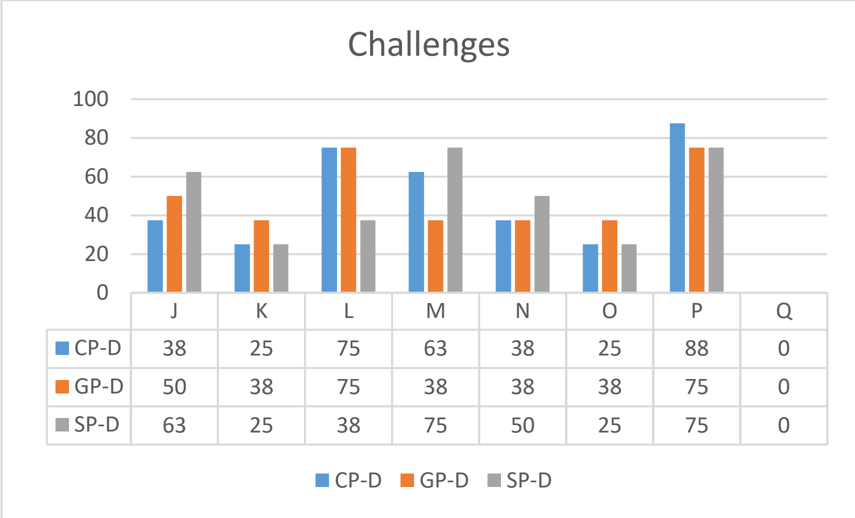

Figure 6-12 Challenges – cross-sectional

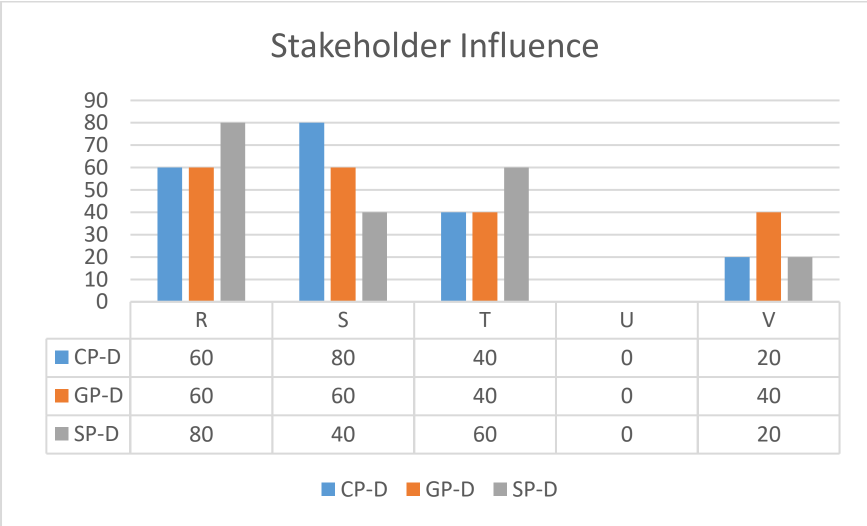

Figure 6.13 Stakeholders' influence – cross-sectional

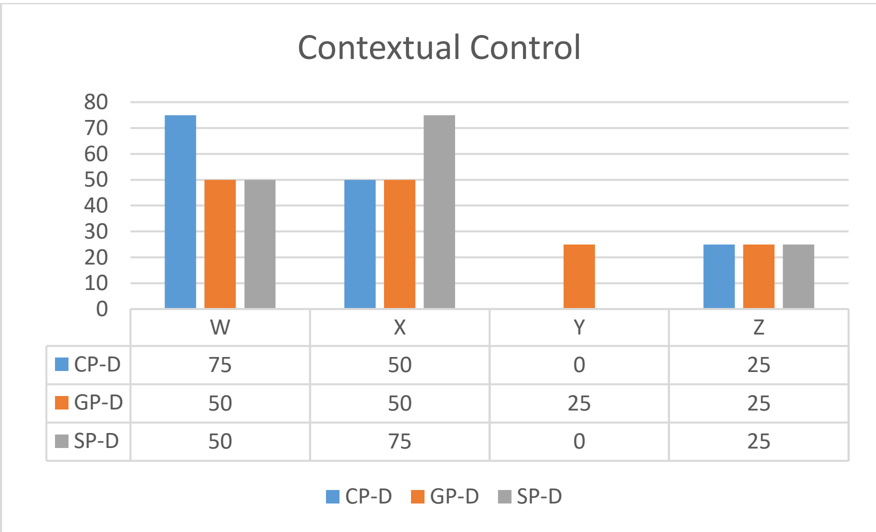

Figure 6-14 External contectual control – cross-sectional

Table 6-73 Ranking of propositions (attitudes, stakeholder influence, contextual control)

Propositions (Factors) – Cross-sectional case studies									
	A	B	C	D	E	F	G	H	I
Avgs	7.33	6.33	4.67	1.67	5.33	2.00	5.33	1.33	2.00
RANK	R1	R2	R4	R6	R3	R5	R3	R7	R5
	J	K	L	M	N	O	P	Q	
Avgs	4.00	2.33	5.00	4.67	3.33	2.33	6.33	0.00	
RANK	R4	R6	R2	R3	R5	R6	R1		
	R	S	T	U	V				
Avgs	3.33	3.00	2.33	0.00	1.33				
RANK	R1	R2	R3		R4				
	W	X	Y	Z					
Avgs	2.33	2.33	0.33	1.00					
RANK	R1	R1	R3	R2					

All the findings regarding using PBSC (benefits, challenges, stakeholder influence, and external contextual control) are confirmed by the three case studies of complex office developments, except the challenge factor of 'low-quality image' and the subcontractors as influential. Also, the factor of 'manufacturing capacity' was not confirmed by case studies CP-D or SP-D. The ranking is illustrated in Table 6-73. The scale employed for the ordinal category of propositions is Low – Medium – High for qualitative findings. The percentages of frequencies range between zero and six. Therefore, the researcher subjectively defined the range for attitudes and stakeholder influence as follows: 'Low' is (0.0 < X < 2.0), 'Medium' is (2.1 < X < 4.0), and 'High' is (4.1 < X < 6.0 +). Whereas, for external contextual control, the range of 'Low' is (0.0 < X < 0.9), 'Medium' is (1.0 < X < 2.0), and 'High' is (2.1 < X < 3.0 +).

The cross-sectional analysis of case studies confirms the impact of all factors (propositions) except the challenge factor 'low-quality image' and subcontractor as a stakeholder influencer. Similarly, the cross-sectional analysis confirms that the top three benefits are, 1) quality of the product, 2) speed of construction, 2) design efficiency, and 3) construction cost. The top three ranked challenges are, 1) limitation of making changes onsite, 2) reduction of design flexibility, and 3) more preparation requirements. Also, the top two stakeholder influences are, 1) consultants and 2) clients. Finally, the top two external contextual controls are, 1) financial support and 2) governmental regulations.

6.10 Summary

Chapter 6 discussed the analysis results of the quantitative method. As previously highlighted, this research adopted the model of the TPB. A questionnaire survey was constructed in three major sections. The first section (A) concerned organisation information. The second section (B) was designed based on the propositions derived from the interviews (Phase I: Qualitative), which were also based on the TPB. Section (C) was designed directly from the interview findings regarding the reasons preventing non-practitioners of preassembly from using PBSC in complex office developments. Then, a reliability test for the questionnaire survey was provided. A descriptive analysis was highlighted regarding organisational background, the location of organisations, and experience. A question of the application was a key question to predict the intention of participants towards using PBSC in complex office developments. The answer for this question was either a (yes) or a (no); if (yes), the participant remains in Section (B); if (no), the participant moves to Section (C).

The levels of applications of PBSC include prefabricated horizontal/vertical distribution, terminal unit preassembly, and preassembled building services units/modules. The overall utilisation of PBSC in complex office developments is low. The attitudes towards using the PBSC include nine benefits and seven challenges, with one DV challenge variable (low-quality image) not supported. Also, four stakeholders influence the decision to use PBSC, with one DV stakeholder influence (supplier) not supported. Finally, the external contextual controls include four variables Table 6-60).

Similarly, the reasons that prevent non-practitioners from using PBSC in complex office developments were provided. The results reveal that four factors were agreed on by both consultants and contractors (Table 6-66)

The case studies were performed to validate these results. The analysis of Case Study 1 reveals that all the propositions (factors) are validated in real life except the challenge factor of ‘low-quality image’, the stakeholder influence factor of ‘subcontractor’, and the external contextual factor of ‘manufacturing capacity’ (Table 6-68). The analysis of Case Study 2 reveals that all the propositions (factors) are validated except the challenge factor of ‘low-quality image’ and the stakeholder influence factor of ‘subcontractor’ (Table 6-70). Finally, the analysis of Case Study 3 reveals that all the propositions (factors) are validated except the challenge factor of ‘low-quality image’, the stakeholder influence factor of ‘subcontractor’, and the external contextual factor of ‘manufacturing capacity’. On the other hand, based on the discussion and the inclusion of the eight challenge factors, the highest-scored challenge factors are making changes onsite (S1), preparation requirements (S1), and overall project cost (S2). The medium-scored factors are transport (S3) and design flexibility (S4). Finally, the low-scored factors for challenges are risk involvement (S5) and maintenance capability (S5). The ‘low-quality image’ factor failed in this evaluation.

Table 6-Overall, the cross-sectional analysis of all three cases revealed that all the propositions (factors) were validated except the challenge factor of 'low-quality image' and the stakeholder influence factor of 'subcontractor'. The ranking of factors is illustrated in Table 6-73.

Chapter 6 has analysed and discussed the results of the quantitative method and confirmed these results via three case studies. Thus, this chapter met the research objectives designed to answer the research question: '*What are the influences of consultants and contractors towards using preassembled building services components in complex office developments in Saudi Arabia*?' The nature and extent of PBSC applications were explored, the perceptions of consultants and contractors towards PBSC were assessed, and the relationship between consultant and contractor perceptions regarding using PBSC was examined. Also, the consultant and contractor intentions were determined, as well as the reasons preventing non-practitioners from using PBSC. The answer to the research question is in the conclusion in Chapter 7

.

CHAPTER 7: CONCLUSION

7.1 Introduction

This chapter concludes this study, answers the research question, and fills the knowledge gap. This research was conducted to explore the use of PBSC in complex office developments in the Saudi context. It highlights some of the key governmental and industrial objectives and provides results that contribute to improving the construction industry and to meeting the Government vision for 2030 regarding energy efficiency solutions and similar targets. The use of PBSC is currently limited in complex office developments due to several challenges. The key findings and outcomes were highlighted through various phases of the research, and were then validated and tested. This chapter theoretically and practically reports the implications of this study, explains the limitations, and concludes with the contributions to the body of knowledge. Then, recommendations for future research are made considering the key findings. The aim of this study is to contribute to knowledge by exploring consultant and contractor perceptions regarding the use of PBSC in complex office developments in Saudi Arabia. The prime objective of the research is to identify the benefits and challenges (attitudes), the stakeholder influence (SN), and the perceived contextual control (PBC) of the decision to use PBSC.

7.2 Addressing the Research Question

The main research question is: *What are the influences of consultants and contractors towards using preassembled building services components in complex office developments in Saudi Arabia?* The research explored the use of PBSC in complex office developments by investigating the current benefits and challenges facing the building services industry; the influence on the decision to use PBSC by stakeholders; and the contextual behavioural control. These factors assisted in predicting the intention of consultants and contractors to use PBSC. Furthermore, these factors measured the relationship between consultants and contractors. In addition, the study addressed the reasons that discourage non-practitioners from using PBSC in complex office developments. However, the introduction of appropriate strategies for promoting applications and the uptake of PBSC remain limited due to several factors, which were different from the viewpoints of PBSC practitioners and non-PBSC practitioners.

The TPB model that was used to classify the research findings was obtained from secondary and primary studies that provides the building services industry with a robust, practical model. This model provides PBSC practitioners with a wider understanding of the existing situation. The findings and outcomes of this research are believed to enhance and promote the use of PBSC in complex office developments through understanding their potential benefits in the Saudi construction industry, as well as addressing the challenges facing the applications of PBSC.

Preassembly practitioners noted that the benefits of using PBSC in complex office developments include, but are not limited to, 1) increasing the quality of products, 2) improving the schedule speed, and 3) reducing the construction cost (Sections 5.4.1 and 6.5.2). Moreover, these practitioners highlighted the challenges that limit the use of the PBSC in complex office developments, which include, but are not limited to, 1) reducing the options to make changes onsite, 2) reducing the flexibility of designs, and 3) increasing the overall project cost (Sections 5.4.2 and 6.5.2). Furthermore, the stakeholders with the most influence on decision-making include, 1) the client, 2) the consultant, and 3) the government regulators (Sections 5.5 and 6.5.3). Also, the most contextual influences that control decision-making include, 1) financial support, 2) government regulations, and 3) skilled labour (Sections 5.4.2 and 6.5.4). Finally, the reasons that hinder non-practitioners from using PBSC in complex office developments include, but are not limited to, 1) increase in the overall project cost, 2) reduction in design flexibility, and 3) lack of financial support (Section 6.8.1).

7.3 Review of the Research Aim, Objectives, and Methodology

This research aimed *to explore the influence of consultants and contractors towards using preassembled building services components in complex office* *developments in the Saudi context*. The aim intended to address the knowledge gap associated with the existing use of PBSC in complex office developments in Saudi Arabia. To answer the research question and fill the knowledge gap, five objectives were designed and stated in the introduction (Section 1.4). A methodology (exploratory, sequential mixed-methods) was chosen to explore the Saudi context due to shortages in the research data and the information required to achieve the research aim and objectives. A comprehensive review of literature on the subject strongly drove the research towards a mixed-methods approach (qualitative and quantitative approaches), which was used for primary data collection and analysis. In addition, the research used the TPB to predict certain participants' intentions to engage in specific behaviour at a specific time and place. The research appropriately used different research methods for each objective to collect the required data. The outlined methodology (Section 1.7), integrated with the research objectives, is now discussed and summarised.

7.3.1 *Objective 1: To Explore the Current Nature and Extent of Utilisation of Preassembled Building Services Components in Complex Office Developments.*

The literature on the subject was comprehensively reviewed to achieve this objective, to highlight the existing knowledge, and to identify practices noted in earlier studies regarding the use of PBSC in the construction industry on an international scale. As secondary data, this research reviewed definitions of the term 'PBSC' and its classifications (Section 2.3.1). Also, the history of PBSC in different construction industry contexts was provided (Section 2.3.3). Furthermore, the forms and applications of PBSC were stated (Section 2.4) and the building services systems in office developments were highlighted (Section 2.6). In addition, the TPB was reviewed (Section 3.2) and used as a conceptual framework to predict intentions. Also, the design and construction processes were reviewed (Sections 2.7 and 3.7). For the primary data, the research identified the nature and extent of using PBSC in complex office developments, which enabled the construction of semi-structured interviews

(Section 4.9.1) based on the conceptual framework of the TPB. The nature and extent of using PBSC in complex office developments in the Saudi context were clearly revealed by the results of this research (Section 6.4). However, the applications of PBSC in complex office developments in Saudi Arabia are limited to prefabricated horizontal and vertical distribution and terminal unit preassembly. Furthermore, the uptake of PBSC remains limited due to several factors, which were different from the viewpoints of the practitioners and non-practitioners. Consequently, the applications of PBSC are low in complex office developments, in which less than a quarter (only 23% respondents of consultants and 22% of contractors) used PBSC in Saudi Arabia.

7.3.2 *Objective 2: To Assess the Perception of Consultants and Contractors Towards Using Preassembled Building Services Components in Complex Office Developments in the Framework of the Theory of Planned Behaviour.*

A comprehensive literature review was performed regarding attitudes (Sections 3.8; 3.9; 3.10; 3.11; and 3.12), stakeholder influence (Section 3.13), and external contextual control influence (Section 3.14). This review was necessary to adopt the TPB as a framework for this objective (Section 3.2). The literature review assisted also in understanding the adoption of innovation theory for entrepreneurship (Section 3.4). Semi-structured interviews were conducted (Sections 4.9.1; 4.9.2; and 4.9.3) based on grounded theory (Section 4.9.4), and questionnaires were constructed based on the findings of the interviews (Sections 4.9.5; 4.9.6; and 4.9.7). The nine key benefits and eight key challenge factors (attitudes) towards using PBSC in complex office developments were investigated through the combination of the semi-structured interviews and the questionnaires. The results reveal that the consultants and contractors agreed on all factors, except for the challenge factor of ‘low-quality image’ (Section 6.5.2). Similarly, the influence of five key stakeholder factors on the decision to use PBSC in complex office developments was investigated via the combination of the semi-structured interviews (Section 5.5) and the questionnaire surveys (Section 6.5.3). The consultants and contractors agreed on all factors, except the ‘subcontractors’ as decision influencers. Moreover, the influence of four key external contextual factors that hinder the decision to use PBSC was investigated through the combination of the semi-structured interviews (Section 5.6) and the questionnaire surveys (Section 6.5.4). Consequently, achieving this objective delivered a full understanding of the perception of consultants and contractors towards using PBSC in complex office developments in the Saudi context. The research revealed the key benefits and challenges towards using PBSC, identified key stakeholder influence regarding the decision to use PBSC, and identified key external contextual control factors that hinder the decision to use PBSC in complex office developments in Saudi Arabia. The benefits of using PBSC in complex office developments include increasing product quality, improving the speed of construction, improving workplace safety, improving energy efficiency, increasing project design efficiency, reducing construction waste, reducing construction cost, improving coordination of staff and tasks, and simplifying tasks. The challenges of using PBSC in complex office developments include increasing the overall project cost, increasing risk, reducing the design flexibility, requiring more preparation work, increasing transport logistics, and increasing the need for maintenance. However, neither the consultants nor the contractors supported the proposition that PBSC ‘have a low-quality image’. The stakeholders who largely influence the decision to use PBSC in complex office developments include clients, consultants, and government regulators. However, neither the consultants nor the contractors supported the proposition that ‘subcontractors and suppliers’ influence the decision to use PBSC. The external contextual controls of the decision to use PBSC in complex office developments include financial support, government regulations, manufacturing capacity, and the shortage of skilled labour.

7.3.3 *Objective 3: To Examine the Relationship Between Consultant and Contractor Perceptions on the Use of Preassembled Building Services Components in Complex Office Developments.*

The literature review assisted in identifying the most appropriate SPSS test (Section 4.10) to measure and compare the means of consultants and contractors. Accordingly, Francis' (2004) t-Test manual was used in analysing the TPB, and the results were provided in Section 6.6. These relationships were discussed in Section 6.6.1. The results reveal that all the factors (propositions) have no difference in means, except the benefit factor 'reduce construction waste', the influencer factors 'client' and 'government regulators', and the external contextual control factor 'government regulations'. These exceptional factors revealed a significant difference in means (Section 6.5.5). The discussion regarding this relationship is presented in Section 6.6.1. Consequently, the results of all the attitudes, including both the benefits and the challenges, displayed no significant relationship, except the variable related to reducing construction waste, which displayed a significant relationship between consultants and contractors. The results of stakeholder influence (SN) displayed no significance, except the variables related to the influence of the client and the government regulators, which displayed significant relationships between consultants and contractors on the decision to use PBSC. The results of the external contextual control (PBC) of the decision to use PBSC displayed no significance, except the variable related to the control of government regulations on the use of PBSC, which displayed a significant relationship between consultants and contractors.

7.3.4 *Objective 4: To Determine Consultant and Contractor Intention to Adopt Preassembled Building Services Components in Complex Office Developments.*

A comprehensive literature review was used to adopt the TPB as a framework for this objective (Section 3.2), and a literature review regarding the adoption of innovation theory for entrepreneurship was employed to understand the nature of entrepreneurship (Section 3.3). Then, the questionnaire survey was constructed based on the conceptual framework of the TPB (Sections 4.9.5; 4.9.6; and 4.9.7). The conceptual framework included two dimensions, which are direct and indirect measurements for each IV. The indirect measurements investigated two aspects: the outcomes and the likelihood for each factor. The results of the indirect measurements were used to examine the multiple regressions (Section 6.6) with direct measurements to predict the intention of consultants and contractors to adopt PBSC in complex office developments. The results reveal that there is significant intention (Section 6.7) from both consultants and contractors to use PBSC in complex office developments in the Saudi context (Sections 6.7.1 and 6.7.2).

7.3.5 *Objective 5: To Determine the Reasons that Prevent Consultants and Contractors from Using Preassembled Building Services Components in Complex Office Developments.*

The literature review assisted in identifying the reasons that hinder the use of PBSC in the construction industry (Sections 2.2; 3.12; and 3.14). These reasons were investigated through the use of two sets of questionnaires: the first set targeted non-practitioners of preassembly (consultants and contractors) and aimed at understanding the reasons that hinder their use of PBSC; whereas, the second set targeted PBSC practitioners and aimed at identifying the challenges that they face (Section 6.8). This objective delivers a full understanding of the perception of consultants and contractors towards the reasons that hinder the use of PBSC. Through analysing the responses of consultants and contractors, the research revealed 11 key reasons that hinder the use of PBSC in complex office developments in Saudi Arabia (Section 6.8.2). On the other hand, comparing the means of the non-practitioners of consultants and contractors revealed no difference, except in the ‘increase of overall project cost’, ‘increase in risk’, and ‘increase in transport logistics’ factors (Section 6.8). These exceptional factors appeared significant when the means were compared (Sections 6.8.1 and 6.8.2). Consequently, the reasons that prevent non-practitioners from using PBSC in complex office developments include the increase in the overall project cost, the reduction in the design flexibility, the lack of governmental regulations, and the manufacturing capacity. Both the consultants and the contractors were neutral on other propositions, and these are, therefore, considered unsupported. These propositions include the increase in risk, the need for more preparation work, the limitation in making changes to work onsite, the increase in transport logistics, the increase of required maintenance, the lack of financial support, the low-quality image, and the shortage of skilled craft workers.

7.4 Contribution of the Study to Knowledge and Practice

In Saudi Arabia, the construction sector is considered a developing industry. This research makes a significant and original contribution to knowledge through a full understanding of consultant and contractor perceptions towards using PBSC in complex office developments. The perceptions include the benefits, challenges, stakeholder influence, and external contextual control factors that affect the decision to use PBSC. In addition, this research provides client guidance that can enhance project delivery by using PBSC in complex projects.

The contribution of this study includes the establishment of nine key benefits, seven key challenges, four key stakeholder influences, and four key external contextual controls towards using PBSC in complex office developments. These factors are based on the model of the TPB. The top three key benefits are, 1) increasing the quality of the product, 2) improving the speed of construction, and 3) reducing construction cost. The top three key challenges are, 1) reducing the flexibility of designs, 2) limiting making changes to work onsite, and 3) requiring more preparation work. The top three key stakeholders who influence decisions are, 1) clients, 2) consultants, and 3) government regulators. The top three key external contextual controls that influence decisions are, 1) financial support, 2) government regulations, and 3) skilled craft workers. Furthermore, this research identified the reasons that hinder non-practitioners of preassembly from using PBSC in complex office developments. This validated model will assist and guide government authorities and agencies, the construction industry, and PBSC practitioners in developing a construction strategy for promoting the use of PBSC in complex office developments

This research contributes also to knowledge through successfully addressing the 10 main reasons that hinder non-practitioners from using PBSC in complex office developments. The top three reasons are, 1) increasing the overall project cost, 2) reducing the flexibility of designs, and 3) lacking financial support. The research provides a clear and unbiased perception of both the practitioners and non-practitioners towards using PBSC in complex office developments.

Another significant contribution of the study is enhancing the awareness of using PBSC for complex office developments, which will consequently improve health and safety and result in the reduction of energy consumption, project duration, defects, environmental impacts, and accidents, as well as improving building performance, all of which are main targets for the Government and the industry. Also, this research revealed that the PBSC market remains immature and is yet to fully embrace adopting these technologies.

The impact of building services is high on the whole-life cost of complex office developments, and this research significantly contributes to knowledge of the subject, focusing on the solutions that PBSC offer to several beneficiaries, including the client, government agencies, energy national grid, and national water supply.

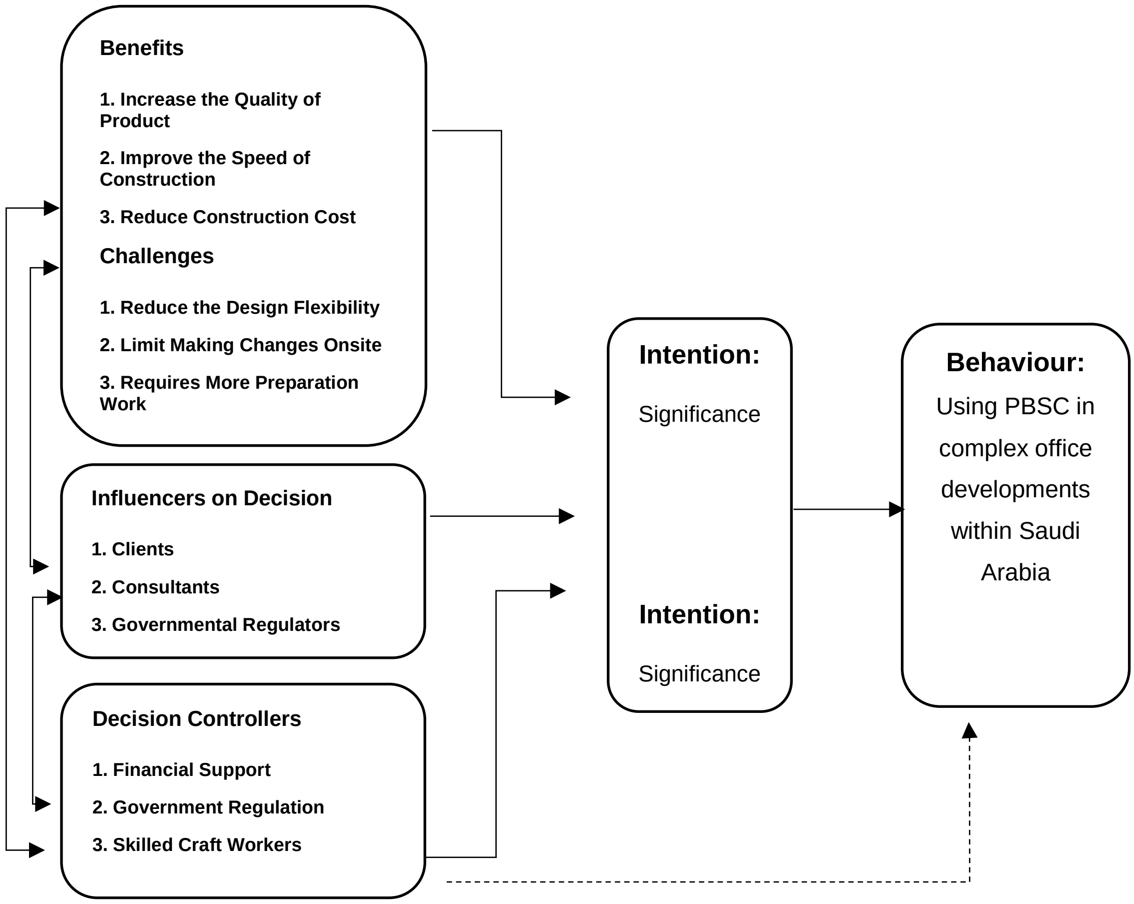

Figure 7-1 Adopted model for the use of PBSC in complex office developments

7.5 Contribution to Beneficiaries

- *Clients* The Saudi Arabian Government and private companies are regarded as the main beneficiaries in terms of using PBSC in complex office developments. The benefits include, but are not limited to, meeting both client and end-user satisfaction.
- *Construction Industry* The construction sector, general contractors, specialist contractors, and manufacturers/suppliers benefit from using PBSC through the adoption of new technologies in both the design and construction phases.
- *Academia – Architecture/Construction* Research institutes and universities benefit from the utilisation of PBSC in terms of meeting the

market needs for an offsite construction programme, training, research, and assisting initiatives for construction innovations.

7.6 Research Limitations

A number of limitations were encountered during this research, which affected the progress and approaches taken. These limitations are now summarised.

The literature review revealed that there is a notable lack of literature regarding offsite construction in Saudi Arabia in general and PBSC in particular. In addition, time and cost placed a great constraint on travelling between provinces. Accordingly, this study focused on the main three provinces in Saudi Arabia (the Riyadh, Makkah, and Eastern provinces), which account for more than 80% of respondents in this study.

The final model of this study includes key factors identified from the Saudi context regarding the use of PBSC in complex office developments only. Therefore, these factors are not necessarily applicable to other building types (e.g. houses, public buildings, or industrial buildings), other industries, or other contexts due to differences in nature and characteristics.

This study only focused on the technical aspects regarding the delivery in design and construction processes of complex office developments. Therefore, this study investigated the views of consultants (design team) and contractors (general contractors and specialised subcontractors). Clients, developers, and government regulators were excluded from this study.

7.7 Recommendations for Future Work

This section offers a number of recommendations for future research, focusing on the applications of PBSC in the Saudi construction industry.

Further research is required to assess strategies to promote the adoption of PBSC in complex office developments in both the public and the private sectors. Also, it is important that these strategies address the most recent strategic models worldwide. Strategic models are essential for the entire marketing process, including PBSC supply chains and manufacturers. It is clear that, in developed markets, suppliers play an important role in the process of promoting the use of preassembly technologies. On the other hand, the role of subcontractors also needs to be enhanced through these strategies to professionally assist the PBSC market. However, the promotion of strategies needs to consider the client and their consultant as a decision-maker. Therefore, several aspects need to be focused on, including advertising, training, and financing solutions.

Further research is required to study pods in terms of design and finish. This research revealed that both consultants and contractors are satisfied with the final products of PBSC, but noted a limitation in using pods and kitchen products. On the other hand, this study revealed that the factor of 'low-quality image' failed. This failure was noted in the qualitative analysis, in which the respondents stated that most PBSC applications in complex office developments are concealed. Therefore, practitioners of PBSC may not be sufficiently aware of other advanced problems encountered that are related to the design and specification of pods and kitchens.

Further research is required to examine procurement methods in relation to the applications of PBSC in Saudi Arabia. Moreover, this research revealed that both government regulators and government regulations largely influence the decision to use PBSC in complex office developments. Early studies revealed that the most-used procurement method in the Saudi Arabian construction industry is the design-bid-build (traditional method). This traditional procurement method depends on the lowest reasonable bid, which, consequently, works against the use of the more expensive option of PBSC. However, the Government can largely contribute to both enforcing the use of PBSC, as the example of the Malaysian experience IBS indicates, and improving the PBSC industry through increasing PBSC application support (banking facilities) to lower prices and improve the procurement system.

Finally, further research is required to investigate the health-and-safety aspects for end-users involved in the application of PBSC in complex office developments. This research includes the consideration of design and specifications in terms of improving final products through applying more reliable engineering regarding PBSC applications.

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APPENDICES

Appendix A: PBSC Interview Questions

Appendix B: PBSC Questionnaire Survey

Appendix C: Case Study - PBSC Consideration Review – Assessment Tool

Appendix D: RIBA Plan of Work 2012

Appendix E: AIA Plan of Work 2013

Appendix F: Ethical approval

Appendix A: PBSC Interview Questions

University of Strathclyde Glasgow

Semi-Structured Interview

An examination of the influence of design team and constructors on the use of offsite construction techniques including preassembled building services components in complex office developments

Saudl Arabia

Sample Size

Sample size includes 15 interviewees divide into two sections: 8 consultants 7 general constructors. Therefore, each question will be divided into two parts: design team and constructors. In the interview, A/Es section will be inquired for design team's aspect while GCs section will be inquired for constructors' aspect.

<u>Semi-structured interview questions for **design team (A/Es)** are shown next:</u>

Questions	**Probes**		
	Benefits الفوائد		**Difficulties** المعيقات
	Perceived Usefulness الفائدة الملموسة	**Perceived Ease of Use** سهولة الاستخدام الملموسة	1 - project costs
			تكاليف المشروع
	1 quality	1 coordination	Non traditional designs
	الجودة	التنسيق	تصاميم غير تقليدية
	Cost	2- facilitation of tasks	- image of poor quality
	التكلفة	تسهيل المهام	صورة الجودة رديئة
	Duration		- maintenance
What are the attitudes of design team towards PBSCs' adoption? ما هو موقف فريق التصميم نحو/تجاه اعتماد تطبيق/استخدام هذه التقنية ؟	المدة الزمنية		أعمال صيانة
	energy efficiency		- transportation
	كفاءة الطاقة		وسائل النقل
	construction waste		- Risks of new processes
	مخلفات البناء		مخاطر العمليات الجديدة
	6 -Health and safety		preparatory requirements
	الصحة و السلامة		متطلبات العمل التحضيري
			aligning to traditional designs
			مواءمة مع التصاميم التقليدية
			- standa'disation vs. flexibility
			التوحيد القياسي مقابل المرونة
			10 - Reliance on specific suppliers
			الاعتماد على موردين معينين
What types of stakeholders do design team believe influence PBSCs' adoption decisions? باعتقادك/ من هم اصحاب المصلحة المؤثرون على قرارات اعتماد تطبيق/استخدام هذه التقنية؟	1 Trades & subcontractors		الحرفيين والمقاولين من الباطن
	Clients		العملاء
	- Government & regulatory		الحكومة والتنظيم
	- Finance Institutions		المؤسسات المالية
	- Suppliers		الموردين
	- Industry rep. bodies		هيئات تمثيل الصناعة
	- Architects		المهندسين المعماريين
	- Developers		المطورين
	9 - Engineers		المهندسون
What types of contextual Influences do design team believe Impact PBSCs' adoption decisions? باعتقادك/ ما هي العوامل المؤثرة على قرار اعتماد تطبيق/استخدام هذه التقنية؟	1 - Competitiveness		القدرة التنافسية
	- Financing support		الدعم التمويلي
	- Government & regulatory support		الدعم الحكومي والتنظيمي
	- Macroeconomic situations		وضع الاقتصادي الكلي
	- Energy efficiency requirements		متطلبات كفاءة الطاقة
	- Labour and skills availability		توفر العمالة والمهارات
	7 - Climate change		التغيرات المناخية

Semi-structured interview questions for constructors (GCs & SCs) are shown next:

Questions	Probes		
	Benefits **الفوائد**		**Difficulties** **العقبات**
	Perceived Usefulness **الفائدة الملموسة**	**Perceived Ease of Use** **سهولة الاستخدام الملموسة**	1 - project costs
			تكاليف المشروع
What are the attitudes of constructors towards PBSCs' adoption? ما هو موقف المقاولون نحو/اتجاه اعتماد تطبيق/استخدام هذه التقنية ؟	1- quality	1- coordination	- Non-traditional designs
	الجودة	التنسيق	تصاميم غير تقليدية
	Cost	2- facilitation of tasks	- Image of poor quality
	التكلفة	تسهيل المهام	صورة لجودة رديئة
	Duration		- maintenance
	المدة الزمنية		اعمال صيانة
	energy efficiency		- transportation
	كفاءة الطاقة		وسائل النقل
	construction waste		- Risks of new processes
	مخلفات البناء		مخاطر العمليات الجديدة
	6- Health and safety		- preparatory requirements
	الصحة و السلامة		متطلبات العمل التحضيري
			- aligning to traditional designs
			مواءمة مع التصاميم التقليدية
			- standardisation vs. flexibility
			التوحيد القياسي مقابل المرونة
			10 - Reliance on specific suppliers
			الاعتماد على موردين معينين
What types of stakeholders do constructors believe influence PBSCs' adoption decisions? باعتقادكم من هم اصحاب المصلحة المؤثرون على قرارات اعتماد تطبيق/استخدام هذه التقنية	1 - Trades & subcontractors		الحرفيين والمقاولين من الباطن
	Clients		العملاء
	Government & regulatory		الحكومة والتنظيم
	- Finance Institutions		المؤسسات المالية
	- Suppliers		الموردين
	- Industry rep. bodies		هيئات تمثيل الصناعة
	- Architects		المهندسين المعماريين
	- Developers		المطورين
	9 - Engineers		المهندسين
What types of contextual influences do constructors believe impact PBSCs' adoption decisions? باعتقادكم ما هي العوامل المؤثرة على قرار اعتماد تطبيق/استخدام هذه التقنية؟	1 - Competitiveness		القدرة التنافسية
	- Financing support		الدعم التمويلي
	- Government & regulatory support		الدعم الحكومي والتنظيمي
	- Macroeconomic situations		وضع الاقتصادي الكلي
	- Energy efficiency requirements		متطلبات كفاءة الطاقة
	- Labour and skills availability		توفر العمالة والمهارات
	7 - Climate change		التغيرات المناخية

Appendix B: PBSC Questionnaire Survey

Survey Questionnaire

Title: Investigation on Consultants and Contractors' Use and Perceptions of Preassembled Building Services Components in Complex Office Developments in Saudi Arabia

Direction: The purpose of this survey is to identify the use and perceptions of consultants and contractors in regard to preassembled building services components in complex office developments. this survey investigates the benefits and challenges of using these techniques as well as the influential parties on decision and the influential control factors. The scope of study only covers the largest three regions of Saudi construction industry including: Riyadh, Makkah, and Eastern region. I would appreciate if you would complete the attached questionnaire as instructed.

In this study, preassembled building services components are defined as those construction techniques that accomplished offsite applications where building systems or assemblies are manufactured or fabricated away from the building site prior to installation. Those techniques include:

- Integrated services with modular buildings
- Preassembled building services units/modules
- Prefabricated horizontal / vertical distribution
- Terminal unit preassembly

Section A: company Information

1a. What is your company type?

consultants	Engineering professional corporation	
	Engineering consulting office	
Contractors	General contractors	
	Specialised Subcontractors	

1b. What is your profession?

Architect		Mechanical engineer	
Project manager		Electrical engineer	
Cost engineer		Civil engineer	
Other, please specify			

1c. In which region is your Head Office located?

Riyadh	Makkah	Dammam

1d. How many years of experience?

10-15	16-20	21 +

2. Have you ever applied preassembled building services components in complex office developments?

☐ Yes (please go to next section B)
☐ No (please go to section C)

Section B: Opinions on Using Preassembled Building Services Components

3. What kind of preassembled building services components have you ever used? (Please select all which apply)

	Level 1	Integrated services with modular buildings
	Level 2	Preassembled building services units/modules
	Level 3	Prefabricated horizontal / vertical distribution
	Level 4	Terminal unit preassembly

4. What is your opinion of upgrade the level of using preassembled building services components?

	Strongly disagree	disagree	Neither agree or disagree	agree	Strongly agree
Worthwhile					
Supported by most parties important to you					
Easy to do					

5a. What criteria do you likely consider when upgrading the level of using preassembled building services components?

	highly unlikely	unlikely	Neither likely or unlikely	likely	highly likely
Increase the quality of product					
Improve the speed of construction					
Improve workplace safety					
Improve the energy efficiency					
Increase the project design efficiency					
Reduce construction waste					
Reduce construction cost					
Improve coordination of staff & tasks					
Simplify tasks					
Increase overall project cost					
Increase risk					
Reduce the flexibility of designs					
Require more preparation work					
limit making changes to work onsite					
Increase transportation logistics					
Increase needs for maintenance					
have an image of poor quality outcome					

5b. In your opinion, what is likely to be the impact of upgrading the level of using preassembled building services components on your company?

	Very negative	negative	No effect	positive	Very positive
Increase the quality of product					
Improve the speed of construction					
Improve workplace safety					
Improve the energy efficiency					
increase the project design efficiency					
Reduce construction waste					
Reduce construction cost					
Improve coordination of staff & tasks					
Simplify tasks					
Increase overall project cost					
Increase risk					
limit the flexibility of designs					
Require more preparation work					
limit making changes to work onsite					
Increase transportation logistics					
Increase needs for maintenance					
have an image of poor quality outcome					

6a. In your opinion, who are most likely to support the greater use of preassembled building services components in complex office developments?

	Strongly disapprove	disapprove	neither	approve	Strongly approve
Consultant					
Owners					
Government and regulators					
Suppliers					
Subcontractors					

6b. Who of the following parties' opinions have the most influence on the greater use of preassembled building services components in complex office developments?

	Not at all	Not very much	Somewhat	A fair bit	A lot
Consultant					
Owners					
Government and regulators					
Suppliers					
Subcontractors					

7a. In your opinion, which of the following factors have the most influence on the increased use of preassembled building services components in complex office developments?

	Not at all	Not very much	Somewhat	A fair bit	A lot
finance support					
government regulations					
manufacturing capacity					
skilled craft workers					

7b. In your opinion, which of the following factors would likely lead to the greater use of preassembled building services components in complex office developments?

	highly unlikely	unlikely	neither	likely	highly likely
finance support					
government regulations					
manufacturing capacity					
skilled craft workers					

Section C: Reasons of NOT using Preassembled Building Services Components

8. What are the reasons that unable you using preassembled building services components?

		Disagree Strongly	Disagree	Neutral agree or disagree	Agree	Agree strongly
1	Increase overall project cost					
2	Increase risk					
3	Reduce the flexibility of designs					
4	more preparation work					
5	limit making changes to work onsite					
6	Increase transportation logistics					
7	Increase needs for maintenance					
8	image of poor quality outcome					
9	Shortage of skilled craft workers					
10	Lack of governmental support					
11	Lack of financial support					
12	Lack of products in the market					

If you would like to receive feedback from this survey or participate in interview, please complete your contact details below. Replies will be treated in strict confidence and anonymity.

Name	
Position	
Organization	
Telephone	
E-mail	
Postal Address	

comments

Survey Questionnaire

Title: Investigation on Consultants and Contractors' Use and Perceptions of Preassembled Building Services Components in Complex Office Developments In Saudi Arabia

Direction: The purpose of this survey is to identify the use and perceptions of consultants and contractors in regard to preassembled building services components in complex office developments. this survey investigates the benefits and challenges of using these techniques as well as the influential parties on decision and the Influential control factors. The scope of study only covers the largest three regions of Saudi construction Industry including: Riyadh, Makkah, and Eastern region. I would appreciate if you would complete the attached questionnaire as Instructed.

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- Integrated services with modular buildings
- Preassembled building services units/modules
- Prefabricated horizontal / vertical distribution
- Terminal unit preassembly

القسم أ: معلومات الشركة

(١ – أ) ما هو نوع الشركة

استشاري	شركة مهنية تضامنية هندسية	
	مكتب استشارات هندسية	
مقاول	مقاول عام	
	مقاول باطن متخصص	

(١ – ب) ماهي مهنتك

مهندس ميكانيكا		معماري	
مهندس كهرباء		مدير مشروع	
مهندس مدني		مهندس تكاليف	
غير ذلك / يرجى التحديد			

(١ – ج) في أي منطقة يقع المكتب الرئيسي للشركة

الرياض	مكة	المنطقة الشرقية

(١ – د) كم عدد سنوات الخبرة

١٠ – ١٥	١٦ – ٢٠	٢١ +

٢ – هل سبق لكم استخدام تقنيات خدمات المبنى مسبقة التجميع في مشاريع المباني المكتبية؟

☐ نعم (يرجى الانتقال إلى القسم التالي ب)
☐ لا (يرجى الانتقال إلى القسم ج)

القسم ب: أراء حول استخدام تقنيات خدمات المبنى مسبقة التجميع

٢ – ماهي أنواع تقنيات خدمات المبنى مسبقة التجميع التي سبق لكم استخدامها؟ (يرجى تحديد كل ما ينطبق)

مستوى ١	الخدمات المتكاملة مع المباني النموذجية	
مستوى ٢	وحدات خدمات المبنى المجمعة بشكل مسبق	
مستوى ٣	التوزيع الأفقي والعمودي الجاهز	
مستوى ٤	الوحدة الطرفية مسبقة التجميع	

٤ – ما هو رأيك في رفع مستوى استخدام تقنيات خدمات المبنى مسبقة التجميع؟

	أوافق بشدة	أوافق	لا أوافق ولا أعارض	يعارض	يعارض بشدة
جدير بالاهتمام					
متعلق بدعم أصحاب المصلحة الرئيسيين بالنسبة لك					
يمكن تحقيقه					

(٥ – أ) ماهي المعايير التي من المحتمل اخذها بعين الاعتبار في حال رفع مستوى استخدام تقنيات خدمات المبني مسبقة التجميع؟

	من المحتمل جدا	من المحتمل	ليس من المحتمل أو من غير المحتمل	من غير المحتمل	من غير المحتمل جدا
زيادة جودة المنتج					
تحسين سرعة البناء					
تحسين السلامة في مكان العمل					
تحسين كفاءة الطاقة					
زيادة كفاءة تصميم المشروع					
تقليل مخلفات البناء					
تقليل التكلفة الإنشائية					
تحسين التنسيق بين اطراف المشروع					
تسهيل المهام الانشائية					
زيادة التكلفة الإجمالية للمشروع					
زيادة المخاطر					
تقليل مرونة التصاميم					
تتطلب المزيد من الاعمال التحضيرية					
تحد من إجراء تغييرات في الموقع					
زيادة الاعمال اللوجستية للنقل					
زيادة الصيانة					
ينظر لها كمنتجات ذات نوعية رديئة					

(٥ – ب) برأيك، ما هو تأثير رفع مستوى استخدام تقنيات خدمات المبنى مسبقة التجميع على شركتكم؟

	إيجابي جدا	إيجابي	بدون تأثير	سلبي	سلبي جدا
زيادة جودة المنتج					
تحسين سرعة البناء					
تحسين السلامة في مكان العمل					
تحسين كفاءة الطاقة					
زيادة كفاءة تصميم المشروع					
تقليل مخلفات البناء					
تقليل التكلفة الإنشائية					
تحسين التنسيق بين اطراف المشروع					
تسهيل المهام الانشائية					
زيادة التكلفة الإجمالية للمشروع					
زيادة المخاطر					
تقليل مرونة التصاميم					
تتطلب المزيد من الاعمال التحضيرية					
تحد من إجراء تغييرات في الموقع					
زيادة الاعمال اللوجستية للنقل					
زيادة الصيانة					
ينظر لها كمنتجات ذات نوعية رديئة					

(٦ – أ) برأيك، من هم على الأرجح الداعمين لزيادة استخدام تقنيات خدمات المبنى مسبقة التجميع في مشاريع المباني المكتبية؟

	أوافق بشدة	أوافق	لا أوافق ولا أعارض	يعارض	يعارض بشدة
الاستشاري					
المالك					
الحكومة والهيئات التنظيمية					
الموردون					
مقاولون الباطن					

(٦ – ب) أي من الأطراف التالية يكون لرأيها التأثير الأكبر على زيادة استخدام تقنيات خدمات المبنى مسبقة التجميع في مشاريع المباني المكتبية

	الكثير	بعض الشيء	متوسط	ليس كثيرا	على الإطلاق
الاستشاري					
المالك					
الحكومة والهيئات التنظيمية					
الموردون					
مقاولون الباطن					

(٧ – أ) برأيك، أي من العوامل التالية لها التأثير الأكبر على زيادة استخدام تقنيات خدمات المبنى مسبقة التجميع في مشاريع المباني المكتبية؟

	الكثير	بعض الشيء	متوسط	ليس كثيرا	على الإطلاق
الدعم المالي					
التنظيم الحكومي					
قدرة المصانع على تلبية الاحتياج السوقي					
العمالة الماهرة في المصانع					

(٧ – ب) برأيك: أي من العوامل التالية من المحتمل أن يؤدي إلى زيادة استخدام تقنيات خدمات المبنى مسبقة التجميع في مشاريع المباني المكتبية؟

	من المحتمل جدا	من المحتمل	ليس من المحتمل أو من غير المحتمل	من غير المحتمل	من غير المحتمل جدا
الدعم المالي					
التنظيم الحكومي					
قدرة المصانع على تلبية الاحتياج السوقي					
العمالة الماهرة في المصانع					

القسم ج: أسباب عدم استخدام تقنيات خدمات المبني مسبقة التجميع

٨ – ما هي أسباب عدم استخدامكم لتقنيات خدمات المبني مسبقة التجميع؟

	أوافق بشدة	أوافق	لا أوافق ولا أعارض	أعارض	أعارض بشدة
زيادة التكلفة الإجمالية للمشروع					
زيادة المخاطر					
تقليل مرونة التصاميم					
تتطلب المزيد من الأعمال التحضيرية					
تحد من إجراء تغييرات في الموقع					
زيادة الأعمال اللوجستية للنقل					
زيادة الصيانة					
ينظر لها كمنتجات ذات نوعية رديئة					
نقص العمالة الماهرة					
نقص التنظيم الحكومي					
نقص الدعم المالي					
نقص المنتجات في السوق					

في حال رغبتكم الاطلاع على نتائج هذا الاستبيان او المشاركة في المقابلات، يرجى تعبئة بيانات الاتصال الخاصة بكم أدناه. وسيتم التعامل مع البيانات بسرية وعدم الكشف عن الهوية.

الاسم	
الوظيفة	
الشركة	
رقم الهاتف	
البريد الالكتروني	
العنوان البريدي	

تعليقات

Appendix C: Case Study - PBSC Consideration Review

Case Study

Title: Investigation on Consultants and Contractors' Use and Perceptions of Preassembled Building Services Components in Complex Office Developments in Saudi Arabia

Direction: The purpose of this interview is to validate the results of a study that examine the use and perceptions of consultants and contractors in regard to preassembled building services components in complex office developments. this form of matrices investigates the benefits and challenges of using these techniques as well as the influential parties on decision and the influential control factors. The scope of study only covers the largest three regions of Saudi construction industry including: Riyadh, Makkah, and Eastern region. I would appreciate if you would be involved in as instructed.

In this study, preassembled building services components are defined as those construction techniques that accomplished offsite applications where building systems or assemblies are manufactured or fabricated away from the building site prior to installation. Those techniques include:

- Integrated services with modular buildings
- Preassembled building services units/modules
- Prefabricated horizontal / vertical distribution
- Terminal unit preassembly

Table 1: matrix of selection indicators

	Benefits	A	B	C	D	E	F	G	H	I
A	Quality of product	0								
B	Speed of construction		0							
C	Construction cost			0						
D	Construction waste				0					
E	Energy efficiency					0				
F	Workplace safety						0			
G	Coordination among parties							0		
H	Construction Tasks								0	
I	Design efficiency									0

	Challenges	J	K	L	M	N	O	P	Q
J	Overall project cost	0							
K	Design flexibility		0						
L	Make changes onsite			0					
M	Transportation				0				
N	Maintenance capability					0			
O	Preparatory requirements						0		
P	Image of low quality							0	
Q	risky								0

	Challenges	R	S	T	U	V
R	Clients	0				
S	Consultants		0			
T	Governmental regulators			0		
U	Subcontractors				0	
V	Suppliers					0

	Challenges	W	X	Y	Z
W	Financial support	0			
X	Governmental regulations		0		
Y	Manufacturing capacity			0	
Z	Skilled craft workers				0

Benefits

	Indicators	Consideration		Importance		
		Yes	No	Low	Mid	High
1	Quality of product					
2	Speed of construction					
3	Construction cost					
4	Construction waste					
5	Energy efficiency					
6	Workplace safety					
7	Coordination among parties					
8	Construction Tasks					
9	Design efficiency					

Challenges

Indicators	Consideration	Importance

comments

Appendix D: RIBA Plan of Work 2013

RIBA

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

www.ribaplanofwork.com

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

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

Appendix E: AIA Plan of Work 2013

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
Programming /Deciding What to Build	**Schematic Design/Rough Sketches**	**Design Development/Refining the Design**	**Preparation of Construction Documents**	**Hiring the Contractor**	**Construction Administration**	**Project Close Out**
The owner and architect discuss the requirements for the project (how many rooms, the function of the spaces, etc.), testing the fit between the owner's needs, wants and budget.	The architect prepares a series of rough sketches, known as schematic design, which show the general arrangement of rooms and of the site. Some architects also prepare models to help visualize the project. The owner approves these sketches before proceeding to the next phase.	The architect prepares more detailed drawings to illustrate other aspects of the proposed design. Floor plans show all the rooms in correct size and shape. Outline specifications are prepared listing the major materials and room finishes.	Once the owner has approved the design, the architect prepares detailed drawings and specifications, which the contractor will use to establish actual construction cost and build the project. The drawings and specifications become part of the building contract.	The owner selects and hires the contractor. The architect may be willing to make some recommendations. In many cases, owners choose from among several contractors they've asked to submit bids on the job. The architect can help you prepare bidding documents as well as invitations to bid and instructions to bidders.	While the contractor will physically build the home or the addition, the architect can assist the owner in making sure that the project is built according to the plans and specifications. The architect can make site visits to observe construction, review and approve the contractor's application for payment, and generally keep the owner informed of the project's progress. The contractor is solely responsible for construction methods, techniques, schedules and procedures.	The architect can help bring your project to a close by ensuring that it is complete and ready for use, and that the contractor is entitled to final payment. You now have a working relationship with your architect, and no one knows your building better. You may wish to retain the same firm to assist with start-up, to review operations at a later date, for tenant related services, or for later alterations and modifications.

Figure 1cource (https://www.aiaetn.org/find-an-architect/design-to-construction/)

Appendix F: Ethical approval

OFFICE USE ONLY
UEC
//14
Paper

University of Strathclyde Glasgow

Ethics Application Form

Please answer all questions

1. Title of the investigation

The Influence of Consultants and Constructors on the Use of Preassembled Building Services Components in Office Building Developments in Saudi Arabia

Please state the title on the PIS and Consent Form, if different:
N/A

2. Chief Investigator (must be at least a Grade 7 member of staff or equivalent)

Name: Dr. Andrew Aqapiou
☐ Professor
☐ Reader
☒ Senior Lecturer
☐ Lecturer
☐ Senior Teaching Fellow
☐ Teaching Fellow
Department: Architecture
Telephone: 0141 548 3067
E-mail: andrew.agapiou@strath.ac.uk

3. Other Strathclyde investigator(s)

Name: Mohammed Alghaseb
Status (e.g. lecturer, post-/undergraduate): PhD student
Department: Architecture
Telephone: 07342785720
E-mail: mohammed.alghaseb@strath.ac.uk

4. Non-Strathclyde collaborating investigator(s) (where applicable)

Name: N/A
Status (e.g. lecturer, post-/undergraduate):
Department/Institution:
If student(s), name of supervisor:
Telephone:
E-mail:
Please provide details for all investigators involved in the study:

5. Overseas Supervisor(s) (where applicable)

Name(s): University of Hail
Status: N/A
Department/Institution: Architecture
Telephone: +96665358200
Email: k.almadini@uoh.edu.sa
I can confirm that the local supervisor has obtained a copy of the Code of Practice: Yes ☐ No ☐
Please provide details for all supervisors involved in the study:

6. Location of the investigation

At what place(s) will the investigation be conducted
Saudi Arabia, regions: Riyadh, Makkah, and Eastern

If this is not on University of Strathclyde premises, how have you satisfied yourself that adequate Health and Safety arrangements are in place to prevent injury or harm?
very satisfied

7. Duration of the investigation

Duration(years/months) : 3 Months

Start date (expected): 30 / 08 / 2017 Completion date (expected): 30 / 11 / 2017

8. Sponsor
Please note that this is not the funder; refer to Section C and Annexes 1 and 3 of the Code of Practice for a definition and the key responsibilities of the sponsor.

Will the sponsor be the University of Strathclyde: Yes ☐ No ☒
If not, please specify who is the sponsor: SACB

9. Funding body or proposed funding body (if applicable)

Name of funding body: N/A
Status of proposal – if seeking funding (please click appropriate box):
☐ In preparation
☐ Submitted
☐ Accepted
Date of submission of proposal: / / Date of start of funding: / /

10. Ethical issues

Describe the main ethical issues and how you propose to address them:

11. Objectives of investigation (including the academic rationale and justification for the investigation) Please use plain English.

The purpose of this questionnaire survey is to identify the current use of offsite construction techniques (OCT) including preassembled building services components (PBSC) in complex office building of the Saudi construction industry, and to investigate the benefits and challenges of using these PBSC.

12. Participants

Please detail the nature of the participants:

Selected decision makers of consultants and constructors who licensed by Saudi Council of Engineers (SCE) and Saudi Contractors Authority (SCA) to participate in this phase of the research as well as quantity surveyors and subcontractors.

Summarise the number and age (range) of each group of participants:

Number: 400 Age (range) 30-50

Please detail any inclusion/exclusion criteria and any further screening procedures to be used:

classified architecture firms included @ https://saudieng.sa and contractors included in Ministry of municipalities list @ https://contractors.momra.gov.sa/ and

13. Nature of the participants

Please note that investigations governed by the Code of Practice that involve any of the types of participants listed in B1(b) must be submitted to the University Ethics Committee (UEC) rather than DEC/SEC for approval.

Do any of the participants fall into a category listed in Section B1(b) (participant considerations) applicable in this investigation?: Yes ☐ No ☒

If yes, please detail which category (and submit this application to the UEC):

14. Method of recruitment

Describe the method of recruitment (see section B4 of the Code of Practice), providing information on any payments, expenses or other incentives.

Prior arrangement are done before performing questinnaire survey besides a survey monky.

15. Participant consent

Please state the groups from whom consent/assent will be sought (please refer to the Guidance Document). The PIS and Consent Form(s) to be used should be attached to this application form.

Participant consent will be taken orally after providing them with a copy of Information Sheet

16. Methodology

Investigations governed by the Code of Practice which involve any of the types of projects listed in B1(a) must be submitted to the University Ethics Committee rather than DEC/SEC for approval.

Are any of the categories mentioned in the Code of Practice Section B1(a) (project considerations) applicable in this investigation? ☐ Yes ☒ No
If 'yes' please detail:

Describe the research methodology and procedure, providing a timeline of activities where possible. Please use plain English.
the questionnaire survey will be translated into Arabic before been conducted

What specific techniques will be employed and what exactly is asked of the participants? Please identify any non-validated scale or measure and include any scale and measures charts as an Appendix to this application. Please include questionnaires, interview schedules or any other non-standardised method of data collection as appendices to this application.

Where an independent reviewer is not used, then the UEC, DEC or SEC reserves the right to scrutinise the methodology. Has this methodology been subject to independent scrutiny? Yes ☐ No ☒
If yes, please provide the name and contact details of the independent reviewer:

17. Previous experience of the investigator(s) with the procedures involved. Experience should demonstrate an ability to carry out the proposed research in accordance with the written methodology.

N/A

18. Data collection, storage and security

How and where are data handled? Please specify whether it will be fully anonymous (i.e. the identity unknown even to the researchers) or pseudo-anonymised (i.e. the raw data is anonymised and given a code name, with the key for code names being stored in a separate location from the raw data) - if neither please justify.
Questionnaire survey will be collected and data will be confidential

Explain how and where it will be stored, who has access to it, how long it will be stored and whether it will be securely destroyed after use:
Data will be stored @ university's server and deleted by the end of PhD study

Will anyone other than the named investigators have access to the data? Yes ☐ No ☒
If 'yes' please explain:

19. Potential risks or hazards

Describe the potential risks and hazards associated with the investigation:
N/A

Has a specific Risk Assessment been completed for the research in accordance with the University's Risk Management Framework (Risk Management Framework)? Yes ☐ No ☐

If yes, please attach risk form (S20) to your ethics application. If 'no', please explain why not:

20. What method will you use to communicate the outcomes and any additional relevant details of the study to the participants?
Delphi test

21. How will the outcomes of the study be disseminated (e.g. will you seek to publish the results and, if relevant, how will you protect the identities of your participants in said dissemination)?
publish the results on academic journal and include them on PhD thesis

Checklist	**Enclosed**	**N/A**
Participant Information Sheet(s)	☒	☐
Consent Form(s)	☒	☐
Sample questionnaire(s)	☒	☐
Sample interview format(s)	☐	☒
Sample advertisement(s)	☐	☒
Any other documents (please specify below)		
	☐	☐
	☐	☐
	☐	☐
	☐	☐
	☐	☐

22. Chief Investigator and Head of Department Declaration
Please note that unsigned applications will not be accepted and both signatures are required

I have read the University's Code of Practice on Investigations involving Human Beings and have completed this application accordingly. By signing below, I acknowledge that I am aware of and accept my responsibilities as Chief Investigator under Clauses 3.11 – 3.13 of the Research Governance Framework and that this investigation cannot proceed before all approvals required have been obtained.

Signature of Chief Investigator

Please also type name here: Dr. Andrew Agapiou

I confirm I have read this application, I am happy that the study is consistent with departmental strategy, that the staff and/or students involved have the appropriate expertise to undertake the study and that adequate arrangements are in place to supervise any students that might be acting as investigators, that the study has access to the resources needed to conduct the proposed research successfully, and that there are no other departmental-specific issues relating to the study of which I am aware.

Signature of Head of Department

Please also type name here Prof. Ashraf Salama

Date: 31 / 08 / 2017

23. Only for University sponsored projects under the remit of the DEC/SEC, with no external funding and no NHS involvement

Head of Department statement on Sponsorship
This application requires the University to sponsor the investigation. This is done by the Head of Department for all DEC applications with exception of those that are externally funded and those which are connected to the NHS (those exceptions should be submitted to R&KES). I am aware of the implications of University sponsorship of the investigation and have assessed this investigation with respect to sponsorship and management risk. As this particular investigation is within the remit of the DEC and has no external funding and no NHS involvement, I agree on behalf of the University that the University is the appropriate sponsor of the investigation and there are no management risks posed by the investigation.

If not applicable, tick here ☐

Signature of Head of Department

Please also type name here

Date: / /

For applications to the University Ethics Committee, the completed form should be sent to ethics@strath.ac.uk with the relevant electronic signatures.

24. Insurance
The questionnaire below must be completed and included in your submission to the UEC/DEC/SEC:

Is the proposed research an investigation or series of investigations conducted on any person for a Medicinal Purpose? Medicinal Purpose means: ▪ treating or preventing disease or diagnosing disease or ▪ ascertaining the existence degree of or extent of a physiological condition or ▪ assisting with or altering in any way the process of conception or ▪ investigating or participating in methods of contraception or ▪ inducing anaesthesia or ▪ otherwise preventing or interfering with the normal operation of a physiological function or ▪ altering the administration of prescribed medication.	Yes / No

If "**Yes**" please go to **Section A (Clinical Trials)** – all questions must be completed
If "**No**" please go to **Section B (Public Liability)** – all questions must be completed

Section A (Clinical Trials)

Does the proposed research involve subjects who are either: i. under the age of 5 years at the time of the trial; ii. known to be pregnant at the time of the trial	Yes / No

*If "**Yes**" the UEC should refer to Finance*

Is the proposed research limited to: iii. Questionnaires, interviews, psychological activity including CBT; iv. Venepuncture (withdrawal of blood); v. Muscle biopsy; vi. Measurements or monitoring of physiological processes including scanning; vii. Collections of body secretions by non-invasive methods; viii. Intake of foods or nutrients or variation of diet (excluding administration of drugs).	Yes / No

*If "**No**" the UEC should refer to Finance*

Will the proposed research take place within the UK?	Yes / No

*If "**No**" the UEC should refer to Finance*

Title of Research		
Chief Investigator		
Sponsoring Organisation		
Does the proposed research involve:		
a) investigating or participating in methods of contraception?		Yes / No
b) assisting with or altering the process of conception?		Yes / No
c) the use of drugs?		Yes / No
d) the use of surgery (other than biopsy)?		Yes / No
e) genetic engineering?		Yes / No
f) participants under 5 years of age(other than activities i-vi above)?		Yes / No
g) participants known to be pregnant (other than activities i-vi above)?		Yes / No
h) pharmaceutical product/appliance designed or manufactured by the institution?		Yes / No
i) work outside the United Kingdom?		Yes / No

If **"YES"** to **any** of the questions a-i please also complete the **Employee Activity Form** (attached).
If **"YES"** to **any** of the questions a-i, and this is a follow-on phase, please provide details of SUSARs on a separate sheet.
*If "**Yes**" to any of the questions a-i then the UEC/DEC/SEC should refer to Finance (aileen.stevenson@strath.ac.uk).*

Section B (Public Liability)	
Does the proposed research involve :	
a) aircraft or any aerial device	Yes / No
b) hovercraft or any water borne craft	Yes / No
c) ionising radiation	Yes / No
d) asbestos	Yes / No
e) participants under 5 years of age	Yes / No
f) participants known to be pregnant	Yes / No
g) pharmaceutical product/appliance designed or manufactured by the institution?	Yes / No
h) work outside the United Kingdom?	Yes / No

*If **"YES"** to any of the questions the UEC/DEC/SEC should refer to Finance(aileen.stevenson@strath.ac.uk).*

For NHS applications only - Employee Activity Form

Has NHS Indemnity been provided?	Yes / No
Are Medical Practitioners involved in the project?	Yes / No
If YES, will Medical Practitioners be covered by the MDU or other body?	Yes / No

This section aims to identify the staff involved, their employment contract and the extent of their involvement in the research (in some cases it may be more appropriate to refer to a group of persons rather than individuals).

Chief Investigator		
Name	**Employer**	**NHS Honorary Contract?**
Dr. Andrew Agapiou	University of Strathclyde	Yes / No
Others		
Name	**Employer**	**NHS Honorary Contract?**
Mohammed Alghaseb	University of Strathclyde	Yes / No
		Yes / No
		Yes / No
		Yes / No

Please provide any further relevant information here:

Survey Questionnaire

Title: Investigation on Consultants and Contractors' Use and Perceptions of Preassembled Building Services Components in Complex Office Developments in Saudi Arabia

Direction: The purpose of this survey is to identify the use and perceptions of consultants and contractors in regard to preassembled building services components in complex office developments. this survey investigates the benefits and challenges of using these techniques as well as the influential parties on decision and the influential control factors. The scope of study only covers the largest three regions of Saudi

Re: Ethical approve for Case Study data - Message (HTML)

FILE | MESSAGE | McAfee E-mail Scan

Ignore | Delete | Reply | Reply All | Forward | Meeting | More | Dr Andrew | Team Email | Reply & Delete | To Manager | Done | Create New | Move | Rules | OneNote | Actions | Mark Unread | Categorize | Follow Up | Translate | Find | Related | Select | Zoom

Delete | Respond | Quick Steps | Move | Tags | Editing | Zoom

Fri 24/08/2018 14:20

Ashraf Salama

Re: Ethical approve for Case Study data

To Mohammed Alghaseb; Andrew Agapiou

You replied to this message on 25/08/2018 04:33.
This message was sent with High importance.

Message | Ethics_Application_Form_MA_AA_Validation_Survey.pdf (301 KB)

Hi Mohammed / Andrew —
Now this is signed.
Kind regards,
Ashraf

Professor ASHRAF M. SALAMA, PhD, FRSA - FHEA
Head of Architecture | University of Strathclyde

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[illegible]

W: [illegible]
Webpage: [illegible]
Publications: [illegible]
Books - Featured Authors: [illegible]
Google Scholar: [illegible]
Archnet-IJAR: International Journal of Architectural Research: [illegible]

On 22 Aug 2018, at 11:13, Andrew Agapiou <andrew.agapiou@strath.ac.uk> wrote:

Hi Mohammed and Ashraf,
Please see signed form for your attention.
Ashraf- would you mind doing the honours please and signing off the approval form.
Regards
Andrew

Andrew Agapiou LLM PhD
Senior Lecturer

Joint Co-ordinator, CIB W113 Law and Dispute Resolution
Working Commission

Department of Architecture
Strathclyde University
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LinkedIn Profile: http://www.linkedin.com/pub/andrew-agapiou/37/51b/724
Skype ID: andrew.agapiou
Twitter: @AndrewAgapiou

Ashraf Salama Automatic reply: Ethical approve for Case Study data