DEVELOPMENT OF VALUE BASEDDecision Making Tool For
The Selection Of Offsite Manufacturing Of Buildings
Versus Traditional Method Of Construction

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Declaration

This work has not been previously submitted for a degree or diploma in any university. To the best of my knowledge and belief, this report contains no material previously published or written by another person except where due reference is made in the report itself.

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Bashir Tijani
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Abstract

The traditional method of construction involves erecting buildings through assembling the bricks, blocks and scaffolders onsite. For many years, this has been the most common method of construction used in the construction industry. The major challenges associated with this traditional method are well documented. They include requiring time extensions; increased construction costs; high worksite accidents, and difficulties around the disposal of construction waste. Against this brief background, Off Site Manufacturing (OSM) appears to be a sound alternative method of construction.

OSM is increasingly considered by researchers and some construction professionals due to its benefits, as evidenced from experiences in a variety of countries. However, despite OSM’s superiority over the traditional method of construction, in terms of time/cost savings, better quality control and enhanced safety performance, its uptake has been slow and rather limited. Reasons behind this slow uptake are varied and have been widely reported. A major reason appears to be the inability of OSM stakeholders (i.e. Clients, Developers, Manufacturers and Designers) to ascertain the short and long-term Value that OSM will contribute, for a particular construction project, compared to that of the traditional construction method.

To complicate matters further, project stakeholders, as one would expect, perceive the Value aspects of OSM differently. A critical literature review established the presence of a large number of Value aspects: 1) Product Value (e.g. usability, flexibility, etc.); 2) Process Value (e.g. profitability, customer satisfaction, etc.); and 3) Sustainability Value (e.g. life cycle costing, return on investment, waste generation, embodied energy, etc.). It is a certain combination of these Value aspects that may represent the source of motivation for stakeholders’ adoption of OSM.

In a step towards addressing this challenge, this thesis presents a robust approach to assist decision-makers (i.e. project stakeholders) to make an informed decision about whether or not to adopt OSM for a particular construction project. In doing so, the thesis utilises the well-established Analytical Network Process (ANP) for determining Value aspects weightings, where each Value aspect is individually compared to other aspects, and the results are entered in a matrix for evaluation. To provide a user-friendly interface, Visual Basic for Applications (VBA) programming was employed. This programming language is the mechanism behind the
functionality of the developed decision-making tool which generates relative weights and ranks, as well as benefit-to-cost ratios for both OSM and traditional method of construction for performing an objective comparison.

In order to confirm the functionality of the developed decision making tool, validation tests were carried out using two hypothetical scenarios. This is to demonstrate that the tool conforms to the aims of the research. The validity criteria were based on the comparison of the manual calculations with the output of the decision making tool. The results from the hypothetical scenarios indicate that the tool functions are both correct and reliable.
List of publication

**Conference paper**

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Chapter 1

Introduction

The importance of improving the uptake of OSM in Australia cannot be overemphasised, as it is recognised as central for driving building processes and efficiency improvements within the Australian construction industry over the next decades (Blismas and Wakefield, 2009; Hampson and Brandon, 2004).

This thesis discusses an MPhil research study that aims to investigate the current state of offsite manufacturing (OSM) of buildings in Australia, including the barriers, drivers and stakeholders’ value perceptions of the adoption of OSM compared to the traditional method of construction. The primary aims of this research are to capture OSM stakeholders’ perceived values and to develop a decision making tool to choose between OSM and the traditional method of construction.

1.1 Research background

The traditional method of construction involves erecting buildings through assembling the bricks, blocks and scaffolders onsite. For many years, this has been the most common method of construction used in the construction industry (Elnass, 2014). However, the inability to meet changes in client needs and the problems encountered while developing construction projects has called for an alternative method of construction (Elnass & Philip, 2014). The major challenges encountered during building development usually include requiring time extensions; increased construction costs; and difficulties around housing affordability, construction waste and building sustainability (Pan et al., 2007).

OSM is an alternative method of construction that is increasingly considered by researchers and some construction professionals due to its benefits, as evidenced from experiences in a variety of countries. OSM has been employed in the construction industry as far back as the twelfth century; however, its uptake has been slow and limited (Gibb, 1999). Researchers and
professionals have defined OSM in numerous ways. For example, Dale et al. (2013) identified OSM as a system of manufacturing whole houses or housing components offsite in a factory setting, before assembly onsite. Pan et al. (2007) described OSM as some innovations in-house buildings, mostly offsite technologies and moving construction works from onsite to offsite. The similarity between all definitions of OSM is that they focus on the manufacturing of buildings or components offsite.

There are significant differences between the traditional construction method and OSM. First, the obvious difference between OSM and the traditional method of construction is that the former involves the manufacture of buildings offsite, while the latter involves producing buildings onsite (Yau, 2006). Second, OSM produces a lower number of greenhouse gas emissions than does the traditional method of construction (Barrett and Wiedmann, 2007; MBI, 2010a). Third, according to Yau (2006), the advantages of OSM over the traditional method of construction include increased construction productivity and reduced project delays by up to half. Different countries have adopted OSM for various reasons, including the need to meet housing demand, develop high-quality buildings and provide environmentally sustainable buildings (Pan et al., 2007; Construction, 2014; Daly, 2009). For example, the UK employs OSM because of increased demand from stakeholders to develop low-cost, high-quality, environmentally friendly buildings with less construction waste. In Japan, the United States (US), Germany and the European Union (EU), countries have adopted OSM as a suitable method for affordable housing and high-quality, sustainable and rapidly erected buildings. However, the level of OSM uptake in these countries remains low (Nadim, 2012).

In Australia, housing shortages and the demand for sustainable buildings, coupled with the inefficiency and low productivity of the Australian construction industry, suggest that OSM could be a suitable alternative construction method for this country (Blismas and Wakefield, 2009). The above problems in the Australian construction industry have had a slight influence on shifting the traditional method of construction towards OSM. In addition, it is important to analyse the current state of OSM in Australia—including the drivers and barriers of OSM—and to compare this context to other developed countries. By comparing different countries’ similarities and differences in OSM, a critical argument can be presented regarding the perspectives of OSM in developed countries.

Although research has been undertaken on stakeholder management in construction, more research is required that focuses on OSM to enable a more holistic view of the current trends.
in the adoption of OSM, research evidence of the benefits of OSM and decision making process in the selection between OSM and the traditional method of construction. Some researchers such as Blismas and Wakefield (2009) and Rahman (2013) have examined and reported the sustainable benefits of OSM in developed countries; however, they have failed to classify these benefits based on stakeholders. Classification of the benefits based on stakeholders’ perceptions is necessary to indicate how each stakeholder would benefit from the adoption of OSM.

While research on OSM has been undertaken in the UK, the US and Japan, it is inappropriate to apply all these previous studies’ research findings to Australia due to differences in the countries’ geographical size and economic situations (Blismas and Wakefield, 2009). Thus, Australia requires specific research on OSM due to the differences in stakeholders’ perceptions and the economic situation, even though the UK construction industry is similar to that in Australia. Differences arise due to the distinctive characteristics of Australia’s geographical size and culture. Therefore, research focusing on Australia is paramount to obtain factual information that is particular to the Australian construction industry (Blismas and Wakefield, 2009).

The implementation of OSM in Australia has been the focus of important research since 2006 in order to understand the concept of OSM in Australia. It was predicted that the level of usage of OSM would rise over the past 15 years; however, this has not occurred (Hampson and Brandon, 2004). In contrast to the Australian situation, the UK government invested approximately £9.7 million into OSM research projects between 1997 and 2001, rising to £19.40 million when industry funding is taken into consideration (Gibb, 2001). In comparison, little research has been undertaken in Australia, with no direct government funding for OSM studies (Blismas and Wakefield, 2009). Hence, most published literature has focused on the UK, where the government has indicated an interest in OSM research. While a few research papers have been published in the US, China and Malaysia, their percentage is lower than the literature from the UK.

In Australia, Blismas et al. (2006) and Blismas and Wakefield (2009) were one of pioneer researchers who published research papers on OSM; explored the state of OSM, including its drivers, constraints and prospects; and considered tools for measuring the benefits of OSM. However, comparing the number of papers published in Australia to those in the UK, US and EU illustrates that the Australian government, researchers and professionals are yet to
understand the potential of using OSM. The major reason for the slow adoption of OSM by contractors and clients appears to be their inability to ascertain the benefits that OSM will contribute to construction projects (Pasquire and Gibb, 2002).

To examine the holistic advantages of OSM, the value aspects of OSM need to be captured, so that the benefits would be quantified based on value rather than drivers of OSM (Blismas and Wakefield, 2009). According to Barima (2010), value is a concept that influence construction project delivery and stakeholders adoption frequency. It is imperative to clarify the difference between the values and benefits of OSM because of the need to understand the driving forces for the uptake of OSM. In construction project delivery, value has been the source of motivation for stakeholders (Barima, 2010). Therefore, delivering stakeholders’ values is one system for improving their satisfaction, which is expected to have a great effect on OSM demand in construction projects. As Olander (2007) stated, project stakeholders’ expectations affect the management of a project; thus, it is imperative to understand stakeholders’ perceived values of OSM. The benefits of OSM adoption, as a method of construction, rest with the drivers of OSM; however, they are not the only source of motivation towards the decision to adopt OSM.

Despite the importance of the value capturing stated in Barima (2010) and Blismas and Wakefield (2009), little research has been undertaken on value capturing in Australian construction projects. As noted previously, research has mainly focused on the barriers and drivers of OSM in Australia, without considering stakeholders’ perceived values, which relate to stakeholders’ motivational construct (Cheng and Fleischmann, 2010). Developing a decision making tool based on value capturing would help stakeholders choose between adopting OSM or the traditional method of construction, based on the stakeholders’ needs.

Decision making analysis has been embraced in various sectors of the construction industry. It is used when selecting contractors for house building and for optimising the use of OSM in housebuilding (Pan et al., 2007). The decision making analysis in Pan et al. (2007) was based on the matrix and ranking method. However, a robust decision analysis is required to efficiently capture stakeholders’ perceived values, and to select a method with the most benefits and cost effectiveness. This basic concept led to the aims of this study. The purpose of this research is to develop a decision making tool using visual basic for application (VBA) to choose between OSM and the traditional method of construction, and to capture stakeholders’ perceived values.
1.2 Research rationale

The study’s rationale derives from the reasons for selecting this research topic and the contribution it will make to the existing research. The decision to undertake the current research was based on the gaps identified by a critical literature review of OSM in Australia and other developed countries. Most previous research on OSM has focused on the drivers, constraints, future opportunities and supply chains of OSM, as well as the current state of OSM in Australia (Blismas and Wakefield, 2009; Mostafa et al., 2014; Goodier and Gibb, 2007). Critically, while this previous research explains the merits and demerits of adopting OSM, it has failed to tackle the problem of the low uptake of OSM in Australia. Various factors have contributed to the inability of research to substantially influence the wider adoption of OSM. One factor is OSM stakeholders’ lack of understanding and perceived values regarding the uptake of OSM compared to the traditional method of construction (Emmitt, 2005). Hence, capturing stakeholders’ perceived values is paramount because of the role that stakeholders play in construction projects.

Currently, the value-analysis techniques used in the construction domain are incapable of capturing stakeholders’ perceived values because value is defined as a function of cost, time, price and quality (Barima, 2010). From a wider perspective, value is a complex concept with various definitions based on stakeholders’ perceptions of value. Thus, selecting a research approach that can capture stakeholders’ perceived values for the decision making process is essential because of its implications for choosing a construction method with greater values (Zhang and El-Gohary, 2015).

Moreover, the core rationale behind this research is developing a decision-support tool that indicates the benefit–cost ratio of OSM versus the traditional method of construction, based on stakeholders’ perceived values. This research seeks to advance the decision making tools used previously in Gidado et al. (2012) and Pan et al. (2007), which were based on decision matrix and ranking. A decision matrix is a method of listing alternatives as rows and criteria as columns in a table during a decision to select between two or more alternatives (Elnass, 2014). Ranking is a method of selecting a method based on ranking of the factors on a Likert scale. A robust decision making tool is necessary for critical evaluation of different stakeholders’ perspectives regarding the adoption of OSM compared to traditional construction.
1.3 Research aims and objectives

The aims of this research are to capture stakeholders’ perceived values, and to develop a decision making tool for the construction industry to use during the decision making process of choosing between OSM and the traditional method of construction. As a result, stakeholders’ needs can be incorporated into the development of OSM in Australia. This guidance will assist the OSM industry to meet their stakeholders’ expectations, which is the core factor towards increasing the uptake of OSM in Australia. To achieve the research aims and answer the above research questions, the following research objectives were identified.

Objective 1: To study the current state of OSM in Australia and other international developed countries:

- Understand OSM and traditional development in Australia
- Compare the percentage use of OSM to the traditional method of construction in Australia
- Review the rate of adoption of OSM in Australia and other international countries.

Objective 2: To identify the core stakeholders and the values that influence their decisions regarding the uptake of OSM versus the traditional method of construction:

- Review relevant literature to determine the key stakeholders.
- Understand the concept of value and its parameters that drive stakeholders to choose OSM.

Objective 3: To develop a robust decision making tool for stakeholders to choose between OSM and the traditional method of construction:

- Gather stakeholders’ perceived values and benefits of the perceived values into the decision making tool for further analysis
- Develop the decision making tool.

Objective 4: To validate the decision making tool:

- Select the desired stakeholders’ perceived values based on the listed perceived values
- Pairwise comparison of the selected stakeholders’ perceived values and their benefits
- Choose between OSM and the traditional method of construction based on benefit–cost ratio.
1.4 Delimitation of research scope

According to Perry (1998), delimitations refer to the aspects of the planned research scope that are within the researcher’s control, while limitations are beyond the researcher’s control. This study is based on the below scope delimitations:

- The study is based on house and commercial buildings, and does not extend to civil engineering works.
- The major aim of this study is to develop a decision tool for building selection. However, the decision tool only consists of 11 stakeholders perceived values attributes, chosen from sustainable value parameters.

1.5 Significance of the research

Currently, OSM adoption is a contentious topic among researchers and construction professionals around the world due to its drivers, constraints and advantages in comparison to onsite traditional construction methods. However, OSM research is lacking in Australia; thus, focusing this research on that topic will help tackle the problems faced by the Australian construction industry (Hampson and Brandon, 2004). While some recent research has shed more light on the barriers, benefits and future of OSM in Australia, there remains a low uptake of this method. Although this previous research has contributed to understanding the issues, it is imperative that the reasons for the low uptake are investigated. No previous research has captured stakeholders’ perceived values as a method for improving the value generated by OSM. Such factors are paramount due to the influence of stakeholders in construction projects. The stakeholders can influence construction project by increasing or decreasing the adoption of a construction method and the value generated by the construction project (Jergeas et al., 2000).

In addition, there have been limited studies developing a decision analysis tool for choosing between OSM and the traditional method of construction. Channelling the research in this direction will enable stakeholders to choose between OSM and traditional construction based on their perceived values and preferences, rather than relying on the anecdotal evidence reported by previous studies on the benefits of OSM over the traditional method of construction. For instance, Blismas and Wakefield (2009) used a focus group method to report the drivers, constraint and benefits of OSM. There are limited studies that adopted case studies approach to justify the benefits of OSM.
The current study is significant because it explores an innovative way to capture stakeholders’ perceived values of OSM, rather than examining function, cost or other value measurement systems used in the construction industry. Further, it provides theoretical and empirical knowledge on stakeholders’ perceived values, which previous research has not considered. Finally, it develops a flexible decision tool for selecting the construction method, which was also not considered in previous OSM studies.

1.6 Overview of the research methodology

Researchers need to consider which methodological approach to employ to find solutions to research questions (Fellows and Liu, 2009). Research should consist of a detailed research design that can be used as a framework for data collection and analysis. Research design provides a link between each chapter of the research. This study adopts the explanatory research concept. According to Fellows and Liu (2009), explanatory research investigates certain issues, or answers certain research questions. In this research, the identification of stakeholders’ perceived values parameters and core stakeholders were considered to answer Research question 1. Moreover, a critical literature review was undertaken to determine the most efficient value-measuring technique to capture stakeholders’ perceived values. The critical literature review was used to form the value parameters employed to design the VBA decision tool, which answer the Research question 2.

1.6.1 Conceptual decision making tool development

Critical review of OSM and traditional method of construction literature was carried out to develop background knowledge and current state of OSM, which led to the formation of the research questions. To answer the research questions, a decision making tool was developed based on the literature review and VBA programming knowledge. As a result, the developed tool consists of 11 stakeholders’ perceived values attributes and their benefits. The developed tool functions with ANP principles to generate relative weight, rank and the benefit to cost ratio of the stakeholders’ perceived values with respect to OSM and traditional method of construction.

1.6.2 Validation of the decision making tool

Following the tool development through VBA and ANP principles, a tool validation was conducted to determine the workability and the accuracy of the tool in comparison to manual
calculation. This validation is necessary because it confirms the reliability of the tool in the value decision making process. To achieve this, hypothetical scenarios were used to validate the tool. The criteria for the tool validation are that the manual calculation must be the same as the tool result. It is the most appropriate criteria because the stakeholders need changes with time, thus, the validity cannot be based on previous case studies. In addition, the limited studies on decision making tool using ANP principle contribute to the selection of the validity criteria adopted in this study. The hypothetical scenarios results confirm the validity of the tool.

1.7 Outline of the thesis

This thesis consists of seven chapters. A summary of these chapters is provided below.

**Chapter 1: Introduction.** This chapter introduces the research study by presenting the background of the research and rationale, research questions to be addressed, research aims and objectives, significance of the research, outline of the research methodology, and layout of the thesis.

**Chapter 2: Literature review.** The chapter provides a broad review of the literature pertinent to the field of OSM, specifically in developed countries, especially Australia. The critical review identifies the arguments of previous researchers on the barriers, benefits and future of OSM in Australia, as well as exploring the existing research gaps. Further, the chapter reviews the concept of values and how they can be captured to meet stakeholders’ needs. It highlights the significance of value to stakeholders and how it influences stakeholders’ decisions regarding the adoption of OSM. Through this, the core stakeholders are identified via the literature and industry consultation.

**Chapter 3: Research methodology.** This chapter focuses on the method required to gather the data needed to achieve the aims and objectives of this study. Initially, research philosophy is discussed as a basis for justifying the selection of the appropriate methodology. In addition, the methods of collecting the research data and the reasons for selecting the particular methods are explained. This research employs qualitative methods for data collection. The tools employed are literature review and programming language.
Chapter 4: Development of decision model. This chapter presents the concept adopted for developing the decision making tool. It further explains the mechanism for calculating the relative weight, normalised matrix and consistency ratio.

Chapter 5: Description and data handling used to populate the tool. This chapter presents validation of the model through the use of hypothetical scenarios. The purpose of the chapter is to test the workability of the tool. Further, this chapter shows how this study answers the research questions.

Chapter 6: Conclusion and future research. This chapter summarises the entire report and discusses the research conclusion. It also makes suggestions for future research. Finally, it explores the contributions, limitations and implications of the current study.
This chapter presents a critical review of the existing literature on OSM in Australia and other developed countries. It provides an overview of OSM topics, such as OSM in context, the current state of OSM in Australia and other developed countries, the benefits of OSM, and a comparison of OSM with the traditional method of construction. It also provides an overview of stakeholders’ perceived values, measures of stakeholders’ perceived values, and decision making analysis for choosing between OSM and the traditional method of construction. This chapter discusses the need to discover stakeholders’ perceived values and the importance of value in adopting OSM instead of the traditional method of construction. Based on the significance of values and stakeholders’ involvement in decision making, a value-measuring technique is selected among all other techniques to capture the values that drive stakeholders to adopt OSM.

Various sources are explored to obtain the relevant literature on OSM, including the journal of the American Society of Civil Engineers, the Australia Research Council publications, various construction and economics journals, Queensland’s building codes, various conference papers, construction textbooks, Emerald journals, and Google Scholar. These sources were selected because of their relevance and the reliability of their information.

Table 2-1 below presents the estimated number of papers reviewed and their contributions to the literature review.
Table 2-1 : Estimated research publications reviewed on OSM

<table>
<thead>
<tr>
<th>Country/authors</th>
<th>Number of papers</th>
<th>Contributions</th>
<th>Gaps in the literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Australia</td>
<td>13</td>
<td>• Barriers and constraints of OSM</td>
<td>• Limited research work on the barriers and enablers of OSM from stakeholders’ perspectives</td>
</tr>
<tr>
<td>(Blismas and Wakefield, 2009;Blismas et al., 2005)</td>
<td></td>
<td>• Perspectives of UK housebuilders on the use of OSM</td>
<td>• Production control in OSM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Assessing the benefits of pre-assembly construction</td>
<td>• Discovering stakeholders’ perceived values of OSM</td>
</tr>
<tr>
<td>2. UK</td>
<td>24</td>
<td>• Demystifying the cost barriers of OSM</td>
<td>• Value delivery system in OSM</td>
</tr>
<tr>
<td>(Goodier and Gibb, 2005)</td>
<td></td>
<td>• Encouraging appropriate use of OSM</td>
<td></td>
</tr>
<tr>
<td>3. US</td>
<td>6</td>
<td>• Improving efficiency and productivity through using OSM</td>
<td></td>
</tr>
<tr>
<td>(Lu and Liska, 2008;Zhengdao et al., 2014)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. New Zealand</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Shahzad, 2011)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Hong Kong</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Pan et al., 2004)</td>
<td></td>
<td></td>
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</tbody>
</table>

2.1 OSM definitions

Various definitions and terms have been used for OSM, based on the method of construction and the project development processes. OSM is termed an industrial building system, a modern method of construction, and prefabrication (Kamar et al., 2009;Pan et al., 2007). It is defined as a construction technique with standardised modules that are manufactured in a factory, and transported and assembled onsite (Khalfan et al., 2014). According to Gibb (1999), the term OSM is used by the UK government to describe innovation in house building, and transferring work from the factory to the construction site. The construction process of OSM was adopted from the manufacturing industry, whereby the components, modules or entire building are constructed in the factory, before being transported offsite. This is different from the traditional method, which entails the construction of building onsite (Antillón et al., 2014;MBIa, 2010).

OSM has been employed in buildings and civil engineering works; it has been used successfully to construct houses, hospitals, hotels and civil engineering projects (Ngowi et al., 2005). In the UK, OSM has been adopted for public housing, offices, retail buildings, universities, hotels and supermarkets (Goodier and Gibb, 2007). Further, OSM has been adopted for constructing building and civil engineering works due to its benefits over the traditional method of construction (Pan et al., 2007). However, Tam et al. (2007) has contrary
view in regards to the adoption of OSM in construction industry, stating that OSM is unable to meet the expectations of the construction industry.

According to Blismas and Wakefield (2009), OSM’s benefits include decreased construction time, increased quality, reduced health and safety risks, and reduced environmental effects during construction. Other advantages of OSM include waste reduction, speedier erection, cost certainty and higher quality (Dale et al., 2013). The benefits of OSM have caused many researchers—such as Hampson and Brandon (2004), Tam et al. (2007) and Goodier and Gibb (2007)—to believe that OSM represents the future of the construction industry, and is capable of mitigating the problems inherited from the traditional method of construction.

2.2 Types of OSM

OSM is classified into numerous types, based on the kind of product created, as stated by Kamar et al. (2009), and the location of production (Nadim, 2012). Figure 2-1 shows the classifications of OSM. The types of classification with respect to products are panelised; volumetric units; hybrid subassemblies; and components, such as floors, precast concrete foundation assemblies and engineering composites. The classifications based on the location of production include site-based systems, such as slip forms and jump forms.

Pasquire and Gibb (2002) classified OSM into component sub-assembly, non-volumetric pre-assembly, volumetric pre-assembly and modular assembly. OSM is also classified as a panel-building system, with volumetric (modular), hybrid (semi-volumetric) and sub-assembly components (Burwood and Poul, 2005). Pan et al. (2007) classification (component subassemblies, non-volumetric pre-assembly, volumetric pre-assembly and modular building) is similar to the list by Pasquire and Gibb (2002)—the various classifications are similar, except for the use of the term that describes each type.
2.2.1 Panelised building system

The panelised building system is a type of OSM that comprises floors, walls and roofs in the form of pre-engineered panels that are erected as a box on construction sites (Burwood and Poul, 2005). Shahzad (2011) defined the panelised building system as a building system that is manufactured through using various building panels, which are manufactured under controlled factory conditions. The panels are manufactured and transported to the construction site, before being assembled to form the required structure.

Burwood and Poul (2005) described two main types of panelised building systems: open and closed systems. These panelised building systems are based on the system of manufacturing. For example, open systems are a simpler form of panelised building, such as light frames or timbers, while closed systems are complex structures that are factory finished units with services, insulation, windows and external cladding (Shahzad, 2011).

Numerous benefits are attributed to the panelised building system. Being manufactured in a factory-controlled environment makes it possible to meet the building regulations and codes of different councils (Shahzad, 2011). In addition, this building system reduces labour costs through reducing the numbers of builders required, lowering construction time, reducing construction materials, enabling consistent quality, and allowing design flexibility in terms of room size and building layout (Designbasics, 2015).
Figure 2-2 and Figure 2-3 present the construction phases of panelised buildings. As can be seen from these figures, there are three stages in the construction of a panelised building. These stages contribute to the reasons for the reduced construction time and reduced number of construction workers needed to manufacture the building.

2.2.2 Modular/volumetric building

A modular or volumetric building is a 3D module in which the complete units are manufactured offsite. The 3D units form only part of the whole building. Venables (2004) stated that the units could be pre-finished in the factory with all fixtures and fittings, thereby requiring a limited amount of work onsite. Examples of modular systems include bathrooms, toilets, plant rooms and service risers (Shahzad, 2011). Figure 2-4 indicates the five stages in the manufacture of a modular system.
As aforementioned, a modular building system reduces construction costs and allows more flexibility than in traditional construction methods. Being manufactured in a controlled factory reduces the amount of time spent onsite, which reduces the risk of an accident onsite (Focus, 2015).

### 2.2.3 Non-volumetric building

The non-volumetric building type of OSM comprises pre-assembly units, which do not enclose a usable space. The major building element is built offsite and does not form the primary structure of a whole building. Some examples of non-volumetric buildings are precast concrete bridges, structural steel work trusses, cladding panels, and building service ducts (Shahzad, 2011; Venables, 2004). The phases in the manufacture of non-volumetric building were shown in Figure 2-5.

![Figure 2-5: Construction phases of non-volumetric building](image)

### 2.2.4 Hybrid system

The hybrid building system is a system of combining the panelised system with a volumetric system, where the high-value areas (bathrooms) are manufactured from the volumetric system, and the remaining structures are manufactured from some form of framing system (Venables, 2004). This system speeds up construction without compromising the flexibility required for site characteristics and challenges. Hybrid systems are used for high-service areas, such as bathrooms (NAO, 2005).

### 2.3 OSM and traditional construction method

It is important to justify the reasons for comparing the traditional method of construction and OSM. This comparison is necessary to establish the similarities, differences and benefits of the two construction methods, and the reasons for the study of OSM in this research. To begin, the traditional method of construction is a system of construction that involves the separation of design and construction. In addition, it involves erecting scaffolders and assemblies of bricks
and blocks to construct a building, as shown in Error! Reference source not found.. The majority of activities that contribute to developing the building are performed onsite, which makes it a site-based building. These methods are employed for constructing houses, hospitals, schools and so forth. Figure 2-6 shows the phases of the traditional method of construction, while Error! Reference source not found. shows a photograph of the development of the traditional method of construction.

In contrast, OSM entails manufacturing modules or components in a factory, without the separation of design and construction. It is factory quality-controlled building, without the need for assemblies of bricks, blocks and scaffolders onsite. Many of the activities to develop the building are completed in the factory, which makes it offsite building. These types of construction are used in homes, hospitals, prisons, offices and cabins employed at construction sites.
There are several differences between OSM and the traditional method of construction. First, during project development, OSM has shorter construction phases than traditional construction, as shown in Figure 2-7 and Error! Reference source not found. Based on the diagram, it can be inferred that there is no construction of superstructure and substructure in OSM, compared to the traditional method of construction. Further, site preparation is performed concurrently with the module assemblies in the OSM factory, which reduces labour cost and saves time during construction. The differences in the development phases led Salahudeen (N.D) to conclude that OSM has more benefits than the traditional method of construction, including increased speed of construction, waste reduction, improved quality and reduced labour. Goodier and Gibb (2007) noted that the greatest value advantage of using OSM over other methods of construction is the speed of erection.

The benefits of OSM over the traditional construction method are numerous. However, clients’ inclination to view OSM in terms of cost justification, rather than considering a holistic measure of OSM’s value, has led to the low adoption of OSM (Blismas and Wakefield, 2009). Thus, it is necessary to discuss both the benefits and disadvantages of OSM to enable a critical analysis.
2.4 OSM advantages and disadvantages

One of the core ways to convince stakeholders to adopt OSM is to discuss the pros and cons of using OSM. Stakeholders employ particular construction methods through weighting the benefits against the drawbacks. The benefits, which are shown in Figure 2-8 are the source of enablers in the adoption of OSM, while the disadvantages are barriers that have contributed to its slower uptake. The advantages and disadvantages of OSM are discussed below.

2.4.1 Advantages of OSM

One of the advantages of using OSM for construction projects is construction time reduction. The certainty of time and speed of construction cannot be compromised when developing a construction project, due to the benefits the stakeholders will derive from early completion and time certainty. Since time is an issue for most stakeholders, OSM is a promising alternative to the traditional construction methods, as it reduces the time for construction and enables projects to be completed within a stipulated period, without delay (Blismas and Wakefield, 2009). The capacity to reduce the overall construction time and efficient scheduling is due to the parallel construction process that reduces activities on construction site (Schoenborn, 2012). Pan and Goodier (2011) emphasised that reduced construction time is a benefit of using OSM, while Gidado et al. (2012) posited that time certainty and decreased construction time are an advantage of OSM. Goodier and Gibb (2007) also stated that the largest advantage of OSM over traditional construction is the decreased construction time.

Quality improvement is another benefit of OSM. Being a factory-controlled manufactured system, OSM provides higher quality buildings than does the traditional method of construction (Construction, 2014). According to Gibb and Isack (2003), quality is the second most cited reason for using OSM. OSM entails the ability to achieve good-quality factory-made products, which prevents the need for any rework. OSM produces high-quality products that are tried and tested in a factory, with greater consistency standard (Blismas et al., 2006). Langdon (2011) research identified that the key benefit of OSM is factory-based manufacturing accuracy, which allows some offsite building systems to exceed building regulation requirements for air leakages by up to 70%.

Pan and Sidwell (2011) mentioned that another advantage of OSM is construction waste reduction. Waste minimisation is a large problem in the construction industry, and has a negative effect on construction costs and the environment. OSM reduces site waste by at least
70% through reducing site activities and complete recycling of the OSM module (Greens, N.D). Doran and Giannakis (2011) and Rahman (2013) pointed out that OSM reduces the waste of materials, and this material waste reduction minimises the carbon footprint on the environment (Shahzad, 2011).

The environmental impacts of buildings contribute to the reasons for selecting a particular construction system. Specifically, OSM reduces environmental impacts through construction materials and insulation (Elnaas et al., 2014) that enable a high level of insulation and low embodied energy. These factors produce green buildings (Greens, N.D). In addition, OSM helps improve buildings’ sustainability through the use of energy efficient materials (Khalfan et al., 2014; NAO, 2005).

The potential to lower construction costs is one of the advantages of adopting OSM. Cost saving is important to clients; thus, they opt for construction methods that reduce cost. OSM lowers the preliminary cost, overheads and construction costs (Blismas et al., 2006). Thus, cost reduction and cost certainties are benefits and drivers of OSM (Nadim and Goulding, 2011; Dale et al., 2013). Goodier and Gibb (2005) also concluded that OSM reduces construction costs due to the reduced number of phases during the construction process. However, there is disagreement among researchers about the construction costs of OSM compared to the traditional method. Choosing between the traditional method and OSM tends to be based on anecdotal evidence that offsite manufacturing is more expensive than the traditional method (Blismas et al., 2005; Venables et al., 2004). For example, Blismas and Wakefield (2009) argued that, with the historically entrenched approach to costing, OSM is viewed as more expensive than traditional construction. This costing approach is the method of calculating construction cost based on developmental cost and not whole life costing of building. This approach led to the assumption that OSM is expensive than traditional method of construction. Gibb (2001) corroborated the view of Blismas and Wakefield (2009) that OSM was too costly to justify. However, later research by Pan and Sidwell (2011) indicated that construction cost savings are achievable through OSM. This is due to the reduction in construction activities that often led to high construction cost.
Figure 2-8: Benefits of OSM

- **Benefits of OSM**
  - Process benefits
    - Time: Speedier erection of building
  - Product benefits
    - Health and safety: Safer construction site operation
    - Waste: Reduced onsite material wastage
    - Quality: Higher quality buildings
    - Cost: Lower cost of erecting buildings
    - Energy consumption: Higher energy efficiency rating
    - Carbon footprint: Less carbon dioxide released into the atmosphere
2.4.2 Disadvantages of OSM

Despite the many advantages of OSM, there are also disadvantages of adopting this system of construction. For example, site accessibility is one disadvantage of OSM. Difficulty in transporting the prefabricated modules or houses, due to their volume, has contributed to the barriers towards OSM’s uptake. The OSM module is bulky, as it comprises many panels. Hence, moving the constructed panels to the construction site requires manoeuvring to suit the site dimensions (Blismas and Wakefield, 2009). Thus, according to Elnaas et al. (2014), site accessibility is one the demerits of OSM highlighted by the clients.

Another disadvantage of OSM is design freeze (Elnaas et al., 2014; Blismas and Wakefield, 2009)—that is, OSM does not allow changes to the design after the manufacturer has completed the design of the modules or home. For this reason, design freeze has affected the uptake of OSM, as clients cannot change in their brief. OSM’s inflexibility to late design changes is a core disadvantage of OSM (Rahman, 2013).

Further, extra costs may be incurred when transporting OSM from the factory to the construction site (Zhao and Riffat, 2007), which represents another barrier towards the uptake of OSM. The farther the distance from the factory to the construction site, the higher the transportation costs. This issue has a direct relationship with the availability of production modules locally.

Importantly, the disadvantages of OSM highlighted above arise from improper coordination among stakeholders during the development stages, as well as the unavailability of modules locally. A design freeze is an example of a disadvantage arising from the improper coordination of stakeholders—if OSM stakeholders agreed on the project specifications at the start of the development, there would be no need to change the design scope. All the above factors are disadvantages due to their effect on the total cost of the construction project.

2.5 International uptake of OSM

This section provides a comparison of the current state of OSM—including the barriers, enablers and methods adopted for the wider uptake of OSM—in the UK, the US and New Zealand in order to reveal the state of OSM in these countries. This comparison will assist in developing the techniques necessary to tackle the problem of Australia’s low OSM uptake. Thus, the following regional comparison provides the background to the current research.
2.5.1 OSM in the UK

The UK and other developed European countries are among the pioneer countries using OSM in the construction industry. Their OSM adoption was initially due to a housing shortage and the benefits of using OSM over the traditional method of construction, including the speed of construction and the buildings’ environmentally friendly characteristics (Pan et al., 2007). Nevertheless, the level of adoption of this method is low compared to traditional methods of construction due to the negative attitudes of stakeholders towards this method.

Goodier and Gibb (2005)’s survey indicated that the percentage of the UK offsite market, compared to the total value of the UK construction sector, was 2.1%, while the total value of the OSM market in the UK in 2004 was £2.2 billion—increasing to £6 billion in 2006 (Gibb, 2006). This proportion of OSM value is minimal compared to the challenges facing the UK housing industry. In other research, Pan et al. (2007) stated that the UK housebuilding industry is facing significant challenges in seeking alternative options to deliver high-quality housing, with greater construction productivity. Further, Federation (2009) reported that there is a wide gap between demand and supply, with, for example, five million people estimated to be on housing waiting lists in 2010.

The major factors that hinder the wide adoption of OSM in the UK are house buyers’ perspectives and human perception barriers, grounded in the past failure of OSM (Pan et al., 2004). In addition, the high construction costs, fragmented supply chain, interfacing problems, and site logistics are factors that impede the uptake of OSM. Several studies—such as those by Blismas and Wakefield (2009), Gibb (2006) and Rahman (2013)—have investigated the enablers and barriers of OSM from stakeholders’ perspectives in the UK. The barriers included design fixity, high capital costs, complex interfacing, skills shortages, a fragmented industry structure, the regulatory system, and site constraints (Pan et al., 2007). These barriers need to be addressed to improve the uptake of OSM in the UK. The Parliamentary Office of Science (2003) posited that contractors, architects, developers, maintenance personnel and implementers have a significant influence on the success of contemporary manufactured housing schemes due to their role in the decision making process.

The benefits realised from using OSM in the UK construction industry include waste reduction, reduced health and safety risks, improved profits, improved construction predictability, higher quality, greater time and cost certainty, and improved environmental sustainability (Rahman, 2013; Phillipson, 2001; Gibb, 2006). Fortunately, the UK government is willing to tackle the
housing shortage problem by encouraging house building through the use of OSM (Parliamentary Office of Science, 2003).

2.5.2 OSM in the US

The US is another country that sees the potential of OSM, particularly due to the shortage of construction professionals in the US construction industry. The reduced number of new workforce entrants and shortage of construction workers are challenges currently facing the US construction industry. Further, clients want projects to be completed faster and more cost effectively, without compromising safe and quality performance (Lu and Liska, 2008). OSM is the best solution to these existing problems. The MBl (2010) stated that the proper use of OSM could save construction costs, reduce project completion times, and more efficiently use the resources in the US construction industry.

The barriers to OSM in the US are transportation constraints, the inability to make design changes, the lack of skilled workers, and government regulations, as well as the increased design costs (Lu and Liska, 2008). These barriers appear to arise from the negative perceptions of the stakeholders involved in the supply chain. Therefore, to improve the uptake of OSM, it is important to overcome these barriers.

The percentage of OSM in residential buildings is low compared to commercial and civil OSM. Increasing the number of residential buildings is seen as offering the potential for a newly industrialised technology in the US. However, the traditional construction approach is still paramount in the industry, with the percentage of OSM still low compared to the traditional method of construction in the US. Currently, manufactured housing represents 20% of the residential sector, while 7% of family homes using OSM (Nasereddin et al., 2007). However, the US prefabricated design and construction industry has made remarkable efforts to build and deliver more sophisticated facilities through the use of OSM (Science, 2015). For example, in 2013, the National Institute of Building Sciences established offsite construction councils as research outreach centres for information and reporting on OSM construction in the US. Through this effort, the percentage of OSM building has begun to increase.

2.5.3 OSM in New Zealand

OSM has also been undertaken in New Zealand, a neighbouring country to Australia. New Zealand has a small open economy that operates on a free market (Shahzad, 2011). New Zealand began using OSM decades ago through the importation of panelised housing from the
In New Zealand, the barriers to OSM identified by Shahzad (2011) are design inflexibility, government regulations, the lack of skilled workers, and logistic issues. These barriers are similar to those identified in other developing countries. Although New Zealand’s uptake of OSM has been limited in the past, the construction industry is now ready to adopt the system in the future (Becker, 2005).

2.5.4 OSM in Australia

Gaining an understanding of the concept and current state of OSM in Australia is fundamental to improving residential construction. However, there is a lack of such information due to the limited research undertaken in the residential sector. According to (Building et al., 2003), at present, the Australian construction industry is inefficient and in need of cultural reform. The reasons for the industry’s problems are complex and range from inadequate information technology, time and cost uncertainty from then use of traditional method of construction, and the fragmented nature of the supply chain (Blismas and Wakefield, 2009). To solve these complex problems, there is a need for an alternative method that is capable of improving productivity and efficiency.

The call for an alternative method to increase efficiency and productivity and solve the problems in the construction industry highlights OSM as a suitable option (Blismas and Wakefield, 2009; Khalfan et al., 2014). However, OSM as an alternative solution has not been implemented widely in Australia due to the inability of clients and other stakeholders to perceive the benefits of OSM. In contrast, the UK construction industry has made significant efforts towards adopting OSM as an alternative to solve the problems faced by the UK construction industry. To support OSM adoption, the UK has employed several initiatives, communities of practice, and government-sponsored forums. Additionally, the UK government invested approximately £10 million in OSM research projects between 1997 and 2001 (Gibb, 2001). In contrast, in Australia, little effort has been made in relation to direct government funding. However, in 2001, a Co-operative Research Centre (CRC) was established to improve construction innovation in Australia. This centre developed an industry vision called ‘Construction 2020’, with the aim of exploring the future construction industry and the methods to achieve the construction innovation.

Both the CRC (2007) and Blismas et al. (2006) have recognised the various benefits of OSM in the Australian context, including cost reductions, reduced construction time, improved time certainty, waste reduction, less onsite risks, improved energy performance, higher quality and
greater productivity. These benefits are the major drivers for the uptake of OSM in Australia. However, there has been limited research into the justification and advantages of OSM; rather, the drivers are based on anecdotal evidence, interviews and questionnaires. Thus, to convince stakeholders of the benefits of OSM, confirmatory research is required.

Some barriers to OSM in Australia include design inflexibility, the high initial cost, the lack of skilled professionals in construction OSM, the difficulty in obtaining finances, and regulatory and transport constraints. All these factors contribute to the low uptake of OSM in Australia. Therefore, to improve the uptake of OSM, it is important to focus on the causes of these barriers and how to mitigate these barriers. The barriers of OSM can be traced to the stakeholders in the OSM supply chain—for example, the inability to alter designs is a barrier specified by consultants (Zhengdao et al., 2014). In support of this view, Kenley et al. (2013) confirmed that adoption of OSM remains limited due to stakeholder reluctance.

Despite the barriers to OSM in Australia, OSM is still recognised as the key vision for improving the construction industry’s position by 2020 (Hampson and Brandon, 2004). To benefit from OSM as a method for improving the construction industry, adequate measures must be implemented by the government and construction sector. However, it is not sufficient to merely understand the benefits of OSM—there must also be proper understanding of the application of OSM in order to enable wider uptake of OSM. Moreover, the Australian construction industry faces adequate measures to improve the uptake of OSM. One factor that attracts stakeholders towards the adoption of a particular construction technique or project is the benefits or values attributed to the method. OSM is a system of construction that is an alternative to traditional construction. This system of technology is not new to the construction industry, yet its uptake is low. The benefits of OSM are enormous, especially when compared to traditional methods of construction. Nevertheless, the method still possesses some disadvantages that hinder its uptake.

PrefabAUS in Australia and Buildoffsite in the UK were formed in 2013 and 2014, respectively, to increase awareness of OSM (PrefabAUS, 2015). Improved awareness was achieved through organised seminars and conferences, where case studies of OSM were presented to demonstrate OSM’s benefits over the traditional method of construction.PrefabAUS also encourages research and development programs across the construction industry, which positively advances Australian building prefabrication.
2.6 OSM in Australian housing sector

In Australia, OSM has been used in civil engineering, as well as the commercial and residential sectors; however, the percentage of OSM used in the residential sector is low compared to other construction sectors. Australia’s housing supply gap, housing sustainability and housing affordability, alongside the disadvantages of traditional construction methods, are issues that require addressing through quick and extensive research. Today, the cumulative supply gap of new homes is 243,700 and for rental properties is 539,000, while there are 225,000 families on social housing waiting lists (Greens, N.D).

This severe housing shortage is due to the housing supply rate and affordability index, and is one factor encouraging the adoption of OSM (Duc et al., 2014). An OSM building is more affordable, with lower construction costs and greater waste reduction, especially when compared to the traditional method of construction. Thus, to achieve greater OSM uptake, there is a need to increase the manufacturing of OSM. Increasing the supply of OSM in Australia will boost the housing market through greater demand from stakeholders. Table 2-2 presents the affordability index, median house price, and median household income of developed countries, with Australia at the top of the table.

<table>
<thead>
<tr>
<th>Country (city size considered)</th>
<th>Affordability index</th>
<th>Median house price</th>
<th>Median household income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia (population 50,000+)</td>
<td>6.3</td>
<td>A$357,407</td>
<td>A$57,078</td>
</tr>
<tr>
<td>Canada (population 100,000+)</td>
<td>3.7</td>
<td>CAN$212,398</td>
<td>CAN$57,682</td>
</tr>
<tr>
<td>Ireland (population 50,000+)</td>
<td>5.3</td>
<td>£306,220</td>
<td>£57,960</td>
</tr>
<tr>
<td>New Zealand (population 75,000+)</td>
<td>5.7</td>
<td>NZ$316,113</td>
<td>NZ$55,125</td>
</tr>
<tr>
<td>UK (population 150,000+)</td>
<td>5.5</td>
<td>£145,300</td>
<td>£26,181</td>
</tr>
<tr>
<td>US (population 400,000+)</td>
<td>3.6</td>
<td>US$188,699</td>
<td>US$52,706</td>
</tr>
</tbody>
</table>

Note: affordability index = slightly unaffordable > 3.0, seriously unaffordable > 4.51, severely unaffordable > 5.1.

The traditional method of construction can entail uncertainty in time and cost, high carbon emissions, high costs and variable quality. Overcoming these barriers requires an innovative
method of construction that is capable of solving these problems (Luther, 2009). Further, the traditional method leads to low efficiency and productivity; thus, improving productivity, efficiency, uncertainty in time and cost, and environmental impacts are paramount to stakeholders in the construction industry.

Housing sustainability is important because building development accounts for fifty percent of the greenhouse gas emissions in the environment (Greens, N.D). In Australia, the current traditional housing is unsustainable due to the embodied energy and maintenance energy inherent in the buildings (Luther, 2009). Reducing the energy level is important, given that Australia’s carbon footprint is roughly four times the average level globally (Simpson et al., 2000). Moreover, greenhouse gas emissions are detrimental to the ecology and the house occupier. The current traditional construction method is not sustainable and is unable to reduce the level of greenhouse emissions occurring due to extraction, transportation of materials, and the processing and recycling of the building (ABS, 2013). Congruent with Australian Bureau of Statistics data, Duc et al. (2014) found that the size of the carbon footprint and waste onsite needs to be addressed. Reducing the amount of greenhouse emissions is one the 2020 targets proposed by the Australian government (Australia, 2015). The building construction, the building materials and the development process need to be improved to meet the 2020 targets.

In Australia, the use of OSM is limited in the housing sector; however, there is increased usage in commercial applications, such as hospitals and student apartments. Recently, Melbourne has witnessed the use of unitised building, a division of OSM, for the construction of medium-rise apartment blocks. This project, termed ‘Little Hero’, was constructed in Russel Street (Khalfan et al., 2014). The construction period of the unitised building reduced the time taken for traditional construction by six months. Dale et al. (2013) reported that there is limited focus on prefabrication in the residential housing market in Australia, with residential construction being distinguished from the commercial sector by the level of client attachment to a project.

In summary, the challenges facing the Australian housing market include housing undersupply, sustainability and affordability. These problems need to be tackled to achieve an increase in efficiency and productivity, and to attain the 2020 target (Hampson and Brandon, 2004; Australia, 2015). Table 2-3 presents the Australian Greens Party’s national affordable housing platform target to increase the number of prefabricated houses in Australia.
Table 2-3: National affordable housing platform (Greens, N.D)

<table>
<thead>
<tr>
<th></th>
<th>New homes per year</th>
<th>Total by 2024</th>
<th>Prefab target</th>
<th>Total prefab by 2024</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homelessness</td>
<td>1,000</td>
<td>7,000</td>
<td>50%</td>
<td>3,500</td>
</tr>
<tr>
<td>Social housing</td>
<td>12,200</td>
<td>122,000</td>
<td>33%</td>
<td>40,260</td>
</tr>
<tr>
<td>NRAS</td>
<td>5,000</td>
<td>50,000</td>
<td>33%</td>
<td>16,500</td>
</tr>
<tr>
<td>Student NRAS</td>
<td>2,000</td>
<td>20,000</td>
<td>33%</td>
<td>6,600</td>
</tr>
<tr>
<td>Convert to rent</td>
<td>1,500</td>
<td>15,000</td>
<td>33%</td>
<td>4,950</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>214,000</strong></td>
<td></td>
<td><strong>71,810</strong></td>
</tr>
</tbody>
</table>

Note: NRAS = National Rental Affordability Scheme.

Research is required to investigate the benefits to the Australian construction industry derived from OSM in order to enable wider uptake of the method. The existing limited research has suggested solutions and a design model to enhance the wider uptake of OSM in Australia. However, currently, there is insufficient knowledge of suitable strategies to increase the uptake of OSM. Based on the table above, it can be seen that housing affordability and homelessness are major problems in Australia, and there is a need to tackle these problems with a sustainable method. OSM has solved the issue of housing affordability, housing shortages and homelessness in developed countries such as the UK and US.

Having examined the literature to identify and acknowledge the ability of OSM to address the problems facing Australia’s construction industry and housing industry, it is now necessary to explore ways to improve the wider uptake of OSM in Australia.

### 2.7 OSM barriers

A number of factors as shown in Table 2-4 hinder the adoption of OSM in Australia—most significantly, stakeholders’ inability to see the benefits of OSM and lack of understanding regarding the usage of OSM (Mao et al., 2013; Blismas and Wakefield, 2009; Pasquire and Gibb, 2002). For OSM to succeed in Australia, the barriers hindering its implementation must be identified, and stakeholders’ needs must be met.

Various studies have examined the barriers to OSM in the US, New Zealand, the UK and Australia. The MBla (2010) and Lu and Liska (2008) identified constraints to the use of OSM in the US. In the UK, the constraints were revealed by Duc et al. (2014), Gibb (2001) and Pasquire et al. (2005). The New Zealand constraints and barriers were reported by Shahzad (2011), while the barriers to the use of OSM in Australia were outlined by Blismas et al. (2005),
Blismas and Wakefield (2009) and CRC (2007). The Australian OSM barriers are similar to those in other developed countries. Blismas and Wakefield (2009) reported eight barriers that hinders the uptake of OSM. These barriers are discussed below.

### 2.7.1 High initial cost

The prominent barrier that outweighs other related drivers reported in the literature is OSM’s high initial cost. Currently, there is a perception that OSM is more expensive than the traditional method of construction (Blismas et al., 2005; Blismas and Wakefield, 2009; CRC, 2007; Gibb and Isack, 2003). However, it must be clarified that the high preliminary cost of manufacturing OSM contributes to its high construction cost (CRC, 2007). Nevertheless, Haas et al. (2000) claimed that, under certain circumstances, OSM is capable of reducing construction costs over traditional construction through the reduction of onsite activities and administrative. For example, Pan and Sidwell (2011) argued that OSM for apartment building does not involve higher construction costs, as reported by Blismas et al. (2005), Blismas and Wakefield (2009) and CRC (2007). Additionally, there is a lack of awareness about the method of cost saving during the development process of OSM. Whole-life costs need to be emphasised via a proper understanding of value, rather than the costs of material, plant and labour, which stakeholders use to make judgements when considering the construction cost of OSM (Blismas and Wakefield, 2009).

### 2.7.2 Industry and market culture

The negative cultural perception of OSM is a significant constraint on its adoption because clients’ or end users’ perceptions about a particular construction method are reflected by the demand for the product. In Australia, the adoption of OSM is determined by the way industry practitioners describe the construction, as well as the willingness to leverage their OSM skills. The negative perception of OSM is widespread in Australia and the UK. The post-war and 1960s to 1970s social housing projects gave OSM residential building a bad reputation (Blismas and Wakefield, 2009). In addition, the earlier use of OSM for remote and affordable accommodation gave OSM a reputation for producing low-cost and poor-quality houses (Blismas and Wakefield, 2009).

According to the Parliamentary Office of Science (2003), pessimism towards the quality of OSM building materials and modules, coupled with poor workmanship, has contributed to the negative perceptions of OSM. Moreover, the perceived design inflexibility and difficulty
obtaining funds for OSM—due to the inability of financial institutions to perceive the economic benefits they can derive from investing in OSM—have affected the use of OSM in Australia (CRC, 2007; Blismas et al., 2005; Blismas and Wakefield, 2009).

2.7.3 Supply chain and procurement

Supply chain and procurement are fundamental to the construction of civil engineering projects and housing construction, and are even more critical to OSM projects (Shahzad, 2011). The supply chain involves the process of delivering construction projects to the site, while procurement is the strategy employed to deliver a project. The Australian market has expressed concern over the OSM supply chain due to its small size, coupled with a massive disparity in production centres (Blismas and Wakefield, 2009).

The limited number of manufacturers and suppliers in the OSM market leads to a limited capacity to supply OSM products, which is particularly problematic in some cities in Australia, where the industries are small and rely on importation or distant production, with high transportation costs (CRC, 2007). Further, stakeholders have opined that there is a potential for loss of management control when a large percentage of development work is undertaken in the factory setting. Due to the differences in the procurement of OSM in relation to the traditional method, different payment and cash flow arrangements are required, with agreement needed by all parties in the contract (Blismas and Wakefield, 2009).

2.7.4 Regulatory

The present building regulations in Australia and the US do not provide a suitable regulation policy for OSM, which provides challenges to the uptake of OSM. Further, the regulatory barriers are numerous, with different codes and local regulations. Additionally, the codes for the OSM modules are vague, which creates uncertainties and extra work for construction professionals (Blismas and Wakefield, 2009). The regulatory barriers established by the government also affect the uptake of OSM—particularly because home builders are not ready to opt for a construction method that does not have regulation guidance.

2.7.5 Logistic/site control

The OSM method of construction involves the transportation of heavy modules or panels from the control factory to construction site. The size of the module, road width and transport curfews make it difficult to transport OSM to construction sites, especially in city centres.
These constraints are common in Australia and other countries (Blismas and Wakefield, 2009). Australia’s geographical zone and long distances between cities and towns exacerbate this constraint. As with access to any site, OSM site accessibility involves onsite manoeuvring for the module’s delivery. In the case of OSM, the difficulty of accessibility is increased due to the large panels and storage of the prefabricated module. Thus, onsite accessibility constrains the adoption of OSM (CRC, 2007; Pasquire et al., 2005).

2.7.6 Occupational health and safety

The reduction in onsite risk through improvements to occupational health and safety—including work conditions, lower hazard exposure, fewer tradespeople and people onsite, and lower falls from heights—is described as an average driver of OSM (Blismas and Wakefield, 2009; CRC, 2007). However, the delivery and assembly of OSM modules and panels require the use of larger and heavier industry components, which can lead to accidents. Such construction requirements create a barrier to the use of OSM due to the legal consequences of accidents on the construction site.

2.7.7 Skills and knowledge

Another constraining factor in the use of OSM is inadequate knowledge about the manufacture of OSM. Approaches to design and management tend to be based on the traditional construction method, which is unsuitable for OSM construction (Blismas and Wakefield, 2009). Finer design skills and a greater understanding of OSM are needed for a proper system interface between management and the design for production (CRC, 2007).

Further, there is limited expertise in the marketplace about OSM suppliers and manufacturers, in comparison to the traditional method. This lack of expertise appears to be due to education and training that focuses on conventional construction, with specific OSM skills for practitioners (Blismas and Wakefield, 2009). The lack of research and development in OSM, coupled with inadequate general guidance and information on OSM in the marketplace, create additional barriers to OSM uptake.

2.7.8 Process and programme

The design process for the traditional method of construction is unsuitable for OSM, and poses a great constraint on OSM’s adoption. While Australian designers are familiar with the design process of traditional building methods, they are reluctant or unable to acquire the necessary
design skills for OSM, leading to low uptake of OSM. Additionally, the high fragmentation in the OSM industry, due to the separation of design and construction, hinders the adoption of OSM (Blismas and Wakefield, 2009; CRC, 2007). The differences in the construction system of OSM and the traditional method are that OSM requires a longer lead time and design fixity, especially for pre-planning (Blismas and Wakefield, 2009). Variation within a project is not encouraged in OSM because it would lead to additional costs, making OSM uneconomical for clients.

Table 2-4: OSM barriers

<table>
<thead>
<tr>
<th>OSM barriers</th>
<th>Explanation</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>High initial cost</td>
<td>High initial preliminary and transportation cost</td>
<td>Gibb and Isack (2003), Blismas and Wakefield (2009), CRC (2007), Blismas et al. (2005), Pan et al. (2007)</td>
</tr>
<tr>
<td>Industry and market culture</td>
<td>Professionals’ negative attitudes and cultural barriers</td>
<td>Blismas et al. (2005), Parliamentary Office of Science (2003), Blismas and Wakefield (2009), Pan et al. (2007)</td>
</tr>
<tr>
<td>Regulations</td>
<td>Lack of regulations for OSM buildings</td>
<td>Blismas and Wakefield (2009), Pan et al. (2007)</td>
</tr>
<tr>
<td>Logistics and site control</td>
<td>Site accessibility and inadequate transportation facilities</td>
<td>Pasquire et al. (2005), CRC (2007)</td>
</tr>
<tr>
<td>Occupational health and safety</td>
<td>Likelihood of accident due to the use of large cranes</td>
<td>Blismas and Wakefield (2009), CRC (2007)</td>
</tr>
<tr>
<td>Skills and knowledge</td>
<td>Limited OSM expertise</td>
<td>Blismas and Wakefield (2009), CRC (2007), Blismas et al. (2005), Pan et al. (2007)</td>
</tr>
<tr>
<td>Process and programme</td>
<td>Lack of knowledge on OSM design process</td>
<td>Blismas and Wakefield (2009), CRC (2007)</td>
</tr>
</tbody>
</table>

2.8 Role of decision making in the uptake of OSM

Decision making is the process of choosing a construction approach over others based on certain factors. The major challenge that influences the uptake of OSM over traditional method of construction or vice versa is the lack of decision making knowledge. Based on OSM constraints, barriers and international uptake of OSM explained above and the studies of Goodier and Gibb (2007), and Blismas et al. (2006), it can be inferred that limited knowledge
on the value criteria in the selection between OSM and traditional led to the low uptake of OSM. This is because the constraints in the adoption of OSM are not value attributes.

Goodier and Gibb (2007) and Blismas et al. (2006) mentioned that the adoption of OSM should be based on value. Before emphasising the importance of value in decision making, it is imperative to understand the components of decision making process.

Stakeholders and their perceived values are two components of the decision making process. This is because the stakeholders are people who influence the decision in project development (Olander, 2007). This is why Nadim and Goulding (2011) stressed the importance of in cooperating stakeholders need in the development of OSM. In addition, stakeholders’ perceived values are another component of the decision making that drives the motivation of the stakeholders in the selection process. The next sections elaborated on stakeholders and the perceived values in the decision making process.

2.9 Stakeholders

The development of construction projects involves a network of multiple parties, who influence the project development and execution. Different terms are used to describe these multiple parties, including ‘stakeholders’ and ‘influencers’ (Freeman, 1984).

Stakeholders are individuals or groups of people who have a stake in the success of a project and the environment in which the project operates (Olander, 2007). Freeman (1984) defined project stakeholders as any group or person who can influence or be affected by the achievement of the project’s purpose. These definitions indicate that project stakeholders influence the project’s success, failure and outcomes. Understanding the importance of stakeholders’ involvement in the development of OSM projects is one strategy to deliver the needs of stakeholders. It enables the parties involved to contribute to the development of the project, which allows the stakeholders’ needs to be met.

Despite the understanding of interested parties’ involvement in a construction project, there is a limited knowledge about stakeholders’ involvement process to gains insights into their needs and values in the development of construction project (Storvang and Clarke, 2014).

2.9.1 Importance of stakeholders’ management in projects

The participation of stakeholders is essential in construction projects because they affect the project management process. Based on their influence, project management recognises the
stakeholders to plan and execute a thorough stakeholder management process (Olander, 2007). Negative stakeholder perceptions can obstruct a construction project (Olander and Landin, 2005). However, devoting limited attention to the needs and expectations of stakeholders tends to lead to project failure, even when the project manager does not exceed the initial timing, costings or scope (Bourne and Walker, 2005). Further, project stakeholders are needed to develop the project brief, which addresses the different range of construction needs and values (Bourne and Walker, 2005). However, little research has focused on stakeholders’ perspectives and perceived values of OSM housing in Australia. Table 2-5 indicates the importance attached to stakeholder management, which demonstrates the significance of incorporating stakeholders’ needs into the development of construction projects.

<table>
<thead>
<tr>
<th>Papers</th>
<th>The importance of stakeholder management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarkson (1995)</td>
<td>Continuing success depends on the ability of managers to create sufficient wealth, value and satisfaction for stakeholders.</td>
</tr>
<tr>
<td>Preble (2005)</td>
<td>Inappropriate management of stakeholder activist issues can result in lost markets and revenues, and decline in share prices.</td>
</tr>
<tr>
<td>Bourne and Walker (2005)</td>
<td>Stakeholders are needed to develop project briefs that address the conflicting range of needs and values.</td>
</tr>
</tbody>
</table>

The literature cited in the table above evidences the importance of involving stakeholders in the development process, and subsequently meeting their expectations. However, understanding the needs and values of stakeholders is insufficient without knowing the stakeholders, and understanding how to capture and incorporate their needs into the OSM development process (Gish et al., 2009). This issue led to the identification of the core stakeholders that have influence in the adoption of OSM in Australia.

2.9.2 Identification of stakeholders in the decision process

The initial step towards capturing stakeholders’ perceived values is to identify the core stakeholders that influence the adoption of OSM in Australia. Due to the limited research focusing on stakeholder identification, Bourne and Walker (2005) examined stakeholder identification in construction projects. However, despite the work of Bourne and Walker (2005), little is known regarding how to identify the stakeholders involved in the construction development process (Barrett and Stanley, 1999; Ivory, 2004).
Storvang and Clarke (2014) stated that stakeholder identification could be undertaken with reference to the literature and previous construction projects. Blayse and Manley (2004) augmented the work of Storvang and Clarke (2014) on stakeholder identification by indicating five key groups of stakeholders involved in construction: (1) the regulatory system, (2) the supply network, (3) project-based firms, (4) users and (5) technical support. The research works of Blayse and Manley (2004), Storvang and Clarke (2014) and Zhengdao et al. (2014) assisted in identifying four core OSM stakeholders for this research, as highlighted in Table 2-6. This table presents the list of targeted OSM stakeholders for this research. They were chosen due to their influence and power in OSM adoption.

Table 2-6: List of targeted stakeholders

<table>
<thead>
<tr>
<th>Stakeholders</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Developers—e.g. housing authorities</td>
<td>An individual or company that is responsible for funding OSM projects. They can also be the primary owner of the project.</td>
</tr>
<tr>
<td>2. Manufacturers—e.g. monarch and prebuilt</td>
<td>Companies that work with clients, suppliers and contractors to design and produce OSM buildings, panels and modules.</td>
</tr>
<tr>
<td>3. End users—e.g. tenants and buyers (industrial and commercial)</td>
<td>Occupiers of the building.</td>
</tr>
<tr>
<td>4. Design teams—e.g. architects, quantity surveyors, project managers, civil engineers and builders</td>
<td>The subdivision of OSM stakeholders relates to design and professional advice in regard to the procurement, cost and management of OSM.</td>
</tr>
</tbody>
</table>

![Figure 2-9: OSM stakeholder diagram](image)

2.10 The need to measure stakeholders’ perceived values

The literature review revealed a wide-ranging overview of values, including the way stakeholders’ perceive values, value measurements, value creation, and value generation in
OSM. The study is expected to shed more light on value—especially the value that drives stakeholders’ decisions in the selection between OSM and traditional method of construction.

2.10.1 Value

The concept of value has a rich history in various disciplines, especially in the marketing industry and the notable disciplines of psychology, philosophy and economics (Oliver, 1999). Value, as a concept, has various definitions in different industries. Indeed, there is no single definition for the concept of value due to the perceptions of stakeholders and industries. In economics, a value is defined as the utility of an item (Best and De Valence, 2002), while Price (1993) defined value as ‘the amount of desirability obtained from a product consumed’. In general, value is measured through a comparison with other assets of similar use, cost and attractiveness (Best and De Valence, 2002). In the field of strategic management, value is defined as the amount clients are willing to pay for the service rendered by a company (Porter, 1985). Value is also defined as the ‘properties of products or services that prove the utility’ (Ramirez, 1999).

In the construction industry, value is defined as something beyond the set of properties of a building; rather, it is the driving force for stakeholders’ decision making, and the end of all construction projects (Emmitt et al., 2005; Keeney and McDaniels, 1999). Additionally, value plays a crucial role in construction project delivery. From the two studies by Committee (2001) and Barima (2010), it was apparent that the focus was on lowering the construction costs, rather than the value in the project delivery. Indeed, this was one of the reasons for the poor project delivery of construction products. For this reason, the construction industry must focus more on value delivery.

2.10.2 Why value?

In the construction industry, the concept of value occupies a crucial role in construction project delivery; thus, it is the focus of stakeholders (Barima, 2010; Jahani and El-Gohary, 2012). The importance of value delivery in construction projects was emphasised by Koskela (1992), and has been the major driver for many stakeholders. As the concept of value continues to gain more attention in the construction domain, it is important to understand the value required by stakeholders.

OSM is a branch of construction methods that must deliver value to the stakeholders involved. It is significant due to the clamour for value delivery and the low uptake of OSM in Australia.
Blismas et al. (2006) stated that stakeholders failed to perceive the benefits of OSM due to employing a cost evaluation method, rather than value-based evaluation. This further buttresses the need to capture the values required by stakeholders in OSM. In addition, discovering and analysing stakeholders’ perceived values are conditions for value decision making guidance in built infrastructure (NIBS, 2012). However, understanding the need to capture the stakeholders’ perceived values is insufficient without understanding the indicators or metrics for quantifying this value.

Due to the complexity of the concept of value, it is difficult to ascertain suitable value metrics for OSM projects. There are different types of value metrics used to quantify the value required by stakeholders. However, sustainable value is the most suitable for quantifying the value perceived by stakeholders due to the increasing demand for sustainability in the built environment (Zhang and El-Gohary, 2015). Furthermore, the components of sustainable value, which are environment, economic and social value covers values that are required throughout the whole life and the post occupancy of the building (Zhang and El-Gohary, 2015).

### 2.10.3 Value metrics

Value metrics are a set of parameters used to determine the level of value in a particular project. However, the broad knowledge of value has made it difficult to have specific value metrics for construction projects. Metrics are determined by the construction product, construction process, and sustainability modality (Cuperus and Napolitano, 2005; Jahani and El-Gohary, 2012). The construction product value is a combination of the utility value and market value (Wandahl and Bejder, 2003). The parameters for the product value are usability, flexibility, quality and market demand. Process value is the value associated with managing the construction project; it is the value created during the development of a project (Cuperus and Napolitano, 2005).
### Table 2-7: Value classification

<table>
<thead>
<tr>
<th>Value</th>
<th>Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product value</strong></td>
<td>• Usability: Building function and how users’ needs are fulfilled</td>
</tr>
<tr>
<td></td>
<td>• Flexibility: Building adaptability to change</td>
</tr>
<tr>
<td></td>
<td>• Quality: Building standard and quality</td>
</tr>
<tr>
<td></td>
<td>• Market demand: Users’ or mortgagees’ demand of the building</td>
</tr>
<tr>
<td><strong>Process value</strong></td>
<td>• Customer satisfaction: The satisfaction stakeholders derive during the development stage of building</td>
</tr>
<tr>
<td></td>
<td>• Profitability: Return on capital investment</td>
</tr>
<tr>
<td><strong>Sustainable value</strong></td>
<td>• Time: Faster erection of buildings</td>
</tr>
<tr>
<td></td>
<td>• Cost: Lower cost of erecting buildings</td>
</tr>
<tr>
<td></td>
<td>• Quality: Higher quality building</td>
</tr>
<tr>
<td></td>
<td>• Safety: Safer construction site</td>
</tr>
<tr>
<td></td>
<td>• Life cycle cost: Lower construction cost</td>
</tr>
<tr>
<td></td>
<td>• Return of investment: Higher percentage of return due to faster erection</td>
</tr>
<tr>
<td></td>
<td>• Energy consumption: Higher energy efficiency rating</td>
</tr>
<tr>
<td></td>
<td>• Embodied energy: Lower energy consumed in building production</td>
</tr>
<tr>
<td></td>
<td>• Waste generation: Reduced onsite material wastage</td>
</tr>
<tr>
<td></td>
<td>• Carbon footprint: Less carbon dioxide released into the atmosphere</td>
</tr>
</tbody>
</table>

Of the three value classifications mentioned above, the sustainable value metrics are adopted for this research, as there is an increase in demand for sustainability in the built environment (Jahani and El-Gohary, 2012). In addition, sustainability value provides a more robust metric capable of meeting stakeholders’ expectations than do the process and product value metrics. This is because process and product value metrics shown in Table 2-7 focus on the value in the process of developing a construction project and the value a building possess after its completion. Whereas, the sustainable value cut across the entire life of the building, environment and the post occupancy value of the building.

### 2.11 Stakeholders’ perceived values

Perceived values are stakeholders’ overall assessment of the utility of a product or service; they encompass stakeholders’ perception of what is received against what is given (Cengiz and Kirkbir, 2007). In OSM, stakeholders’ perceived value is the value that stakeholders expect from OSM. Stakeholders have different perceived values that drive their decisions regarding the adoption of OSM. Previous studies have analysed stakeholders’ values in developed countries, as shown in Table 2-8.
2.11.1 Perceived value in decision making process

This section investigates stakeholders’ perceived values in the decision making process between OSM and the traditional method of construction. This section involves robust analysis of stakeholders’ perceived values when adopting OSM versus the traditional method of construction. Data collection occurred via a literature review. The results are analysed to select the stakeholders’ perceived values that will be used for the decision making tool.

2.12 Data collection and analysis: Literature review

This section provides an overview of the literature review’s data collection and analysis of the drivers and perceived values of adopting OSM over the traditional method of construction. It provides insight to the decision making process and stakeholders’ perceived values of the adoption of a particular construction method.

2.12.1 Extensive literature review

Approximately 70 pieces of literature were analysed to determine stakeholders’ perceived values in the decision making process. The literature encompassed various countries to compare similarities and differences in stakeholders’ perceived values. The literature was selected based on year of publication, relevance to the study and reputation of the publishers. The Taylor and Francis journals, *Construction Management and Economics, Automation in Construction, Construction Innovation, International Journal of Project management, International Journal of Information and Journal of Cleaner Production*.

2.13 Stakeholders’ perceived values through literature review

Stakeholders perceived values have been used interchangeably in different literature as KPIs or drivers for OSM. These drivers have been the source of stakeholders’ motivation in the selection of OSM. In addition, stakeholders’ perceived values enable comprehension of stakeholders’ impacts in decision making on the success or failure of the selected method of construction (Cable and Davis, 2004). To capture these motivators, a thorough literature analysis was required to help obtain robust data about stakeholders’ perceived values. This study adopted the literature review method because it enabled larger samples for data collection, has broad acceptance, and has been adopted in a large number research studies (Kostoff et al., 2006; Srinivasan, 2004; Weeber et al., 2001).
This study identified a total of 50 different stakeholders’ perceived values in the literature; however, only 11 stakeholder perceived values were considered for tool development due to the ambiguity that would arise from using a tool with a large number of different values. Further, Lavy et al. (2010) and Slater et al. (1997) stated that perceived values should not exceed 11 for decision making. The selected 11 stakeholder perceived values or drivers encompass three categories—functional, physical and financial—as recommended by Lavy et al. (2010). An objective behind adopting this concept was to ensure that the selected method of construction met the needs of the decision makers. Table 2-8 presents the stakeholders’ perceived values and their sources.
**Table 2-8: Sources of stakeholders perceived values**

<table>
<thead>
<tr>
<th>Stakeholders’ perceived values</th>
<th>Definition</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Time</td>
<td>Faster erection of buildings and time certainty</td>
<td>(Pan, 2006), (Blismas and Wakefield, 2009), (Mao et al., 2013), (CRC, 2007), (Burwood and Poul, 2005), (Davies, 2005), (Zhengdao et al., 2014), (Zhang and El-Gohary, 2015), (Lavy et al., 2014), (Lavy et al., 2010)</td>
</tr>
<tr>
<td>2. Cost</td>
<td>Lower cost of erecting the buildings and cost certainty</td>
<td></td>
</tr>
<tr>
<td>3. Quality</td>
<td>Higher quality buildings and durability</td>
<td></td>
</tr>
<tr>
<td>4. Safety</td>
<td>Safer construction site operations</td>
<td>(Blismas and Wakefield, 2009), (CRC, 2007), (Hampson and Brandon, 2004), (Zhang and El-Gohary, 2015)</td>
</tr>
<tr>
<td>5. Lifecycle cost</td>
<td>Lower cost over the buildings’ operational life</td>
<td></td>
</tr>
<tr>
<td>6. Return of investment</td>
<td>Higher percentage due to faster erection</td>
<td></td>
</tr>
<tr>
<td>7. Energy consumption</td>
<td>Higher energy efficiency rating</td>
<td>(Tam et al., 2007), (Rahman, 2013), (House, 2009), (Zhengdao et al., 2014), (Zhang and El-Gohary, 2015), (Barrett and Wiedmann, 2007)</td>
</tr>
<tr>
<td>8. Embodied energy</td>
<td>Lower energy consumed in building production</td>
<td></td>
</tr>
<tr>
<td>9. Waste generation</td>
<td>Reduced on site material wastage, hazardous waste and generated waste for disposal</td>
<td></td>
</tr>
<tr>
<td>10. Carbon footprint</td>
<td>Less carbon dioxide released into the atmosphere</td>
<td></td>
</tr>
<tr>
<td>11. Sick building syndrome</td>
<td>Lower chronic health risk to building occupants</td>
<td>(Lyles et al., 1991), (Seidner, 1999), (Lavy et al., 2010)</td>
</tr>
</tbody>
</table>
2.13.1 Analysis of selected stakeholder perceived values through literature review

Decision making for the selection between OSM and traditional method should be based on stakeholders’ perceived values due to importance of value and stakeholders involvement in construction project delivery (Barima, 2010). The stakeholders’ perceived values were selected via the literature review based on quantities of literature that reported the value and their influences in the decision making process. Some previous studies, such as Pan (2006) adopted questionnaires, interviews and case studies to capture stockholders’ perceived values, while other studies adopted literature reviews to select perceived values (Lavy et al., 2010; Weeber et al., 2001).

In the current study, of 75 research papers reviewed, 60 reported time as a stakeholder perceived value. Time certainty and speedier erection are major concerns for stakeholders due to their effect on a construction project—timing is the greatest challenge in project development. In addition, 55 papers cited that cost certainty and affordability contribute to stakeholders’ perceived values. The majority of stakeholders favour a construction method that is both affordable and has a cost guarantee. An over-budgeted project is a problem in building construction—numerous construction projects exceed their budget, which leads to client dissatisfaction.

Approximately 49 of the research papers stated that quality is part of stakeholders’ perceived values. Building with high quality is a stakeholder need that relates to the durability of a building and reduces the cost of rework. This is one of the major constraints highlighted by Blismas and Wakefield (2009). Thirty-five of the research publications stated that safety also contributes to stakeholders’ perceived values in the decision making process; the safety of the end users and developers is stressed in the literature.

Twenty-eight of the research publications reported lifecycle cost as one of stakeholders’ perceived values. However, only limited stakeholders are aware of the benefits of considering lifecycle cost, rather than construction cost (Lavy et al., 2014; Blismas and Wakefield, 2009). Fourteen of the literatures stated that return of investment is a stakeholder perceived value. The developers, end users and manufacturers are concerned with the return rate of the selected project. Forty-two of the literatures agreed that energy consumption constitutes a stakeholder perceived value. The energy used by a building is important to end users due to the tariff cost of electricity.
Approximately 30 of the research publications stated that the embodied energy of a building is one of the factors that drive stakeholders during the decision making process. The energy used in the production of building components and construction is another factor when choosing between OSM and the traditional method of construction. Forty-nine of the research publications stated that waste generation is part of stakeholders’ perceived values. The cost and environmental effect of material wastage cannot be overemphasised. Approximately 20 of the literatures reported carbon footprint as a stakeholder perceived value. Carbon footprint is the amount of carbon dioxide emitted by a building.

Further, seven of the literatures stated that sick building syndrome is a factor that stakeholders consider when choosing between OSM and the traditional method of construction. Six of the research publications classified market demand as a stakeholder perceived value, while 21 research publications reported planning issues as a factor that drives stakeholders’ motivation. Figure 2-10 illustrates the percentages of papers that cited different stakeholder perceived values.

![Figure 2-10: Literature review analysis of stakeholder perceived values](image)

Based on the review of the literature, it can be inferred that time, cost, quality, safety, lifecycle cost, energy consumption, embodied energy, waste generation, carbon footprint and planning issues are the most cited stakeholders’ perceived values. However, planning issues were not selected as part of the 11 stakeholders’ perceived values used for the development of this research tool because this factor is not part of the sustainable value criteria cited in Zhengdao et al. (2014). Also, it is difficult to classify planning issues as value due to limited studies that classify it as a value metric.
2.14 Cost through literature review

Cost is financial indicators that indicate the whole lifecycle cost associated with a building. These cost indicators enable financial appraisal of buildings, which is necessary for the decision making process (Lavy et al., 2010). Cost provides a holistic financial measurement for stakeholders; however, there is limited research on OSM that focuses on cost indicators as drivers for adopting OSM, rather than the traditional method of construction. This study identified approximately 12 cost indicators through the critical literature review, yet only five were chosen due to the simplicity of the developed model. Table 2-9 presents the selected cost indicators and their sources.

<table>
<thead>
<tr>
<th>Cost</th>
<th>Definition</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Maintenance cost</td>
<td>The cost associated with the cleaning and facilities management of the building</td>
<td>(Lavy et al., 2010), (Lavy et al., 2014), (Pan, 2006)</td>
</tr>
<tr>
<td>2. Operating cost</td>
<td>The cost of running the building, such as electricity or renewable energy</td>
<td></td>
</tr>
<tr>
<td>3. Rework cost</td>
<td>The cost associated with building renovation and repair of damages</td>
<td></td>
</tr>
<tr>
<td>4. Transportation cost</td>
<td>The cost of transporting building components and materials to the site</td>
<td>(Blismas and Wakefield, 2009), (CRC, 2007), (Pan, 2006)</td>
</tr>
<tr>
<td>5. Construction cost</td>
<td>The total cost of constructing a building</td>
<td></td>
</tr>
</tbody>
</table>

2.14.1 Analysis of the costs for decision making through literature review

Misconceptions about the cost implications of building development have been a great challenge for stakeholders. Lavy et al. (2010) stated that for proper evaluation of a building for decision making, it important to consider the life cost implication. This study considers five costs for decision modelling: maintenance, operating, reworks, transportation and construction costs. Approximately 30 research publications were reviewed to determine the cost implications of building developments. Twelve of the research publications revealed that maintenance cost should be included in the total cost of constructing a building. Ten of the literatures highlighted operating cost as part of the cost for decision making and performance measurement. Five of the literatures cited rework cost as a factor that stakeholders must consider during decision making. Eight of them cited transportation cost as a factor in the
decision making process of selecting OSM. This cost is classified as a constraint due to its effect on the total construction cost. Twenty-seven of them stated that construction cost is the core stakeholders’ perceived value. This refers to the cost of erecting the building, as well as the administration cost. Figure 2-11 illustrates the percentage of research publications that cited different types of costs for decision making and performance measurement.

![Figure 2-11: Cost for decision making](image)

In conclusion, construction, maintenance and operating costs were the most cited costs in the literature. Rework and transport costs were the least cited, yet they are included in the lifecycle cost of a building. As such, they are included in this study’s tool development to obtain a robust decision making output.

**2.15 Discovering stakeholders’ perceived values**

Understanding stakeholders’ perceived values in OSM without also developing an appropriate measuring technique does not enhance value creation or decision guidance during the development of OSM. Value measurement is required to conceptualise the perceived values of OSM. The benefits of value measurement involve capturing stakeholders’ perceived values and the relationship between them, which then serve as guidance for the OSM industry in its endeavours to meet stakeholders’ needs. Value measurement methods can be classified into two types: one-dimensional and multidimensional views (Ruiz et al., 2008; Cengiz and Kırkbir, 2007).
One-dimensional value measurement assesses stakeholders’ perceived values as a single overall concept that can be measured with a set of items that evaluate stakeholders’ perceptions of value (Sánchez-Fernández and Iniesta-Bonillo, 2007). The tool measures the stakeholder’s perceived value as a trade-off between perceived quality and sacrifice, or cost and benefit (Dodds et al., 1991). The multidimensional approach of value measurement measures stakeholders’ values as interrelated components or dimensions (Cengiz and Kirkbir, 2007). The measuring technique goes beyond the one-dimensional approach of considering the trade-off between the perceived quality and sacrifice; rather, it measures the total episode value of the customer. Examples of the multidimensional approach include the Customer Value Hierarchy, Customer Value Typology, Analytic Hierarchy Process (AHP) and Analytic Network Process (ANO) (Leroi-Werelds and Streukens, 2011). The types of value measurements are suitable for capturing stakeholders’ perceived values; however, there are benefits and disadvantages of using one method over another.

The advantage of the one-dimensional view is the simplicity and ease of its implementation (Lin et al., 2005). However, stakeholders’ perceived values are numerous; thus, a one-dimensional value measurement is ineffective in measuring multiple stakeholder perceived values (Ruiz et al., 2008). The multidimensional view can measure stakeholders’ perceived values across several dimensions, which enables an organisation to understand the monetary and non-monetary perceived values. Hence, this approach is more robust and efficient for capturing stakeholder values. This quality makes the multidimensional value measurement a suitable method for measuring stakeholders’ perceived values.

2.16 Types of multidimensional value measurement

The Customer Value Hierarchy, Customer Value Typology, AHP and ANP illustrate in Table 2-10 are the types of value measurement techniques used to capture stakeholder perceived values. These methods use different systems to measure stakeholder perceived values, as discussed below.

2.16.1 Customer value hierarchy

Customer value hierarchy is a multidimensional value measurement that measures customers’ perceived value as an objective layer, a consequence layer and an attribute layer (Yajing et al., 2007). This system ranks and maps a stakeholder’s perceived value to understand the relationship between the objective, consequence and attribute layers. The method provides a
way to identify stakeholders’ demands based on their purchase attributes. Woodruff and Gardial (1996) stated that customer value hierarchy does not measure the stakeholders’ value relative to the competition. Rather, it measures a trade-off between the positive and negative consequences of a product as a perceived value by the stakeholder (Cengiz and Kirkbir, 2007). Customer value hierarchy can identify potential customers’ demand for a product or service with a high level of accuracy. The system requires a large number of questionnaires and interviews to capture stakeholders’ perceived values.

2.16.2 Customer value typology

Customer value typology is another multidimensional value measurement used to capture stakeholders’ perceived values. It achieves this outcome using three dimensions:

- extrinsic value versus intrinsic value
- self-oriented value versus other-oriented values
- active value versus reactive value (Cengiz and Kirkbir, 2007).

Using these three dimensions, Holbrook (1999) developed a matrix representing eight types of stakeholder value: excellence, efficiency, status, esteem, play, aesthetic, ethics and spirituality. The matrix incorporates the coexistence of different types of customer value. For example, customer value typology treats customers’ perceived value as a cost-free benefit, which means that only the benefit side (and not the sacrifice side) is included in the method.

2.16.3 AHP

The AHP method of value measurement was introduced by Saaty (1990) as an excellent multi-criteria decision making tool. It measures stakeholders’ perceived value in a hierarchy, with criteria, sub-criteria, and alternatives (Syamsuddin and Hwang, 2009). The structure is translated into different questions in a general form. The input variables to the AHP model are the decision makers to pairwise comparisons. The advantage of the AHP is its simplicity in capturing stakeholders’ perceived values against other methods of value measurement. It also enables qualitative and quantitative assessments in the same decision making methodology (Syamsuddin and Hwang, 2009). Further, it is useful in accommodating conflictual, multidimensional and incomparable objectives (Mendoza and Prabhu, 2009). The four stages or steps of value measurement of the AHP are as follows:
1. break down the problem into a hierarchy of interrelated components
2. obtain information about the importance of each element to a higher level element in the hierarchy
3. synthesise the value judgements in Stage 2 above for each element in the hierarchy, as described in Stage 1
4. estimate the relative importance of the elements’ values, representing preferences for each element in the hierarchy.

### 2.16.4 ANP

ANP is a branch of value-focused thinking that serves as a basis for evaluating stakeholders’ preferences. Therefore, it is critical that it reflects the values of stakeholders. ANP contains four steps for measuring stakeholders’ perceived value: (1) identification of stakeholders, (2) identification and structuring of objectives or values, (3) identifying measures or attributes of objectives for evaluation and (4) valuation.

The benefits of ANP are the identification of stakeholders’ objectives or values, as well as alternatives for achieving stakeholders’ perceived values. It also assists in identifying and structuring the appropriate value for decision making (Keeney and McDaniel, 1999). ANP is the advanced version of AHP; the difference between the two methods is that ANP measures ways to achieve the captured value and allow feedback, while AHP does not.

<table>
<thead>
<tr>
<th>Factors for effective value measurement</th>
<th>Customer value hierarchy</th>
<th>Customer value typology</th>
<th>AHP</th>
<th>ANP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measures entire stakeholders’ perceived values</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Assists in decision guidance</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Captures ways to achieve the perceived values</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Networking of the perceived values and ways to achieve them</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

Table 2-10: Types of value measurement
2.17 Value-based decision making process

The value-based decision making concept is the driving mechanism for choosing between OSM and the traditional method of construction. It was supported by Blismas et al. (2006), who stated that adopting OSM over the traditional method of construction should be based on value, rather than cost. This indicates the significance of using value as a yardstick when selecting one method over another. However, understanding the importance of value is insufficient without suitable knowledge of the decision making, as decision making enables the use of perceived values in judgement processes when choosing between OSM and the traditional method.

Turban et al. (2005) defined decision making as a pure art and talent that base its style on creativity, intuition and judgement. The decision making process is a two-phase process of judgement, moving from a highly structured to an unstructured process. A structured process is a constant problem with a standard solution, while unstructured processes are a complex and fuzzy problem for which standard solutions do not exist. Contextually, the decision making process is required to tackle complex and simple problems. It plays a larger role when stakeholders are faced with issues of selecting between alternatives. In regard to the problem of adopting OSM over the traditional method of construction, decision making process guidance is needed for stakeholders to select the construction method with the greatest value.

There are two types of decision criteria categorised in the literature when addressing decision problems: (1) one-dimensional criteria, which are used for dealing with a simple problem, and (2) multidimensional criteria, which are used for a complex problem (Sánchez-Fernández and Iniesta-Bonillo, 2007; Cengiz and Kirkbir, 2007). The latter approach covers the complete process from the decision context to sensitivity analysis. Moreover, it is a structured criterion with large numbers of decision criteria. Therefore, a multidimensional criterion is used in this study’s decision making process tool.

2.18 Decision making variables

During decision making, some variables are connected as shown in Figure 2-12 to generate the decision outcome. First, stakeholders are one of the decision making variables. They are responsible for the decision making. Second, a decision problem is a variable in the decision making process that is the basis of the decision problem. Finally, the
decision parameters or attributes are part of the decision variables. According to Turban et al. (2005), there are five decision making variables: decision makers, decision criteria, decision outcome, decision problem and decision context.

Wider knowledge of the relationship between the decision variables would enhance understandings of the decision making process. The variables constitute the stakeholders’ decision during the selection process. Further, they reveal the dynamics in the function of a decision making tool. In regard to this research, they help during the sensitivity analysis of the criteria.

![Decision making variables](image)

**Figure 2-12: Decision making variables**

### 2.19 Significance of decision making in construction method selection

Numerous studies have emphasised the importance of early decision making to determine the perceived values of a selected construction method. Pan (2006) and Saaty (1990) explained that the significance of decision making is the ability to choose a method based on stakeholders’ criteria. While there are numerous publications on the benefits of OSM over traditional construction, and vice versa, they have failed to capture stakeholders’ perceived values in decision making during the selection of construction method.
In addition, construction projects entail risk. Thus, it is paramount for stakeholders to make a decision before choosing a construction method. This call for a decision making tool that is capable of guiding stakeholders to select the construction method with the least risk and greater values. Some reports indicate that a lack of appropriate knowledge about the decision making process leads to greater project risk. Choosing a suitable decision tool would enable stakeholders to select projects with the greatest value and least risk.

2.20 Research gaps

The adoption of OSM in Australia is still low compared to other developed countries, such as the UK. The reasons for this low level are due to the inability of stakeholders to perceive the benefits of OSM. Previous research has highlighted the drivers and constraints of OSM, and the future of OSM in Australia (Blismas and Wakefield, 2009). While this research has contributed to the knowledge of OSM, it does not capture the constraints and drivers from the stakeholders’ perspectives. However, classifying the barriers and constraints in accordance with stakeholders’ views is important because it will reveal the needs of different stakeholders. Further, the data will help serve as a reference for the OSM industry when tackling the constraints to the adoption of OSM.

A large number of studies, such as that by Rahman (2013) have revealed that OSM has achieved improved sustainability and waste reduction, yet little Australian academic research has provided evidence of such claims. As drivers of OSM, sustainability and waste reduction will provide evidence, based on the current research, to aid the adoption of OSM. Even fewer research studies have measured the perspectives of end users and financial institutions regarding OSM in Australia. These areas need greater exploration because of their influence on the adoption of OSM. Specifically, end users influence the market share through their demand for OSM, while financial institutions affect the financing of OSM through mortgages and loans to manufacture the product.

As value is a driver for stakeholders’ decisions regarding the selection of a construction method, it is imperative that the current study focus on how to measure and enhance value creation in OSM. However, there is also a need to research a suitable method to capture value in OSM. Previous research studies have tended to use value engineering, value-based management and total quality management to manage and measure value in construction;
however, these methods only use function, cost and quality as yardstick for measuring value in a project.

Finally, limited studies have designed a decision making model for choosing between OSM and the traditional method of construction. Large numbers of studies have focused on the decision making process through the use of decision matrix and ranking method. However, there is need to design a mathematical model with decision making tool that can enable stakeholders to choose between OSM and the traditional method of construction, based on perceived values. Further, stakeholders’ perceived values change with time; thus, developing decision making tool would enable flexibility in the input of stakeholders’ perceived values.

2.21 Research questions

Based on the research rationale, two research questions were developed. In the context of OSM in Australia, there is a need to answer the following research questions in order to achieve the research aims and objectives. These questions were developed based on the critical analysis of the previous research.

RQ 1: What are stakeholders’ perceived values of OSM compared to the traditional method of construction in Australia, and how can these values be captured?

Developing decision guidance to capture stakeholders’ perceived values entails selecting key stakeholders that influence the adoption of OSM in Australia, as well as an appropriate value-measuring technique. Limited research has focused on value capturing as a medium to increase the uptake of OSM; thus, identifying stakeholders and a relevant value-measuring method serves as a solid platform for this research.

RQ 2: How can a decision making tool be developed to assist construction stakeholders to choose between OSM and the traditional method of construction?

Decision making guidance is one of the strategies that can help the OSM industry develop OSM buildings based on stakeholders’ needs. It involves capturing stakeholders’ perceived needs and determining ways to meet these needs. There are procedures for developing this decision making tool through the use of analytic network process (ANP) software. This software will be adopted to show the connections between stakeholders’ values and ways to achieve these values, which will serve as guidance for the OSM industry.
2.22 Justification for selecting ANP

Selecting an appropriate method to measure stakeholders’ values to enhance value creation in OSM in Australia involves comparing and contrasting multidimensional value measurement techniques. The multidimensional method was chosen for the current study due to its ability to measure stakeholders’ perceived values in multiple dimensions, as opposed to the one-dimensional technique that only considers the value measurement as one entity (Cengiz and Kirkbir, 2007). ANP, Customer Value Hierarchy, Customer Value Typology and AHP measure stakeholders’ perceived values and then rank them based on the importance ascribed to them by stakeholders. The methods aim to improve the market share of the product, assist in the decision making process, and deliver customer perceived value. In the application for OSM, the methods are capable of identifying stakeholders’ perceived values, which would help the OSM industry deliver stakeholders’ needs.

There are differences in the system of measuring stakeholders’ perceived values in ANP, Customer Value Hierarchy, Customer Value Typology and AHP. Customer Value Hierarchy identifies customers’ demands based on their purchase attributes, and measures value as a trade-off between the positive and negative consequences of the product use, as perceived value by the stakeholders. The Customer Value Typology measures customers’ perceived values based on three dimensions: extrinsic value versus intrinsic value, self-oriented value versus other-oriented value, and active value versus reactive value. AHP measures stakeholders’ perceived values through a hierarchy of criteria, sub-criteria, and alternatives, while ANP is a multi-criteria analysis for capturing stakeholders’ perceived values; hence, it reflects the values of stakeholders.

As a multidimensional value measurement, ANP is more suitable for measuring stakeholders’ perceived values than the other techniques, for the following reasons. First, the system adopted by the Customer Value Hierarchy and Customer Value Typology to measure stakeholders’ perceived value is unsuitable to measure stakeholder perceived value in OSM because it is difficult to classify OSM stakeholders’ perceived values within extrinsic, intrinsic, objective, consequence and attribute categories. The two methods of value measurement mostly target customers in the market, rather than all the stakeholders in the supply chain. Meanwhile, AHP measures stakeholders’ perceived value in a hierarchal manner, with goals, sub-goals, factors and alternatives. Its technique of measuring stakeholders’ perceived values is similar to ANP,
yet does not involve pairwise comparison or the means of achieving the stakeholders’ perceived value.

Second, ANP involves identification of stakeholders, capturing stakeholders’ perceived values, and identifying the attributes and relationships between the attributes and values, which other methods fail to consider in their value measurement process. Thus, ANP enables the OSM industry to see the relationship between stakeholders’ perceived values and the influence of one stakeholder’s perceived value over another. These two benefits prompted the adoption of ANP, instead of another multidimensional value measurement, for the current study.

Third, ANP has been used in various industries to measure the influence of a project, and identify and structure values to guide integrated resource planning. For example, it was used to evaluate multi-stakeholder perceptions in the forest industry to improve project effectiveness (Mendoza and Prabhu, 2009). Its adoption for the evaluation was due to its suitability for multi-stakeholder impact assessments, as well as the direct participation of stakeholders in the impact assessment process. The process can capture values, stakeholders’ perceptions, and the procedure to estimate the measure of the relative importance of the stakeholders’ values. The results of the assessment helped the forest industry evaluate its performance against the stakeholders’ expectations.

Additionally, British Columbia Gas employed ANP to develop an integrated resource plan. The plan addressed multiple objectives and the participation of the stakeholders (Keeney and McDaniels, 1999). This assessment was undertaken by capturing value trade-offs from each stakeholder. Through answering the value trade-off questions, stakeholders gave their perspective about the relative value they associated with reduced environmental effects, improved reliability, and improved social-economic benefits. The result was used to evaluate integrated resources plan alternatives values.

Further, application of ANP in the industries mentioned above proved the suitability of the method for capturing stakeholder perceived values. The results obtained through the use of ANP helped the industries capture stakeholders’ perceived values, as well as the relative importance of the values, and assisted the decision making process. Other value-measuring techniques appear not to emphasise the significance of stakeholder involvement in the value-measuring process.
Considering the barriers to OSM in Australia, and the research undertaken to improve OSM’s wider uptake, it can be inferred that there is a need to focus on alternative methods that are capable of delivering value to stakeholders. This approach is important, as the previous research on OSM ignored stakeholder involvement in decision making during the manufacturing process. However, the proffered solutions are incapable of mitigating low OSM adoption. Moreover, ANP was chosen as a suitable technique due to its successfulness in capturing stakeholders’ perceived values in both the forest industry and British Columbia Gas. The analysis helped during the environmental impact assessment, development of an integrated plan that addressed multiple values, and involvement of stakeholders.

Moreover, ANP is the adequate method suitable to assist in answering the RQ2. Generally, ANP is a decision making tool that has been applied successfully in other industries as explained above. Pertaining to this study, the RQ2 was based on decision making tool to assists stakeholders to choose between OSM and traditional method of construction. This question can be answered through the adoption of capable decision making method in designing the tool. Considering customer value hierarchy, customer value typology and AHP against ANP, it can be infer that ANP is the suitable method. The method’s mechanism is the network of the criteria and sub-criteria in reaching a decision during the selection of an option among various options. In application to this study, ANP consider the stakeholders’ perceived values and their sub criteria based on benefits to cost and ignore the risks and opportunities in the selection between OSM and traditional method of construction. Other value capturing methods such as customer value hierarchy, customer value typology and AHP based their working principles on extrinsic, intrinsic value and perceived values without the internetworking of those criteria and sub criteria. These principles are incapable of answering the RQ2 because a robust decision tool cannot be developed based on those principles.

2.23 Chapter Summary

This chapter provided an extensive review of literature pertaining to OSM, traditional method of construction, stakeholders’ perceived values and decision making process. Various definitions of OSM and traditional method of construction were first reviewed to clarify the differences between the two methods of construction. This chapter further identified OSM classification, developmental phases and application of OSM in relation to building construction. The advantages and disadvantages of OSM were summarised in this chapter.
Furthermore, the current state of art of OSM in the developed countries such as US, UK, New Zealand and Australia were established. It identified the drivers and constraints in the adoption of OSM. The drivers and constraints were not value driven, which makes some studies to recommend value capturing as an efficient method to increase the uptake of OSM. This recommendation led to the review of the value capturing process.

Understanding the stakeholders’ management is the first step reviewed in the value capturing process. The chapter presents the importance of stakeholders’ management, identification of stakeholders and needs to measure the stakeholders’ perceived values. Literature review is the secondary data used to gather the stakeholders’ perceived values in this study. Moreover, the cost of the whole life of the construction methods was also addressed.

After the gathering of stakeholders’ perceived values and cost, the next step was the selection of a value measuring method for comparing the value between OSM and traditional method of construction. Previous studies have adopted different approach to capture stakeholders’ values in making the decision to choose between OSM and traditional method of construction. However, this chapter have compare and contrast different types of value measurement to select a suitable method for this study. ANP approach was selected for measuring the stakeholders’ perceived values and its justification was presented.

Lastly, this chapter addressed value based decision process and decision making variables. The next chapter will focus on research methodology and steps to achieve the research aim and objectives.
This chapter provides an overview of the research design and research approach adopted in the current study. The methodology was chosen based on the research aim, objectives and questions. Methodology selection is a critical point in the research process because an inappropriate research methodology could alter the research output. The researcher needs to follow certain steps to accomplish the research aims and objectives via the methodological approach. Fellows and Liu (2009) posited that a researcher must consider the type of research, research approach, empirical design, data collection and data analysis to accomplish the research aims and objectives.

3.1 Research Philosophy

Believe and assumption and research philosophy are two research concepts. The principles behind these concepts should be one of the criteria in the selection of a research method and approach. Believes and assumption according to Saunders (2011) is the research presumption about research topics. Research philosophy is an aspect of research that deals with source, and knowledge of research (Saunders, 2011). They can be categorised into three types: (1) ontology, (2) epistemology and (3) axiology.

3.1.1 Ontology

Ontology is the aspect of research philosophy that deals with reality (Saunders, 2011). It explains the reality of research problems and how researchers view these problems. The ontology concept is needed during the research design selection phase because it helps the researcher understand the reality of the particular research topic and problems.

In this study, ontology plays a role in determining the reality behind OSM research in Australia and other developed countries. It sheds light on the significance of understanding the present
state of OSM as part of the significant factors for selecting the research design. Further, its application enables the researcher to have a different perspective on a viable approach to increase the uptake of OSM.

### 3.1.2 Epistemology

Epistemology focuses on knowledge about assumptions, what constitutes adequate knowledge and how knowledge is conveyed to people (Saunders, 2011). It further explains what constitutes good-quality data, and the kinds of knowledge the research will contribute to existing knowledge. It is imperative to understand the effect of the selected epistemology assumptions on the research findings. In application to this study, epistemology helps understand the factors that constitute good data and their implications for the research outcomes.

### 3.1.3 Axiology

Axiology is a branch of research philosophy that refers to the role of ethics and values in the research process (Saunders, 2011; Creswell, 2009). It relates to the aim of the research and values. Value plays a significant role in interpreting the results, with the researcher adopting both objective and subjective points of view.

The concepts of ontology and axiology were adopted for this study. Ontology was used to understand the reality and current state of OSM and the traditional method of construction in Australia. Further, they are adopted to determine the different types of decision making process and tool. Axiology helps understand the role of the researcher and the value of this study.

### 3.2 Research design

A research design shown in Figure 3-1 is a methodological approach to provide a solution to the research problems. It is the way researchers achieve their research aims and objectives (Fellows and Liu, 2009). There is a relationship between the research design and research approach. The research approach explains the type of research design method required to answer the research question.

In the induction approach, the qualitative research design helps answer the research question, while, in the deduction and abduction approached, the quantitative and mixed approaches, respectively, are the methods that provide solutions to the research problems. Hence, it is
important that the researcher understand the research approach before selecting the research design.

ANP was selected as the most suitable research approach for the current study because it entails a system and an approach that would help answer the research questions. This research involved six steps in evaluating the research design, as follows.

**Step 1:** Identifying stakeholders. The identification of stakeholders was a critical step due to stakeholders’ influence on the selection of a construction method. A literature review and industry consultation helped identify the significant construction stakeholders.

**Step 2:** Identifying stakeholders’ perceived values and objectives. This step captured the stakeholders’ perceived values. It helped answer Research Question 1: what are stakeholders’ perceived values and how can they be captured?

**Step 3:** Selection of a value-measuring technique for the development of the decision making tool. ANP was adopted for the tool development.

**Step 4:** Developing the decision making tool through the VBA program and ANP principle. This step assists the stakeholders in choosing between OSM and traditional method of construction based on value. It assist in answering the Research Question 2: How can a decision making tool be developed to assist construction stakeholders to choose between OSM and the traditional method of construction?

**Step 5:** Validation of the decision making tool.

**Step 6:** Conclusions and suggestions for future research.
Critical literature review

Comparison of OSM and traditional method of construction

Identification of stakeholders and their perceived values

Selection of 11 stakeholders’ perceived values

Types of multidimensional value-measuring techniques

Selection of ANP

Development of a decision making tool

Decision making tool based on benefit–cost ratio

Tool validation

Validation result

Conclusion and future research

Figure 3-1: Research design schematic diagram
3.3 Modelling technique

After capturing the stakeholders’ perceived values via the literature review, as well as professional consultation regarding choosing between OSM and the traditional method of construction, it is important to explain the model that can be used to select a suitable method based on stakeholders’ perceived values. This section focuses on the modelling system and the reasons for adopting analytical modelling.

A model is a detailed analysis of a system used to explain the working mechanism of the system. It is used to break down a complex problem into a simple problem, which makes the problem easier to solve.

3.4 Classification of models

There are four types of the decision making model, namely: gaming, analytical, simulation and operation exercise models (Bradley et al., 1977). Model classification explains the concept behind each model and justifies the selection of a model.

3.4.1 Gaming model

A gaming model is an interactive model with the capacity to simplify the representation of a real environment. This decision model allows a stakeholder or decision maker to make selections that affect the interests of other decision makers (Turocy and Von stengel, 2001). The major aim of a game model is to strengthen strategic decision making.

The idea of a gaming model is to provide a language code to formulate structure and analyse and understand the strategic problem in order to evaluate the effectiveness of alternatives. It is also used as a learning device for developing some inherited complexities in the decision making process. Moreover, it can be used to show the interaction between marketing strategies and finances during decision making.

3.4.2 Analytical model

The analytical model adopts a logical approach to tackling a complex problem by defragmenting the problem into units or sub-units (Saaty, 1990; Raji, 2013). This model is easy and cheap to develop. The major goal of the analytical model is to maximise or minimise an identified functional entity, subject to the constraint that reproduces conditions in the system.
Further, the analytical model structures criteria hierarchically based on their importance. It is part of the concept of an analytical model to structure criteria or sub-criteria in a hierarchy based on their importance to decision makers. This structuring demonstrates the dependence of criteria on each other.

### 3.4.3 Simulation model

The simulation model is a type of model similar to the gaming model, except that it omits stakeholders in the modelling process. This type of model is similar to the gaming model, yet different to the analytical model because of the non-inclusion of alternatives. The simulation model is used to assess the performance of alternatives identified by stakeholders.

In most cases, behaviours are described algorithmically in a system through developing the model in a computer simulation. Simulation models have an inference with a longer chain than the analytical modelling, which is the reason the current study adopted the analytical model.

### 3.4.4 Operational exercise model

The operational model conducts an experiment within the study environment, and interprets the experiment result. Operational exercise implementation requires an understanding of the problem, experiment execution and interpretation of the result (Raji, 2013).

The result of the completed operational exercise model is interpolated to other situations due to the limited number of observation. The core advantage of the operational exercise model is the absence of abstraction facilities’ direct interaction with the real problem (Raji, 2013).

### 3.5 Analytical model as a selected approach

Considering the concepts of the above different types of models and their application to the purpose of the research, it can be inferred that the analytical model is the most suitable method for this study. The arguments for selecting this model are as follows.

First, the gaming model is a decision making model that allows decisions selected by the individual to affect the interests of others, without providing alternatives. In application to the objectives of the research—to capture stakeholders’ perceived values and develop a decision model to choose between OSM and the traditional method of construction—the gaming method is incapable of meeting these objectives due to its inability to generate alternatives and links between the stakeholders’ perceived values.
Second, the operational exercise model focuses on conducting an experiment for decision modelling, which is beyond the scope of this research. Thus, applying the concept of this model would not fulfil the aims of this research. Moreover, the operational exercise model omits alternatives, which makes it unsuitable for this research.

Third, the simulation model fails to include stakeholders and alternatives in its modelling process, which makes it unsuitable for this study.

The analytical model is an appropriate method due to its ability to structure complex problems in a hierarchy and provide alternatives. In addition, the analytical model is a multi-criteria decision making concept, which can meet the aims of this research.

### 3.6 Data collection

The data collection process is a system used to obtain the appropriate data to test a hypothesis, achieve the research objectives and answer the research questions (Fellows and Liu, 2009). There are two types of data collection: primary and secondary data collection. These types are discussed below.

#### 3.6.1 Types of data collection

Primary data is information obtained first-hand by the researcher for the specific purpose of a research study. Examples of primary data are questionnaires, case studies, focus groups and interviews (Bougie and Sekaran, 2010). Secondary data are data obtained from second parties or sources that already exist. Examples are literature reviews, government publications and census data.

The data for the current study were collected through the use of secondary sources to capture the stakeholders’ perceived values. The source of data collection was a literature review. The reason behind the selection of literature review for the data collection has been explained in Section 2.12.

### 3.7 Sampling

Sampling is the selection of a certain percentage of respondents from the entire population. The information obtained from the sample will be used and generalised for the entire population; therefore, care must be taken during the sampling selection. Naoum (2012) advised that a researcher must ensure that the characteristics of the chosen sample are the same as the entire
population. In addition to the characteristics of the chosen sample, the research questions, aims, objectives and population must be considered when selecting the sample (Naoum, 2012; Fellows and Liu, 2009). Researchers seldom neglect sampling error during sample sizing because it is important to reveal any error or bias in the data obtained from the respondents. As posited Fellows and Liu (2009), it is paramount to consider bias in the information gathered from respondents.

There are two types of sampling: random sampling and non-random sampling. Random sampling involves selecting a sample at random from the sampling frame using a computer program or random number table (Saunders, 2011; Naoum, 2012). The procedure for random sampling involves numbering the cases in the sampling frame with unique numbers, and selecting cases using random numbers. Non-random sampling is a selected sampling technique that uses the interview approach. The sampling begins with chosen lists and addresses of specific respondents (Naoum, 2012). This process is different to random sampling because it involves selecting specified respondents.

For the current study, random sampling was adopted due to the nature of the research questions and research design. The sampling frames included developers, manufacturers, end users and design teams. Thus, the sample for this study was drawn from listed sampling frames.

3.8 Stakeholders perceived values attributes

Stakeholders’ perceived values are the needs of stakeholders when selecting a construction method. These perceived values were captured through the literature review. This was one of the major steps towards meeting the aims of this research. Without stakeholders’ perceived values, it would be difficult to select the optimal construction method. Only 11 stakeholders’ perceived value attributes were considered for the development of the decision tool in order to avoid complexity in the use of the tool. The 11 stakeholders’ perceived value attributes are listed in the table below.
Table 3-1: Stakeholders perceived values attributes

<table>
<thead>
<tr>
<th>Stakeholders perceived values attributes</th>
<th>Compared to traditional methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>Faster erection of buildings</td>
</tr>
<tr>
<td>Cost</td>
<td>Lower cost of erecting buildings</td>
</tr>
<tr>
<td>Quality</td>
<td>Higher quality buildings</td>
</tr>
<tr>
<td>Safety</td>
<td>Safer construction site operations</td>
</tr>
<tr>
<td>Lifecycle cost</td>
<td>Lower cost over the buildings’ operational life</td>
</tr>
<tr>
<td>Return of investment</td>
<td>Higher percentage due to faster erection</td>
</tr>
<tr>
<td>Energy consumption</td>
<td>Higher energy efficiency rating</td>
</tr>
<tr>
<td>Embodied energy</td>
<td>Lower energy consumed in building production</td>
</tr>
<tr>
<td>Waste generation</td>
<td>Reduced onsite material wastage</td>
</tr>
<tr>
<td>Carbon footprint</td>
<td>Less carbon dioxide released into the atmosphere</td>
</tr>
<tr>
<td>Sick building syndrome</td>
<td>Lower chronic health risk to building occupants</td>
</tr>
</tbody>
</table>

Of these 11 stakeholders ‘perceived values shown in Table 3-1, the stakeholders could only select a maximum of 6 stakeholders’ perceived values in order to ensure the simplicity of the model and ease of using the decision making tool.

Six stakeholders’ perceived values attributes were used due to the Lavy et al. (2014) and Slater et al. (1997) studies suggested that there should be no more than four to six facilities objectives. The selected perceived values were the data used in the decision making tool to generate an output for the decision making.

3.9 Pairwise comparisons and scale

To make trade-offs among the selected six stakeholders’ perceived values for choosing between OSM and the traditional method of construction, the pairwise comparison should be qualitative terms expressed in numerical format. The trade-offs are achieved through pairwise comparison, rather than assigning an arbitrary score out of stakeholders’ memory (Saaty, 2008). Pairwise comparison indicates the scale of the relative values of perceived values priorities. It is essential to derive priorities in the form of an eigenvector matrix of pairwise comparison due to the inevitable inconsistency in the comparison (Saaty, 1990; Saaty, 2008).

The relative weight of the stakeholders’ value attributes and their benefits are calculated through pairwise comparison as illustrated in Table 3-2. The values in the table is just an
example to show the pairwise comparison of time, cost and quality. This is the best method for these calculations because it shows the consistency ratio and random index of the judgement, unlike the rating method, which assigns value to attributes without comparing their importance to other attributes, and lacks the ability to demonstrate the consistency of the stakeholder judgements. However, before pairwise comparison, stakeholders require a standard fundamental scale for the judgemental process. This scale indicates the intensity of the selected perceived values over other perceived values. Thus, the priorities and relative weight of the selected perceived values can be derived.

Table 3-2: The fundamental scale of pairwise comparison

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Time</td>
<td>1/1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Cost</td>
<td></td>
<td>5/1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Quality</td>
<td></td>
<td></td>
<td>1/3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Waste generation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Carbon footprint</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Energy consumption</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.9.1 Pairwise comparison of the selected perceived values

As explained in ANP evaluation, after selecting the perceived values based on stakeholders’ preferences and needs, the next step is to pairwise compare them using the fundamental scale.

Table 3-3 below illustrates the judgement using the pairwise comparison scale.
Table 3-3: Example of pairwise comparison

<table>
<thead>
<tr>
<th>Intensity of importance</th>
<th>Definition</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
<td>Two activities contribute equally to the objective</td>
</tr>
<tr>
<td>2</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Moderate importance</td>
<td>Experience and judgement slightly favour one activity over another</td>
</tr>
<tr>
<td>4</td>
<td>Moderate plus</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Strong importance</td>
<td>Experience and judgement strongly favour one activity over another</td>
</tr>
<tr>
<td>6</td>
<td>Strong plus</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Very strong or demonstrated importance</td>
<td>An activity is favoured very strongly over another; its dominance demonstrated in practice</td>
</tr>
<tr>
<td>8</td>
<td>Very, very strong</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Extreme importance</td>
<td>The evidence favouring one activity over another is of the highest possible order of affirmation</td>
</tr>
</tbody>
</table>

The below tables are extracted from

Table 3-3. The pairwise comparison in the tables shows that time is more strongly important than cost, and time is equally important to time.
The purpose of the pairwise comparison is to show the relative weight of each selected perceived values. This is an efficient method for rating the importance of selected perceived values because it involves comparing one factor to another. A direct rating method would not show the relative weight of the perceived value based on their relation to other perceived values.

There is a need to determine the consistency of stakeholders’ judgement during the pairwise comparison. Using judgement does not guarantee the coherence of the comparison, which can affect the relative weight of the perceived values (Saaty, 2008). For example, if B > A and A > C, logically, this means that B > C; however, if C > B, this shows that the results are not consistent. Stakeholder knowledge is inadequate to correct this inconsistency, and, if it is not corrected, there will be difficulty in reaching a decision.

The consistency index (CI) is the degree of deviation or consistency in human judgement. The CI is calculated in this study to determine the level of consistency in stakeholders’ decisions. The formula for calculating CI is as follows:

\[
CI = \frac{\lambda - n}{n - 1}
\]

where \(\lambda\) = size of comparison matrix and \(n\) = number of selected stakeholders’ perceived values.

Saaty (1990) suggested comparing CI with the random index (RI) to obtain the consistency ratio. Table 3-4 below shows the random CI.

<table>
<thead>
<tr>
<th>Order (n)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td>0</td>
<td>0</td>
<td>0.52</td>
<td>0.89</td>
<td>1.11</td>
<td>1.25</td>
<td>1.35</td>
<td>1.40</td>
<td>1.45</td>
<td>1.49</td>
<td>1.52</td>
<td>1.54</td>
<td>1.56</td>
<td>1.58</td>
<td>1.59</td>
</tr>
</tbody>
</table>
To compare the CI with the RI, Saaty (2008) proposed using the consistency ratio (CR), which is the ratio of CI to RI. The formula for CR is as follows:

$$ CR = \frac{CI}{RI} $$

If the CR is less than or equal to 0.10, the inconsistency is acceptable. However, if it is greater than 0.10, there is need to revise the judgemental process in the pairwise comparison. There are three solutions recommended by Saaty (1990) and Saaty (2008), which were adopted in this study. The recommendations are as follows:

1. find the most inconsistent judgement in the pairwise comparison in the matrix
2. determine the range of the value, which the inconsistent judgement can be reduced to CR value that is less or equal to 0.1
3. render advice to the decision makers or stakeholders to change their judgement on the selected perceived values during the comparison.

### 3.10 Benefits, opportunities, costs and risks

ANP considers criteria and sub-criteria for effective decision making to enable stakeholders to consider sub-criteria in their decision making. According to Saaty (2008), decision making requires analysis of the decision according to:

- **benefits**—the advantages of making the decision
- **opportunities**—the future benefits of making the decision
- **costs**—the monetary and economic values that would result from making the decision
- **risks**—the potential pains that can result from the decision.

Benefits, opportunities, costs and risks (BOCR) are sub-criteria in the decision making model. It is part of decision making to consider the relative weight of these factors. Selecting a suitable method of construction is based on BOCR; however, there is limited research on decision making with BOCR as sub-criteria to select the optimal option. BOCR is a suitable option for a complex problem because it enables selection between alternatives based on BOCR and stakeholders’ perceived values, rather just the perceived values. Stakeholders perceived values are the control criteria in the model development, while BOCR serves as the sub-criteria. In this study, the opportunities and risks of pairwise comparison are not considered due to the scope of the research, time constraints, and the need to avoid cumbersome modelling.
3.10.1 Pairwise comparison of the benefits of perceived values

Each perceived value has benefits that serve as sub-criteria for the control criteria. The stakeholders consider the benefits during selection. There are three benefits in each perceived value attribute for the decision making process. These benefits are pairwise compare to calculate their relative weight. The steps to calculate the relative weight of the perceived values are the same as those for calculating the benefits of the perceived values. Table 3-5 illustrates the pairwise comparison of the benefit of time. The values in the table is just an example of pairwise comparison of time, extension of time and cost overrun prevention against claim avoidance.

<table>
<thead>
<tr>
<th>Benefit of time</th>
<th>1. Time</th>
<th>2. Extension of time</th>
<th>3. Cost overrun prevention</th>
<th>Relative weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Claim avoidance</td>
<td>1/1</td>
<td>5/1</td>
<td>1/3</td>
<td></td>
</tr>
<tr>
<td>2. Extension of time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Cost overrun prevention</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The relative weight of perceived values benefits is tabulated to determine their ranking. The relative weight with the highest value is the most important to stakeholders, while the weight with the lowest value is the least important. The reason for considering the relative weight of the perceived values benefits is to have a robust analysis towards the selection between OSM and traditional method of construction.

It is part of the ANP decision making process to pairwise compare the perceived values benefits against OSM and the traditional method of construction. The purpose of this pairwise comparison is to determine the level of intensity of OSM and the traditional method of construction to meet the perceived values benefits. Stakeholders use this concept as selective criteria for the two methods of construction. The relative weight of OSM and traditional construction, coupled with the relative weight of the perceived values, are used to determine...
the most suitable method for stakeholders. Table 3-6 shows the pairwise comparison calculation of the perceived values benefits against OSM and the traditional method of construction.

<table>
<thead>
<tr>
<th>Claim avoidance</th>
<th>OSM</th>
<th>Traditional method of construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSM</td>
<td>1</td>
<td>3/1</td>
</tr>
<tr>
<td>Traditional method of construction</td>
<td>1/3</td>
<td>1</td>
</tr>
</tbody>
</table>

**3.11 Cost pairwise comparison**

Cost is another factor that ANP considers for decision making modelling. Effective decision analysis should consider the cost implications of the benefits of selecting a particular construction method. However, some decision making concepts—such as rating method and Conjoint Value Hierarchy—ignore cost implications during decision making.

In this study, five costs were considered for choosing between OSM and the traditional method of construction: maintenance, operating, rework, transportation and construction costs. These costs are the costs associated with the whole life of the building. Whole-life costing is the systematic consideration of all the relevant cost and revenue related to acquisition and ownership of an asset (Kishk et al., 2003). Five costs were chosen out of the whole-life costs parameters due to the complexity of the model and to ensure ease of using the decision making software. These costs help decision makers consider the entire costs, rather than only the construction costs. Considering only the construction costs would affect the stakeholders’ budget (Dale, 1993). This is because the post construction costs, such as, maintenance cost and the operating cost would be neglected during the decision making process, which often lead to inaccuracy in the cost forecast of the building. Table 3-7 below depicts the total costs adopted in the decision making tool.

**Table 3-7: Total costs**

<table>
<thead>
<tr>
<th>Costs</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Maintenance cost</td>
<td>The cost associated with the cleaning and facilities management of the building</td>
</tr>
<tr>
<td>2. Operating cost</td>
<td>The cost of running the building, such as electricity or renewable energy</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>3. <strong>Rework cost</strong></td>
<td>The cost associated with building renovation and repair of damages</td>
</tr>
<tr>
<td>4. <strong>Transportation cost</strong></td>
<td>The cost of transporting building components and materials to the site</td>
</tr>
<tr>
<td>5. <strong>Construction cost</strong></td>
<td>The total cost of constructing a building</td>
</tr>
</tbody>
</table>

Part of the research methodology is to pairwise compare the associated cost when choosing between OSM and the traditional method of construction. This calculation seeks to identify the level of importance of these costs to stakeholders during decision making. The relative weight is calculated based on stakeholders’ input for the pairwise comparison. A higher relative weight means that the cost is most important to stakeholders. Table 3-8 below shows how to pairwise compare the costs associated with the decision making process.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Maintenance cost</td>
<td>1/1</td>
<td>1/9</td>
<td>1/3</td>
<td>7/1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Operating cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Rework cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Transportation cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Construction cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Further, the costs are a pairwise comparison between OSM and the traditional method of construction. The aim of this pairwise comparison is to reveal the most cost-effective method based on stakeholders’ needs. The relative weight of OSM and the traditional method of construction are compared to determine the best method for stakeholders. Table 3-9 illustrates the pairwise comparison of OSM and the traditional method of construction in relation to the costs. Table 3-10 shows the relative weight of the stakeholders’ perceived values against OSM and the traditional method of construction.

**Table 3-9: Pairwise comparison of OSM and traditional method of construction**

<table>
<thead>
<tr>
<th></th>
<th>OSM</th>
<th>Traditional method of construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance cost</td>
<td>1</td>
<td>5/1</td>
</tr>
<tr>
<td>Traditional method of construction</td>
<td>1/5</td>
<td>1</td>
</tr>
</tbody>
</table>

**Table 3-10: Relative weight of stakeholders’ perceived values against OSM and traditional method of construction**

<table>
<thead>
<tr>
<th></th>
<th>OSM</th>
<th>Traditional method of construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating cost</td>
<td>1</td>
<td>3/1</td>
</tr>
<tr>
<td>Traditional method of construction</td>
<td>1/3</td>
<td>1</td>
</tr>
</tbody>
</table>
3.12 Benefit–cost ratio

After the pairwise comparison of the stakeholders perceived values, benefits of the perceived values, and costs associated with OSM and the traditional method of construction, the next step is to use these comparisons for decision making. Using the comparisons entails knowledge of the benefit to cost ratio, benefits of the perceived values, and costs associated with OSM and the traditional method of construction. These three concepts are adopted in decision making in ANP.

This study adopted the benefit–cost ratio for two reasons. First, it is a method for making a decision by comparing the benefits and costs associated with the alternatives. In contrast, other methods of decision making—such as the rating or ranking method—do not consider the benefits and costs involved in choosing between different methods of construction, which can lead to the adoption of a method with high benefits and high costs, which is unreasonable.

Second, the benefit–cost ratio is a simple mathematical calculation. In comparison to the benefit, opportunities to cost and risk ratio in ANP, it is simpler to calculate, and the model is easier to develop. The opportunities and risk are not considered for simplicity and to ensure ease in using the decision making tool. The method with a higher benefit–cost ratio should be selected above methods with a low benefit–cost ratio due to the former method indicating greater benefits and lesser cost. The benefit to cost ratio is the total relative weight of the perceived values benefits divide by the relative weight of costs.

\[
\text{Benefit to cost ratio} = \frac{\text{Relative weight of perceived value of benefit}}{\text{Relative weight of costs}}
\]

3.13 Visual Basic for Application (VBA)

The application of ANP principles required an analytic model as mentioned in Section 3.5 for the selection between OSM and traditional method of construction. Without the adequate analytical tool, it is difficult for the stakeholders to make the right decision to select between OSM and the traditional method of construction (Raji, 2013).

VBA was chosen based on the research aims and its successful application in other industries for decision making analysis. VBA assists to develop a user friendly software for the selection between OSM and traditional method of construction. The benefit of adopting VBA above other program is the readily available Microsoft office program that contains user interface and
calculation tool compare to other tools with spatial relations between cells defined within a grid (Brandelik, 2009).

The tool will be develop by writing programming languages that use ANP principles in the selection between OSM and the traditional method of construction. The tool’s mechanism is the selection of six stakeholders’ perceived values, benefits and costs for pairwise comparison. The result of the pairwise comparison via the ANP is use in the selection between OSM and traditional method of construction. These are the fundamentals of the VBA tool, which form the bedrock of the research methodology.

### 3.14 Chapter Summary

This chapter outlines the research approach, research design, modelling technique and data collection method used in this study. The research approach adopted the ANP. As a result, the research design comprises of two analysis phases followed the comparison of OSM and traditional method of construction and identification of stakeholders perceived values attributes and their benefits. For the modelling technique, the study employed the analytical model based on the comparison with other modelling technique in relation to the aim of the study. The data collection employed is literature review to gather the stakeholders perceived values attributes for the decision making tool.

The fundamental calculations behind ANP were explained by showing how to pairwise compare the stakeholders’ perceived values and their benefits. In addition, the cost comparison were also illustrated. The benefit to cost ratio was explained with justification for its selection in this study. The development of a decision tool that used the ANP principles in its functionality to enable stakeholders to choose between OSM and traditional method of construction were presented in Chapter (4).
Chapter 4

Development of decision making tool

The literature review in Chapter (2) has justified the need to develop a decision making tool for the stakeholders to aid their selection between OSM and traditional method of construction. The extensive literature review in Chapter (2) has investigated different types of decision making approaches and the key indicators that motivate stakeholders during decision making.

This chapter presents the development of a decision making tool that has been developed through the literature review, ANP and VBA. A decision making tool is a reliable tool use in construction and other industries to help make a decision between alternatives based on the stakeholders perceived values. The development of the decision making tool comprises of six steps; (1) decision problem identification, (2) stakeholders’ perceived values selection, (3) pairwise compare of the stakeholders’ perceived values, (4) benefits of the stakeholders’ perceived values selection, (5) cost associated with the development of a construction method selection and (6) Examination of result.

The six steps for the development of the decision making tool is structured into three parts; (1) the description and the basics of the development of the tool, (2) the analysis of the tool using hypothetical scenarios and (3) the validation of the tool. Hypothetical scenarios were used for the tool validation and analysis due to limited case studies on decision making in the selection between OSM and traditional method of construction.

The decision making tool provides a transparent and logical model for the stakeholders during the selection between OSM and traditional method of construction. The tool is flexible, which allows changes to the perceived value based on the need of the stakeholders. The tool validation concept would be elaborated in Chapter (5) to compare the result from manual calculation against the decision tool output.

4.1 Decision making tool overview

Decision making tool in this study is a tool for stakeholders to choose an appropriate construction method based on their perceived values. It provides a transparent, robust and reliable approach to decision making. It is used at the feasibility and early phase of project
development by Pan (2006). There are different types of decision making tools used for selection of a construction method. The tools consider material, plant, labour, time, and cost rather than perceived value attributes as their decision making parameters (Blismas et al., 2006).

On the other hand, some decision making tools such as (Pan, 2006) only use the stakeholders’ perceived values as their decision making parameters for the operation of the tool. Holistically, making a decision based on stakeholders’ perceived values without considering the cost, risk and opportunities associated with the alternatives is one of the deficiencies addressed by Saaty (1990). It is important because the stakeholders would select a construction method based on different criteria. The decision making tool developed in this study is to address the deficiencies in OSM and traditional method of construction selection, by ensuring that a method of construction is selected based on stakeholders’ perceived values, benefits of the stakeholders’ perceived values and the cost rather than ranking method.

The decision making tool consists of 11 common stakeholders’ perceived values and 5 cost types associated with the whole life of a building. It is designed to incorporate benefits and cost in the decision making to address the issue of selecting a particular method of construction based on anecdotal evidence and non-value parameters. It is the decision making tool that adopted the concept of ANP designed by Saaty (1990). However, the developed tool for this study did not consider the risks and opportunities in the selected stakeholders’ perceived values due to the complexities of the tool and the time constraint of the research.

Furthermore, the decision making tool for this study addressed one of future research works of Pan (2006). A large number of studies on OSM and traditional method of construction did not consider the decision making tool, and IT interface such as C++ programming. The decision making tool would enable the stakeholders to pairwise compare their selected perceived values and their benefits and cost to generate a decision output. Its working principle and development are different from other decision tools, such as Pan (2006) and Elnaas (2014). The working principle is different because it used an ANP approach based on benefit to cost ratio as one of the yardsticks for choosing between OSM and traditional method of construction while the cited examples of decision making tools used AHP and decision matrix approach. In addition, the tool development employed VBA as its computer programming language while others does not use any programming language.
The decision making tool used the concept of ANP and VBA for the development of the tool for the stakeholders. The ANP concept formed the mathematical process behind the mechanism of the tool while the VBA concept formed the programming language of the tool. The extensive literature review in Chapter (2) and research methodology in Chapter (3) have discussed the existing knowledge about different types of decision making tools, models and the stakeholders’ perceived value. This chapter has built on the theoretical framework of the chapters above to presents the six steps for the development of the decision making model for this study.

The six design steps of the decision making tools for this study was based on multi-criteria decision making analysis due to its benefits above unit dimensional and other stakeholder perceived value measurement as stated in (Cengiz and Kirkbir, 2007; de Piante Henriksen and Palocsay, 2008). These steps are explained in details in Figure 4-1 below. The steps show the chronological order of the tool development. Detailed explanations of the decision making tool are shown in Section 4.2 below. Figure 4-2 shows the flow chart of the decision making model. It shows the working process of the tool.
1. Decision problem identification.

2. Stakeholders’ perceived value selection.

3. Pairwise compare the stakeholders’ perceived value.

4. Benefits of the stakeholders’ perceived value selection.

5. Cost associated with the decision making selection.

6. Examination of the results

Figure 4-1: Decision making tool process
4.2 STEP 1- Decision making problems

A decision problem is the whole administrative, political and social structures that surround the decision made by the individuals or stakeholders (Dodgson et al., 2009). Also, the decision problem is the challenges that stakeholders are facing or their needs. Central to the decision problems are the stakeholders, who are affected by the decision making and those who make the decision. Establishing the decision problem entails the understanding of the problem, stakeholders and the factors that resulted in the problem.


4.2.1 Knowledge of the decision problems

There are various ways of understanding the problems in the construction industry and particularly decision making problems in the adoption of OSM over traditional method of construction or vice versa. The decision problems can be specific, measurable and agreeable (Dodgson et al., 2009). The knowledge of the decision problem requires extensive literature review and industry consultation. In this study, the major decision problem in the adoption of OSM over the traditional method of construction is the inability of the stakeholders to comprehend the benefits of the two methods of construction and the tools for decision making process.

Blismas and Wakefield (2009), and CRC (2007) highlighted the decision problems in the adoption of OSM over the traditional method of construction in Australia. In addition, many research studies have reported the problems in the adoption of these methods, but there is a limited tool for the stakeholders to help them make a decision.

4.2.2 Identifying the stakeholders

The importance of stakeholders’ management was analysed in Chapter (2). Stakeholders’ management, which is the identification of stakeholders and their needs, is one of the concepts of decision making problem. Without the knowledge of the stakeholders, it is difficult to develop a decision making model that is capable of guiding the stakeholders on the right choice. Dodgson et al. (2009) refer to the stakeholders as key players that represent important perspectives on the subject in the decision making. The stakeholders have been explained at length in Chapter (2).

The stakeholders have been selected based on extensive literature review. They were chosen based on their level of influence on the adoption of OSM and traditional method of construction. Four stakeholders selected for this study are a developer, manufacturer, end user and designer. These were selected because they are the major influencers and also to allow simplicity in the networking of the clusters. Selection of stakeholders’ perceived value is the next step after the identification of the decision making problems. Figure 4-3 below is the screenshot of the user interface created using VBA for the selection of the stakeholders’ role.
Figure 4-3 above was designed for the selection of stakeholder position in the decision making process. The tool allows a stakeholder to select a role. The purpose of designing the Figure 4-3 above is to link the decision making output to a specific stakeholder.

4.3 STEP 2- Stakeholders perceived value selection

Step 2 is the selection of stakeholders’ perceived values. The VBA tool allows the stakeholders to choose a maximum of 6 stakeholders’ perceived values due to the recommendation of Lavy et al. (2010) and to allow simplicity in the operation of the tool. The selected stakeholders’ perceived values were based on the stakeholders’ preferences among the 11 stakeholders’ perceived values listed in the combo box of the VBA tool. This is the page 2 of the decision tool. Without the selection of the perceived values, there are no basic criteria for the judgmental scaling of OSM and traditional method of construction.
Figure 4-4 above was designed in the matrix form to conform to ANP principles. The boxes in the first column are called combo boxes that consist of 11 stakeholders’ perceived values, in which the stakeholders select the 6 perceived values of their choice. The first row of page 2 is programmed to contain the stakeholders’ perceived values chosen in the combo boxes. It can be done through the pressing of any key on the keyboard. The selected stakeholders’ perceived values are sent to the Microsoft Excel spreadsheet for background calculation.

4.4 STEP 3- Pairwise comparison of the selected stakeholders’ perceived value

Step 3 is the pairwise comparison of the selected perceived value. This is to determine their level of importance to the stakeholders. ANP has a fundamental scale for the pairwise comparison. The scale measures the intensity or importance of the selected perceived values to the stakeholders. The submit button at the button of the page sends the pairwise comparison calculation into the excel sheet for generating the relative weight of each stakeholders’ perceived value.
Figure 4-5: Pairwise comparison of the selected stakeholders perceived values

Looking closely at the pairwise comparison in Figure 4-5 above and the matrix calculation in Table 4-1, it can be seen that the pairwise comparison is sent to the background Excel spreadsheet. It is called synthesis in AHP. It is the weighting the priorities of criteria on another criteria (Saaty, 2008). The relative weight of each criterion is not normalised in Table 4-1. The stakeholders’ perceived values were selected randomly to show the workability of the tool and not a project case study.

Table 4-1: Matrix calculation for the selected stakeholders’ perceived value

<table>
<thead>
<tr>
<th>Return of investment</th>
<th>Time</th>
<th>Safety</th>
<th>Energy consumption</th>
<th>Life cycle cost</th>
<th>Embodied energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return of investment</td>
<td>1.00</td>
<td>0.33</td>
<td>0.20</td>
<td>7.00</td>
<td>0.11</td>
</tr>
<tr>
<td>Time</td>
<td>3.00</td>
<td>1.00</td>
<td>9.00</td>
<td>0.20</td>
<td>0.11</td>
</tr>
<tr>
<td>Safety</td>
<td>5.00</td>
<td>0.11</td>
<td>1.00</td>
<td>7.00</td>
<td>0.20</td>
</tr>
<tr>
<td>Energy consumption</td>
<td>0.14</td>
<td>5.00</td>
<td>0.14</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Life cycle cost</td>
<td>9.00</td>
<td>9.00</td>
<td>5.00</td>
<td>0.20</td>
<td>1.00</td>
</tr>
<tr>
<td>Embodied energy</td>
<td>5.00</td>
<td>0.33</td>
<td>7.00</td>
<td>3.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Total</td>
<td>23.14</td>
<td>15.78</td>
<td>22.34</td>
<td>18.40</td>
<td>11.42</td>
</tr>
</tbody>
</table>
Normalisation of the matrix is one of the principles of AHP and ANP. The relative importance of the selected stakeholders’ perceived value is normalised. This concept is used when the stakeholders’ perceived value depends on the alternatives, which is OSM and traditional method of construction. The calculation for the normalisation of the perceived value is shown in Table 4-2. Each stakeholder perceived value is normalised by dividing the value of each pairwise comparison over the sum of the pairwise in the column. For example, the return of investment is normalised by dividing $1/23.14 = 0.04$. The value 1 is the result of the pairwise comparison between return investment vs. return investment, and the 23.14 is the sum of the pairwise comparison in the first column.

The criteria weight is the relative weight of the normalised matrix. It is the criteria weight that enables the stakeholders to see the level of importance of the selected perceived values. The consistency measure is the correlation between the stakeholders’ perceived values. It indicates the degree of correlation in the pairwise comparison.

Table 4-2: Normalised matrix of the pairwise comparison

<table>
<thead>
<tr>
<th></th>
<th>Return of investment</th>
<th>Time</th>
<th>Safety</th>
<th>Energy consumption</th>
<th>Life cycle cost</th>
<th>Embodied energy</th>
<th>Total</th>
<th>Criteria weight</th>
<th>Consistency measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return of investment</td>
<td>0.04</td>
<td>0.02</td>
<td>0.01</td>
<td>0.38</td>
<td>0.01</td>
<td>0.02</td>
<td>0.48</td>
<td>0.08</td>
<td>15.23</td>
</tr>
<tr>
<td>Time</td>
<td>0.13</td>
<td>0.06</td>
<td>0.40</td>
<td>0.01</td>
<td>0.01</td>
<td>0.31</td>
<td>0.93</td>
<td>0.15</td>
<td>13.64</td>
</tr>
<tr>
<td>Safety</td>
<td>0.22</td>
<td>0.01</td>
<td>0.04</td>
<td>0.38</td>
<td>0.02</td>
<td>0.01</td>
<td>0.68</td>
<td>0.11</td>
<td>14.30</td>
</tr>
<tr>
<td>Energy consumption</td>
<td>0.01</td>
<td>0.32</td>
<td>0.01</td>
<td>0.05</td>
<td>0.44</td>
<td>0.03</td>
<td>0.86</td>
<td>0.14</td>
<td>17.60</td>
</tr>
<tr>
<td>Life cycle cost</td>
<td>0.39</td>
<td>0.57</td>
<td>0.22</td>
<td>0.01</td>
<td>0.09</td>
<td>0.52</td>
<td>1.80</td>
<td>0.30</td>
<td>13.54</td>
</tr>
<tr>
<td>Embodied energy</td>
<td>0.22</td>
<td>0.02</td>
<td>0.31</td>
<td>0.16</td>
<td>0.44</td>
<td>0.10</td>
<td>1.25</td>
<td>0.21</td>
<td>16.19</td>
</tr>
</tbody>
</table>

Consistency index: -1.17
Random inconsistency index: 1.24
Consistency ratio: -0.94
4.5 STEP 4- Benefits of the stakeholders’ perceived values selection

In ANP decision making concept, it is recommended to include the benefits of the selected criteria as part of the decision making process. Including the sub- criteria as part of the decision making factors enables the stakeholders to view the benefits of the selected perceived values. The benefits are called the sub criteria in ANP.

In this study, the benefits of the stakeholders perceived value shown in Table 4-3 below are included in the decision making tool. The decision maker would have the ability to priorities these benefits based on their importance using the pairwise comparison. The relative weight of the selected stakeholders’ perceived value benefits is calculated through the normalised matrix. The steps for the normalised matrix have been explained in step 3.
These sub-criteria were included in the VBA tool for the stakeholders to make an optimal decision. Various studies have considered the stakeholders perceived value without the sub criteria. It is either due to the complexity of the model or the limited capacity of the modelling technique adopted. Limited studies on OSM and traditional method decision making model such as Pan (2006) have only considered the criteria for the decision making concept. However, to make a sound decision, it is crucial to include the sub criteria, which is the benefits of the selected stakeholders’ perceived value as recommended by Saaty (1990). Figure 4-6 below
shows screenshot of page 4 of the user interface created using VBA for the selection of the benefits of stakeholders’ perceived values.

**Figure 4-6: Benefits of stakeholders’ perceived values**

The stakeholders’ perceived values benefits are selected by the stakeholders. The benefits reflect the advantages of the stakeholders’ perceived value chosen. The selected benefits highlighted are shown in Figure 4-7 below.

**Figure 4-7: Selected stakeholders’ perceived values benefits**

4.6 **Pairwise comparison of the stakeholders’ perceived values benefits**

ANP principle is majorly pairwise comparison. The selected benefits are pairwise compared to determine the relative weight of the benefits. The screen shot in Figure 4-8 and Figure 4-9
illustrates a pairwise comparison of the selected stakeholders perceived values benefits. The purpose of the pairwise comparison is to determine the relative importance of the benefits of the stakeholders perceived values to stakeholders. The Excel spreadsheet shown in Table 4-4 is an example of background calculation on the Excel spreadsheet.

![Figure 4-8: Pairwise comparison of the selected stakeholders’ perceived values benefits 1](image)

![Figure 4-9: Pairwise comparison of the selected stakeholders’ perceived values benefit 2](image)
Furthermore, to analyse the intensity of OSM and traditional method of construction in meeting the stakeholders’ perceived values benefits chosen by the stakeholders, OSM and traditional method of construction are pairwise compared against the benefits of the stakeholders’ perceived values. Through the pairwise comparison, the stakeholders would have the ability to select the best option that is capable of meeting his or her needs. The matrix calculation in Table 4-5 shows the pairwise calculation illustration in the decision making tool developed in Figure 4-10.

![Instructions](image)

**Figure 4-10: Instructions for the pairwise comparison of stakeholders’ perceived values benefits**
Step 5: Costs associated with decision making selection

The next step is the pairwise comparison of the whole life cost related to building. It is considered due to the level of importance attached to whole life cost of the building. Kishk et al. (2003) stated the key benefits of whole life cost to the suppliers, manufacturers and the developers is the delivering of building that demonstrated value for money to their clients. The benefit of the whole life cost to client is the ability of clients to save money through an efficient building. The benefits ascribed to the whole life cost are the reasons for the adoption of whole life cost for the cost rather than construction cost for the pairwise comparison.

The instruction of the cost pairwise comparison is shown in Figure 4-12 below and the cost pairwise comparison in Figure 4-13. The decision makers pairwise compare the costs based on their level of importance. The relative weights of the costs are calculated.
The next step after the calculation of the relative weight of the costs is to pairwise compare OSM and traditional method of construction against the costs as shown in Figure 4-14 below. It would enable the stakeholders to determine the cost effectiveness of OSM and the traditional method of construction against the cost.
Figure 4-14: Pairwise comparison of OSM and traditional method of construction against cost types

The relative weights of the costs of OSM and traditional method of construction are calculated to reveal the cost intensity of the two construction methods. Table 4-6 below shows the Excel calculation for the pairwise in the decision making tool. The relative weight of each cost of OSM and traditional method of construction are added to obtain the costs for determining the benefit to cost ratio.

Table 4-6: Relative weight of the costs of OSM and traditional method construction

<table>
<thead>
<tr>
<th>Maintenance cost</th>
<th>OSM</th>
<th>Traditional method</th>
<th>Relative weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSM</td>
<td>1.0</td>
<td>0.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Traditional method</td>
<td>9.0</td>
<td>1.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>

4.8 Step 6: Examination of result

The examination of the pairwise comparison’s result is the sixth step in the development of the decision making tool. The stakeholders analyse the result to determine the best method of construction capable of meeting their needs. Figure 4-15 below shows the result of the pairwise comparisons.
Figure 4-15: Results of the pairwise comparison

The benefit to cost ratio is the parameter for selecting the best method of construction that is capable of meeting stakeholders’ need. It is calculated by dividing the relative weights of the benefits of OSM and traditional method of construction by the relative weight of costs of OSM and traditional method of construction. A benefit to cost ratio shows the quantity of benefits stakeholders would derive in relative to the cost of the construction method selected. A method of construction with higher benefit to cost ratio is the best method in comparison to other method.
4.9 Network of the stakeholders’ perceived values, benefits of the stakeholders’ perceived values and cost

The Network of stakeholders’ perceived values, their benefits and cost is the last stage of the decision making process in ANP. Although the networking process is not part of the decision making tool operation, rather it is drawn manually to show the effect of the selected criteria and their benefit. This study does not consider the network of the perceived value in the tool development but it forms part of future research study.

Networking of the stakeholders’ perceived values, benefits and cost is one the criteria that distinguish ANP from AHP and other decision making process. ANP is the modification of AHP through the inclusion of networking of the criteria and sub criteria to show the interaction between these factors. It looks beyond structuring problems in a hierarchical manner rather it considers the networking of the decision criteria to determine the dependency of one criterion on the others. The selected stakeholders’ perceived values and their benefits are network for the stakeholders to view the interaction and interdependency between these parameters. Figure 4-16 below shows the network of 11 stakeholders’ perceived values, their benefits and Figure 4-17 shows types of cost.

The interaction between the 11 stakeholders’ perceived values and their benefits is derived through the knowledge of construction management by the author. The factors are network to show the influence of one factor on the other. This means that stakeholders have the capability to see the selected factors that are related to one another. It means that claim avoidance is related to market demand and cost certainty. These sub criteria are dependence on each other. The arrow in the networking diagram in Figure 4-16 indicates the relationships between the factors.

However, this study does not consider the network process in ANP for the decision making process between OSM and traditional method of construction. The Figure 4-16 and Figure 4-17 show the network of the 11 stakeholders’ perceived values and the cost for this study respectively. The network process for the hypothetical scenarios A and B was not considered as it beyond the scope of the developed tool and it is not part of the aim of the research aims and objectives.

The ANP network for this study can be developed from the selected stakeholders’ perceived values through the fundamental understanding of dependency in ANP. The dependency in ANP
is the process of networking criteria and sub-criteria that are dependent on one another (Saaty, 2013). For instance, in green building development, material selection dependent on the carbon footprint. This dependency principle enables the stakeholders to link criteria that are dependent via an arrow as shown in Figure 4-16. For robust decision making, the stakeholders should pairwise compare the criteria that are dependent on each other (Saaty, 2013). This comparison enables the stakeholders to identify the ranking of the criteria. The networking of criteria is complex, thus, careful consideration is required to ensure that the criteria are network properly.

The stakeholders would benefit from the network process by using the dependent criteria to select the best construction method. This is achieved by pairwise compare the dependent criteria against OSM and traditional method of construction. It is an advance decision analysis, which other decision making process does not consider.

4.10 Chapter Summary

This chapter presented the development of a decision making tool to assist in the selection between OSM and traditional method of construction. This tool was develop through an extensive literature to gather the stakeholders’ perceived values, ANP principles and VBA programming. There are six steps in the tool development presented in this chapter. These six steps explained the functionality and mechanism behind the develop tool. Further, the ANP networking principle, its formation and benefits to stakeholders were explained.
Figure 4-16: Network of the perceived value and benefits
Figure 4-17: Network of cost
Decision making tool for choosing between OSM and traditional method of construction. To achieve the aim of the study, a critical review was carried out to capture the stakeholders’ perceived values attributes. Also, a decision making tool was developed as part of means to achieve the aim. The model was developed using 11 stakeholders’ perceived values attributes, ANP principles and VBA. For study completeness, hypothetical scenarios were employed to validate the tool. The result from the tool provided support for the tool validity derived from the hypothetical scenarios.

Underpinned by the research finding mentioned herein, the study sheds more light on the stakeholders’ management by explaining the importance of stakeholders in the selection of construction method and the motivating factors that derives their desire to adopt a construction method over the other. It further explains the concept of value and its significance in the selection between OSM and traditional method of construction. Moreover, the study provides practical implication to the construction industry by offering decision tool that generate a robust outcome, which can be used in the development of construction project. The tool could also assist the end users in selecting a construction method with utmost values.

Finally, this thesis closes with recommended future research directions that paved way for other researchers and construction professionals willing to extend the current findings of value capturing and decision making tool in the selection between OSM and traditional method of construction.
Chapter 5

Tool population and validation

Tool population of the developed decision making tool is one of the principles emphasised by Whitaker (2007) in the ANP and AHP process because of the need to determine the tool’s reliability. Validation is defined as the process of confirming a decision tool via comparing the result obtained from the model against the real-life scenario or existing theory. In this study, validation is the process of testing the tool to compare its output result against manual calculation.

This chapter aims to validate the tool through hypothetical project scenarios in order to determine the workability and viability of the tool in the selection of OSM and the traditional method of construction. Without validation of the tool, it is difficult to know whether one of the research aims has been achieved.

5.1 Model validation concepts

The significance of validating the decision making tool has been discussed previously. However, it is important to understand the fundamental principles behind the validation of the decision making tool. Hypothetical scenarios are used to validate the tool due to limited case studies comparing the value aspect of OSM and the traditional method of construction during building development. Further, it is difficult to base the results of a particular case study on the validity of the tool because stakeholders’ needs change with time.

The fundamental principle of validating a tool is to input the value into the tool and compare the result against the existing results or manual calculation results. However, there are limitations and difficulties surrounding testing the validity of a decision making tool (Ngai, 2003; Yüksel and Dagdeviren, 2007). One of the challenges in validating the ANP model is that the criteria and sub-criteria are not quantitative in nature, and the pairwise comparison is determined by judgement experts (Yüksel and Dagdeviren, 2007). This has made it difficult to obtain the same result each time for different comparisons because the data used in the pairwise comparison might change based on the subjective view of the judgement expert. In addition, it
is impossible to obtain the same results due to differences in the case studies. Thus, the changes in the pairwise comparison output due to different views of the stakeholders should not be a reason for rejecting the validity of this decision making model (Yüksel and Dagdeviren, 2007).

Further, another difficulty encountered when testing the validity of the tool is the unavailability of a previous decision tool for the selection of OSM in Australia. Previous studies on decision making regarding OSM and the traditional method of construction—such as the studies by Pan (2006) and Elnaas (2014)—only considered the AHP principles, without developing a decision making tool for the studies. The limited studies on decision making tools for choosing between OSM and the traditional method of construction make it difficult to ascertain the validity of the decision tool based on previous studies.

Considering these difficulties, the validity of the decision making tool is evaluated via comparing the tool output against the manual calculation. This is the most reliable way to affirm the validity of the tool.

### 5.2 Hypothetical scenario A

Hypothetical scenario A, as shown in Figure 0-1, assumes that the developer is the stakeholder, with a preference for **Time, Cost, Quality, Safety, Lifecycle Cost** and **Return of Investment** as his or her perceived values when selecting OSM and the traditional method of construction, as illustrated in Figure 0-2.

![Image](image_url)

**Figure 0-1: Background information of the stakeholder in hypothetical scenario A**
Figure 0-2: Hypothetical scenario A pairwise comparison

Table 0-1: Matrix calculation for hypothetical scenario A

<table>
<thead>
<tr>
<th>Stakeholders’ perceived values</th>
<th>Time</th>
<th>Cost</th>
<th>Quality</th>
<th>Safety</th>
<th>Lifecycle cost</th>
<th>Return of investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>1.00</td>
<td>3.00</td>
<td>5.00</td>
<td>3.00</td>
<td>5.00</td>
<td>7.00</td>
</tr>
<tr>
<td>Cost</td>
<td>0.33</td>
<td>1.00</td>
<td>3.00</td>
<td>3.00</td>
<td>5.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Quality</td>
<td>0.20</td>
<td>0.33</td>
<td>1.00</td>
<td>3.00</td>
<td>5.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Safety</td>
<td>0.33</td>
<td>0.33</td>
<td>0.33</td>
<td>1.00</td>
<td>3.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Lifecycle cost</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.33</td>
<td>1.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Return of investment</td>
<td>0.14</td>
<td>0.20</td>
<td>0.20</td>
<td>0.33</td>
<td>3.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Total</td>
<td>2.21</td>
<td>5.07</td>
<td>9.73</td>
<td>10.67</td>
<td>22.00</td>
<td>24.00</td>
</tr>
</tbody>
</table>

Table 0-2: Criteria weight and rank of the stakeholders’ perceived values in hypothetical scenario A

<table>
<thead>
<tr>
<th>Stakeholders’ perceived values</th>
<th>Criteria weight</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>0.39</td>
<td>1</td>
</tr>
<tr>
<td>Cost</td>
<td>0.23</td>
<td>2</td>
</tr>
<tr>
<td>Quality</td>
<td>0.16</td>
<td>3</td>
</tr>
<tr>
<td>Safety</td>
<td>0.10</td>
<td>4</td>
</tr>
<tr>
<td>Lifecycle cost</td>
<td>0.06</td>
<td>5</td>
</tr>
<tr>
<td>Return of investment</td>
<td>0.06</td>
<td>6</td>
</tr>
</tbody>
</table>
Table 0-3: Normalised matrix of hypothetical scenario A

<table>
<thead>
<tr>
<th></th>
<th>Time</th>
<th>Cost</th>
<th>Quality</th>
<th>Quality</th>
<th>Lifecycle cost</th>
<th>Return of investment</th>
<th>Total</th>
<th>Normalised criteria weight</th>
<th>Consistency measure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time</strong></td>
<td>0.45</td>
<td>0.59</td>
<td>0.51</td>
<td>0.28</td>
<td>0.23</td>
<td>0.29</td>
<td>2.36</td>
<td>0.39</td>
<td>7.32</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>0.15</td>
<td>0.20</td>
<td>0.31</td>
<td>0.28</td>
<td>0.23</td>
<td>0.21</td>
<td>1.37</td>
<td>0.23</td>
<td>7.53</td>
</tr>
<tr>
<td><strong>Quality</strong></td>
<td>0.09</td>
<td>0.07</td>
<td>0.10</td>
<td>0.28</td>
<td>0.23</td>
<td>0.21</td>
<td>0.98</td>
<td>0.16</td>
<td>7.33</td>
</tr>
<tr>
<td><strong>Quality</strong></td>
<td>0.15</td>
<td>0.07</td>
<td>0.03</td>
<td>0.09</td>
<td>0.14</td>
<td>0.13</td>
<td>0.61</td>
<td>0.10</td>
<td>6.99</td>
</tr>
<tr>
<td><strong>Lifecycle cost</strong></td>
<td>0.09</td>
<td>0.04</td>
<td>0.02</td>
<td>0.03</td>
<td>0.05</td>
<td>0.13</td>
<td>0.35</td>
<td>0.06</td>
<td>7.09</td>
</tr>
<tr>
<td><strong>Return of investment</strong></td>
<td>0.06</td>
<td>0.04</td>
<td>0.02</td>
<td>0.03</td>
<td>0.14</td>
<td>0.04</td>
<td>0.33</td>
<td>0.06</td>
<td>7.18</td>
</tr>
</tbody>
</table>

Consistency index: $-1.17$
Random inconsistency index: $1.24$
Consistency ratio: $-0.94$
5.3 Analysis of pairwise comparison of six stakeholders’ perceived values in hypothetical scenario A

Analysis of hypothetical scenario A is one of the processes of validating the tool. It began with the input of the stakeholders’ perceived value and pairwise comparison. The result of the pairwise comparison in Table 0-1 is used to determine the relative weight and rank of the stakeholders’ perceived value. The higher the relative weight of the perceived value, the higher the values’ rank.

Table 0-3 shows the normalised relative weight of the selected stakeholders’ perceived values. The normalised matrix enables understanding of the consistency between the pairwise comparison and the validity of the tool. Considering Table 0-2 and Table 0-3, it can be inferred that there is a difference in the un-normalised criteria weight and the normalised criteria weight. The equality of manual calculation and the output of the tool will confirm the validity of the tool in total.

5.4 Analysis of the selected stakeholders’ perceived values benefits in hypothetical scenario A

Having a robust analysis is one of the reasons behind introducing benefit as a principle in the decision making process (Saaty, 1990). The purpose of including benefit is to ensure that a decision is made through consideration of the stakeholders’ perceived values benefits. Figure 0-3 below illustrates the selected stakeholders’ perceived values benefits in the hypothetical scenario. In addition, Figure 0-4 and Figure 0-5 show the pairwise comparison of the selected stakeholders’ perceived values benefits. They indicate the judgemental process of the selected stakeholders’ perceived values benefits.
Figure 0-3: Selected stakeholders’ perceived values benefits in the tool

Figure 0-4: Pairwise comparison of the stakeholders’ perceived benefits in hypothetical scenario A
Figure 0-5: Pairwise comparison of stakeholders’ perceived values benefits continuation in hypothetical scenario A

Table 0-4: Pairwise comparison of the benefits of cost

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. High market demand</td>
<td>1.00</td>
<td>3.00</td>
<td>5.00</td>
<td>3.0</td>
</tr>
<tr>
<td>2. Affordable building</td>
<td>0.33</td>
<td>1.00</td>
<td>0.20</td>
<td>0.50</td>
</tr>
<tr>
<td>3. Cost certainty</td>
<td>0.20</td>
<td>5.00</td>
<td>1.00</td>
<td>2.10</td>
</tr>
</tbody>
</table>

Table 0-5: Pairwise comparison of the benefits of time

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Claim avoidance</td>
<td>1.00</td>
<td>5.00</td>
<td>7.00</td>
<td>4.3</td>
</tr>
<tr>
<td>2. Extension of time prevention</td>
<td>0.20</td>
<td>1.00</td>
<td>3.00</td>
<td>1.4</td>
</tr>
<tr>
<td>3. Cost overrun prevention</td>
<td>0.14</td>
<td>0.33</td>
<td>1.00</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 0-6: Pairwise comparison of the benefits of quality

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Building’s rework minimisation</td>
<td>1.00</td>
<td>3.00</td>
<td>3.00</td>
<td>2.3</td>
</tr>
<tr>
<td>2. Durability</td>
<td>0.33</td>
<td>1.00</td>
<td>5.00</td>
<td>2.1</td>
</tr>
<tr>
<td>3. Lower maintenance cost</td>
<td>0.33</td>
<td>0.20</td>
<td>1.00</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Table 0-4, Table 0-5 and

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Building’s rework minimisation</td>
<td>1.00</td>
<td>3.00</td>
<td>3.00</td>
<td>2.3</td>
</tr>
<tr>
<td>2. Durability</td>
<td>0.33</td>
<td>1.00</td>
<td>5.00</td>
<td>2.1</td>
</tr>
<tr>
<td>3. Lower maintenance cost</td>
<td>0.33</td>
<td>0.20</td>
<td>1.00</td>
<td>0.5</td>
</tr>
</tbody>
</table>

depict the manual calculation of the pairwise comparison of the stakeholders’ perceived values benefits. They indicate how the tool calculates the relative weights of the stakeholders’ perceived values benefits. The manual calculation of the stakeholders’ perceived values benefits is the same as the tool calculation, which proves the validity of the decision making tool.

5.5 Pairwise comparison of the benefits against OSM and traditional method of construction

The selected benefits are compared against OSM and the traditional method of construction to determine the intensity of the decision making tool. The screen shot in Figure 0-6 below shows the pairwise comparison in the decision making model. The main aim of the pairwise comparison is to calculate the relative weight of the stakeholders’ perceived values benefits of OSM and the traditional method of construction.

Figure 0-6: Pairwise comparison of the selected benefits of stakeholders’ perceived values against OSM and traditional method
Hypothetical scenario A confirmed the validity of the tool through the manual calculation shown in Table 0-2, which is equal to the output of the decision tool. The relative weights of the selected stakeholders’ perceived values benefits are highlighted in .

Figure 0-7: Pairwise comparison of the selected benefits of stakeholders’ perceived values against OSM and traditional method continuation
Table 0-7 below. The result is generated from the pairwise comparison of the stakeholders’ perceived values benefit via the decision making tool. The results from Figure 0-8 indicate that OSM has a higher benefit to cost ratio than the traditional method of construction.
Table 0-7: Relative weight of the benefits of stakeholders’ perceived values of hypothetical scenario A

<table>
<thead>
<tr>
<th>Benefits of stakeholders’ perceived values</th>
<th>Relative weight</th>
<th>OSM benefits</th>
<th>Traditional method benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Benefits of time</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Claim avoidance</td>
<td>4.3</td>
<td>2.0</td>
<td>0.7</td>
</tr>
<tr>
<td>2. Extension of time prevention</td>
<td>1.4</td>
<td>3.0</td>
<td>0.6</td>
</tr>
<tr>
<td>3. Cost overrun prevention</td>
<td>0.5</td>
<td>3.0</td>
<td>0.6</td>
</tr>
<tr>
<td><strong>Benefits of cost</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. High market demand</td>
<td>3.0</td>
<td>0.7</td>
<td>2.0</td>
</tr>
<tr>
<td>2. Affordable building</td>
<td>0.5</td>
<td>3.0</td>
<td>0.6</td>
</tr>
<tr>
<td>3. Cost certainty</td>
<td>2.1</td>
<td>2.0</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Benefits of quality</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Building’s rework minimisation</td>
<td>2.3</td>
<td>3.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2. Durability</td>
<td>2.1</td>
<td>3.0</td>
<td>0.6</td>
</tr>
<tr>
<td>3. Lower maintenance cost</td>
<td>0.5</td>
<td>2.0</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Benefits of safety</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Insurance and liability cost reduction</td>
<td>2.3</td>
<td>2.0</td>
<td>0.7</td>
</tr>
<tr>
<td>2. Employee performance improvement</td>
<td>0.5</td>
<td>2.0</td>
<td>0.7</td>
</tr>
<tr>
<td>3. Worker health protection</td>
<td>2.1</td>
<td>2.0</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Benefits of lifecycle costs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Cost saving for users</td>
<td>0.5</td>
<td>2.0</td>
<td>0.7</td>
</tr>
<tr>
<td>2. High economic value building</td>
<td>1.4</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>3. High market building</td>
<td>3.0</td>
<td>0.7</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>Benefits of return of investment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Increase cash flow</td>
<td>2.1</td>
<td>2.0</td>
<td>0.7</td>
</tr>
<tr>
<td>2. Profitability</td>
<td>2.3</td>
<td>3.0</td>
<td>0.6</td>
</tr>
<tr>
<td>3. Decision making concept for project selection</td>
<td>0.5</td>
<td>2.0</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Figure 0-8: Result from the decision making tool for hypothetical scenario A

5.6 Hypothetical scenario B

As shown in Figure 0-9, the stakeholder in hypothetical scenario B is an end user who must select between OSM and the traditional method of construction for a house development. The
user selects **Time, Cost, Quality, Lifecycle Cost, Energy Consumption** and **Sick Building Syndrome** as the perceived values, as shown in

Figure 0-10. The user compares the selected perceived values to obtain the relative weight of the selected values and their benefits, the relative weight of the cost, and the benefit to cost ratio.

![Image: Pairwise comparison of the stakeholders' perceived values.]

Figure 0-9: Background information for end user
Figure 0-10: Pairwise comparison of the stakeholders’ perceived values in hypothetical scenario B
Table 0-8: Matrix calculation for hypothetical scenario B

<table>
<thead>
<tr>
<th></th>
<th>Time</th>
<th>Cost</th>
<th>Quality</th>
<th>Lifecycle cost</th>
<th>Energy consumption</th>
<th>Sick building syndrome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>1.00</td>
<td>0.11</td>
<td>3.00</td>
<td>0.20</td>
<td>0.11</td>
<td>3.00</td>
</tr>
<tr>
<td>Cost</td>
<td>9.00</td>
<td>1.00</td>
<td>7.00</td>
<td>3.00</td>
<td>5.00</td>
<td>9.00</td>
</tr>
<tr>
<td>Quality</td>
<td>0.33</td>
<td>0.14</td>
<td>1.00</td>
<td>3.00</td>
<td>0.20</td>
<td>3.00</td>
</tr>
<tr>
<td>Lifecycle cost</td>
<td>5.00</td>
<td>0.33</td>
<td>0.33</td>
<td>1.00</td>
<td>0.33</td>
<td>5.00</td>
</tr>
<tr>
<td>Energy consumption</td>
<td>9.00</td>
<td>0.20</td>
<td>5.00</td>
<td>3.00</td>
<td>1.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Sick building syndrome</td>
<td>0.33</td>
<td>0.11</td>
<td>0.33</td>
<td>0.20</td>
<td>3.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Total</td>
<td>24.67</td>
<td>1.90</td>
<td>16.67</td>
<td>10.40</td>
<td>9.64</td>
<td>24.00</td>
</tr>
<tr>
<td></td>
<td>Time</td>
<td>Cost</td>
<td>Quality</td>
<td>Lifecycle cost</td>
<td>Energy consumption</td>
<td>Sick building syndrome</td>
</tr>
<tr>
<td>------------------</td>
<td>--------</td>
<td>-------</td>
<td>---------</td>
<td>----------------</td>
<td>---------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Time</td>
<td>0.04</td>
<td>0.06</td>
<td>0.18</td>
<td>0.02</td>
<td>0.01</td>
<td>0.13</td>
</tr>
<tr>
<td>Cost</td>
<td>0.36</td>
<td>0.53</td>
<td>0.42</td>
<td>0.29</td>
<td>0.52</td>
<td>0.38</td>
</tr>
<tr>
<td>Quality</td>
<td>0.01</td>
<td>0.08</td>
<td>0.06</td>
<td>0.29</td>
<td>0.02</td>
<td>0.13</td>
</tr>
<tr>
<td>Lifecycle cost</td>
<td>0.20</td>
<td>0.18</td>
<td>0.02</td>
<td>0.10</td>
<td>0.03</td>
<td>0.21</td>
</tr>
<tr>
<td>Energy consumption</td>
<td>0.36</td>
<td>0.11</td>
<td>0.30</td>
<td>0.29</td>
<td>0.10</td>
<td>0.13</td>
</tr>
<tr>
<td>Sick building syndrome</td>
<td>0.01</td>
<td>0.06</td>
<td>0.02</td>
<td>0.02</td>
<td>0.31</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Consistency index $\approx 1.17$
Random inconsistency index $\approx 1.24$
Consistency ratio $\approx 0.94$
Table 0-10: Criteria weight and ranking of the selected stakeholders’ perceived values of hypothetical scenario B

<table>
<thead>
<tr>
<th>Stakeholders’ perceived values</th>
<th>Criteria weight</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>0.07</td>
<td>6</td>
</tr>
<tr>
<td>Cost</td>
<td>0.42</td>
<td>1</td>
</tr>
<tr>
<td>Quality</td>
<td>0.10</td>
<td>4</td>
</tr>
<tr>
<td>Lifecycle cost</td>
<td>0.12</td>
<td>3</td>
</tr>
<tr>
<td>Energy consumption</td>
<td>0.21</td>
<td>2</td>
</tr>
<tr>
<td>Sick building syndrome</td>
<td>0.08</td>
<td>5</td>
</tr>
</tbody>
</table>

Figure 0-11: Result from the decision making tool for hypothetical scenario B
5.7 Analysis of pairwise comparison of six stakeholders’ perceived values in hypothetical scenario B

Analysing hypothetical scenario B is one the processes of validating the tool. It commences with the input of the stakeholders’ perceived values and pairwise comparison. The result from the pairwise comparison in

Figure 0-10 is used to determine the relative weight and rank of the stakeholders’ perceive value. The criterion with the highest relative weight has the highest rank, and vice versa. The result of the six stakeholders’ perceived values pairwise comparisons shown in Figure 0-11 is the same as the results from the manual calculation, shown in

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
<th>Consistency measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lifecycle cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sick building syndrome</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Criteria weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consistency measure</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 0-10 is used to determine the relative weight and rank of the stakeholders’ perceive value. The criterion with the highest relative weight has the highest rank, and vice versa. The result of the six stakeholders’ perceived values pairwise comparisons shown in Figure 0-11 is the same as the results from the manual calculation, shown in

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
<th>Consistency measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lifecycle cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sick building syndrome</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Criteria weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consistency measure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metric</td>
<td>0.04</td>
<td>0.06</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td><strong>Time</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>0.36</td>
<td>0.53</td>
</tr>
<tr>
<td><strong>Quality</strong></td>
<td>0.01</td>
<td>0.08</td>
</tr>
<tr>
<td><strong>Lifecycle cost</strong></td>
<td>0.20</td>
<td>0.18</td>
</tr>
<tr>
<td><strong>Energy consumption</strong></td>
<td>0.36</td>
<td>0.11</td>
</tr>
<tr>
<td><strong>Sick building syndrome</strong></td>
<td>0.01</td>
<td>0.06</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Metric</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Consistency index</strong></td>
<td>−1.17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Random inconsistency index</strong></td>
<td>1.24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Consistency ratio</strong></td>
<td>−0.94</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 0-10. This proves the validity of the tool.

5.8 Analysis of the selected stakeholders’ perceived values benefits in hypothetical scenario B

Critical analysis is one of the reasons that Saaty (1990) introduced benefit as a principle in the decision making process. The purpose of including benefit is to ensure that a decision is made through consideration of the stakeholders’ perceived values benefits. This study uses pairwise comparison of the benefits of stakeholders’ perceived values to determine the relative weight of the stakeholders’ perceived values benefits based on the stakeholders’ judgement. The pairwise comparison reveals the ranking of the benefits. Figure 0-12 is the print screen of the decision making tool showing the selected benefits of the stakeholders’ perceived values, while Figure 0-13 illustrates the pairwise comparison of the selected stakeholders’ perceived values benefits. Table 0-11 presents the calculation of the pairwise comparison for the benefits of time. Other pairwise comparisons of the stakeholders’ perceived values benefit are not illustrated, as the tool automatically completes the calculation. Table 0-11 shows the calculation for the relative weight of each benefit of the stakeholders’ perceived values. The benefits of time are used an example to show the calculation for the figure generated in the second column of Table 0-12.
Figure 0-12: Selected stakeholders’ perceived values benefits for hypothetical scenario B
Figure 0-13: Pairwise comparison of stakeholders’ perceived values benefits for hypothetical scenario B
Figure 0-14: Pairwise comparison of stakeholders’ perceived values benefits for hypothetical scenario B continuation

Table 0-11: Matrix calculation of pairwise comparison of the benefits of time

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Claim avoidance</td>
<td>1.00</td>
<td>0.20</td>
<td>0.14</td>
<td>0.40</td>
</tr>
<tr>
<td>2. Extension of time prevention</td>
<td>5.00</td>
<td>1.00</td>
<td>0.20</td>
<td>2.10</td>
</tr>
<tr>
<td>3. Cost overrun prevention</td>
<td>7.00</td>
<td>5.00</td>
<td>1.00</td>
<td>4.30</td>
</tr>
</tbody>
</table>
Figure 0-15: Pairwise comparison of benefits of stakeholders' perceived values with respect to OSM and traditional method of construction

Figure 0-15 above is a screenshot of the pairwise comparison of the benefits of stakeholders’ perceived values selected in the tool. It shows the pairwise comparison of the benefits against OSM and the traditional method of construction. This comparison expresses the capacity of OSM and the traditional method of construction to meet the benefits of stakeholders’ perceived values, as selected by the stakeholders.

The results of the pairwise comparisons in Figure 0-13, Figure 0-14 and Figure 0-15 are shown in Table 0-12. This table displays the relative weight of the benefits of stakeholders’ perceived values, OSM and the traditional method of construction. The relative weights of the benefits are added up to generate the sum of the relative weight of the stakeholders’
perceived value. Further, the relative weight of the benefits is summed to calculate the relative weight of OSM and the traditional method of construction. The sums of the relative weights of OSM and the traditional method of construction are compared to determine the method of construction with greater benefit. However, the relative weights of OSM and the traditional method of construction are not only the criteria used to select a suitable method of construction—the cost implication of the two methods is also taken into consideration.
Table 0-12: Relative weights of the benefits of stakeholders’ perceived values, OSM and traditional method of construction

<table>
<thead>
<tr>
<th>Benefits of stakeholders’ perceived values</th>
<th>Relative weight</th>
<th>OSM benefits</th>
<th>Traditional method benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefits of time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Claim avoidance</td>
<td>0.4</td>
<td>0.6</td>
<td>3.0</td>
</tr>
<tr>
<td>2. Extension of time prevention</td>
<td>2.1</td>
<td>0.6</td>
<td>3.0</td>
</tr>
<tr>
<td>3. Cost overrun prevention</td>
<td>4.3</td>
<td>0.6</td>
<td>4.0</td>
</tr>
<tr>
<td><strong>Benefits of cost</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. High market demand</td>
<td>0.4</td>
<td>0.6</td>
<td>3.0</td>
</tr>
<tr>
<td>2. Affordable building</td>
<td>3.4</td>
<td>4.0</td>
<td>0.6</td>
</tr>
<tr>
<td>3. Cost certainty</td>
<td>5.0</td>
<td>3.0</td>
<td>0.6</td>
</tr>
<tr>
<td><strong>Benefits of quality</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Building’s rework minimisation</td>
<td>0.5</td>
<td>4.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2. Durability</td>
<td>3.0</td>
<td>5.0</td>
<td>0.6</td>
</tr>
<tr>
<td>3. Lower maintenance cost</td>
<td>2.1</td>
<td>2.0</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Benefits of lifecycle cost</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Cost saving for users</td>
<td>4.3</td>
<td>5.0</td>
<td>0.6</td>
</tr>
<tr>
<td>2. High economic value building</td>
<td>1.4</td>
<td>0.7</td>
<td>2.0</td>
</tr>
<tr>
<td>3. High market building</td>
<td>0.5</td>
<td>0.6</td>
<td>3.0</td>
</tr>
<tr>
<td><strong>Benefits of energy consumption</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Lower energy bills</td>
<td>4.3</td>
<td>3.0</td>
<td>0.6</td>
</tr>
<tr>
<td>2. Reduced greenhouse gas emission</td>
<td>0.5</td>
<td>5.0</td>
<td>0.6</td>
</tr>
<tr>
<td>3. Health and wellbeing impact</td>
<td>1.4</td>
<td>2.0</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Benefits of sick building syndrome</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Employee illness minimisation</td>
<td>2.3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2. Medical cost reduction</td>
<td>1.4</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>3. Increased staff productivity</td>
<td>0.6</td>
<td>2.0</td>
<td>0.7</td>
</tr>
</tbody>
</table>

5.9 Cost pairwise comparison for hypothetical scenario B

Cost comparison is part of ANP principle in the decision making process. It indicates the cost associated with selecting OSM and the traditional method of construction. A higher value is assigned to the method with higher cost, and vice versa. Figure 0-16 shows a screenshot of the pairwise
comparison of the cost associated with the use of OSM and the traditional method of construction. In addition, Table 0-13 shows the calculation of the pairwise comparison of the cost in Figure 0-16. This table indicates the relative weight of the costs, based on stakeholders’ preferences.

Figure 0-16: Cost comparison of OSM and traditional method of construction

Table 0-13: Matrix calculation of cost comparison of OSM and traditional method of construction

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance cost</td>
<td>1.00</td>
<td>3.00</td>
<td>0.20</td>
<td>0.14</td>
<td>0.11</td>
</tr>
<tr>
<td>Operating cost</td>
<td>0.33</td>
<td>1.00</td>
<td>3.00</td>
<td>3.00</td>
<td>0.14</td>
</tr>
<tr>
<td>Rework cost</td>
<td>5.00</td>
<td>0.33</td>
<td>1.00</td>
<td>3.00</td>
<td>0.20</td>
</tr>
<tr>
<td>Method</td>
<td>Transportation cost</td>
<td>OSM</td>
<td>Traditional method</td>
<td>OSM</td>
<td>Traditional method</td>
</tr>
<tr>
<td>-----------------</td>
<td>---------------------</td>
<td>-----</td>
<td>--------------------</td>
<td>-----</td>
<td>--------------------</td>
</tr>
<tr>
<td>Construction cost</td>
<td>7.00</td>
<td>0.33</td>
<td>0.33</td>
<td>1.00</td>
<td>0.14</td>
</tr>
<tr>
<td>Construction cost</td>
<td>9.00</td>
<td>7.00</td>
<td>5.00</td>
<td>7.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Determining the cost implications of the selected method of construction is the next step after calculating the relative weight of the costs. This method enables stakeholders to know the best construction method that is the most cost effective. Each of the costs is pairwise compared against OSM and the traditional method of construction. Figure 0-17 shows a screenshot of the pairwise comparison of the costs against the two methods of construction in the decision making tool.
Figure 0-17: Cost comparison for hypothetical scenario B

Table 0-14: Cost comparison of the maintenance cost

<table>
<thead>
<tr>
<th>1. Maintenance cost</th>
<th>OSM</th>
<th>Traditional method</th>
<th>Relative weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSM</td>
<td>1.0</td>
<td>0.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Traditional method</td>
<td>5.0</td>
<td>1.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Table 0-15: Cost comparison of the operating cost

<table>
<thead>
<tr>
<th>2. Operating cost</th>
<th>OSM</th>
<th>Traditional method</th>
<th>Relative weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSM</td>
<td>1.0</td>
<td>0.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Traditional method</td>
<td>0.2</td>
<td>1.0</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Table 0-16: Cost comparison of rework cost

<table>
<thead>
<tr>
<th>3. Rework cost</th>
<th>OSM</th>
<th>Traditional method</th>
<th>Relative weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSM</td>
<td>1.0</td>
<td>0.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Traditional method</td>
<td>3.0</td>
<td>1.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Table 0-17: Cost comparison of transportation cost

<table>
<thead>
<tr>
<th>4. Transportation cost</th>
<th>OSM</th>
<th>Traditional method</th>
<th>Relative weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSM</td>
<td>1.00</td>
<td>5.00</td>
<td>3.0</td>
</tr>
<tr>
<td>Traditional method</td>
<td>0.20</td>
<td>1.00</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Table 0-14, Table 0-15, Table 0-16 and Table 0-17 present the cost comparison calculations of four of the five costs considered for the selection criteria of OSM and the traditional method of construction. They indicate the relative weights of the costs related to OSM and the traditional
method of construction, and indicate the likely cost for OSM and the traditional method of construction. The costs are added to determine the total cost associated with the adoption of OSM and the traditional method of construction.

Figure 0-18 shows the output of the pairwise comparison of hypothetical scenario B. The result indicates the sum of the relative weight of OSM benefits, sum of the relative weight of traditional method benefits, sum of the relative weight cost of OSM, sum of the relative weight cost of the traditional method of construction, benefit to cost ratio of OSM, and benefit to cost ratio of the traditional method of construction.

![Pairwise comparison output of hypothetical scenario B](image)

Figure 0-18: Pairwise comparison output of hypothetical scenario B
5.10 Comparison of the results from hypothetical scenarios A and B

The comparison of hypothetical scenario A and B results assists in understanding the reason behind the changes in the decision tool output. Hypothetical scenarios A and B include developers and end users, respectively, with different perceived values. The difference in their perceived values is the reason for the variation in the decision making tool output.

With respect to hypothetical scenario A, where the stakeholder selected **Time, Cost, Quality, Safety, Lifecycle Cost** and **Return of Investment** as their perceived values, the decision making tool generated a benefit to cost ratio for OSM of 7.0 and for the traditional method of construction of 1.4, as depicted in Figure 0-8. In contrast, hypothetical scenario B, with **Time, Cost, Quality, Lifecycle Cost, Energy Consumption** and **Sick Building Syndrome** as its perceived values, generated a benefit to cost ratio for OSM of 7.1 and for the traditional method of construction of 1.3, as shown in Figure 0-11.

The output of the decision making tool explained above indicates that the output is subjected to the stakeholders’ perceived value and judgemental process. There are differences in the ranking of the perceived value in hypothetical scenarios A and B, as illustrated in Table 0-2 and

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Time</th>
<th>Cost</th>
<th>Quality</th>
<th>Lifecycle cost</th>
<th>Energy consumption</th>
<th>Sick building syndrome</th>
<th>Total</th>
<th>Criteria weight</th>
<th>Consistency measure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time</strong></td>
<td>0.04</td>
<td>0.06</td>
<td>0.18</td>
<td>0.02</td>
<td>0.01</td>
<td>0.13</td>
<td>0.43</td>
<td>0.07</td>
<td>9.53</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>0.36</td>
<td>0.53</td>
<td>0.42</td>
<td>0.29</td>
<td>0.52</td>
<td>0.38</td>
<td>2.49</td>
<td>0.42</td>
<td>9.35</td>
</tr>
<tr>
<td><strong>Quality</strong></td>
<td>0.01</td>
<td>0.08</td>
<td>0.06</td>
<td>0.29</td>
<td>0.02</td>
<td>0.13</td>
<td>0.58</td>
<td>0.10</td>
<td>8.48</td>
</tr>
<tr>
<td><strong>Lifecycle cost</strong></td>
<td>0.20</td>
<td>0.18</td>
<td>0.02</td>
<td>0.10</td>
<td>0.03</td>
<td>0.21</td>
<td>0.74</td>
<td>0.12</td>
<td>9.07</td>
</tr>
<tr>
<td><strong>Energy consumption</strong></td>
<td>0.36</td>
<td>0.11</td>
<td>0.30</td>
<td>0.29</td>
<td>0.10</td>
<td>0.13</td>
<td>1.29</td>
<td>0.21</td>
<td>9.49</td>
</tr>
<tr>
<td><strong>Sick building syndrome</strong></td>
<td>0.01</td>
<td>0.06</td>
<td>0.02</td>
<td>0.31</td>
<td>0.04</td>
<td>0.46</td>
<td>0.08</td>
<td>10.97</td>
<td></td>
</tr>
<tr>
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<td>-------</td>
<td></td>
</tr>
<tr>
<td>Consistency index</td>
<td>−1.17</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random inconsistency index</td>
<td>1.24</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consistency ratio</td>
<td>−0.94</td>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>
Table 0-10. In summary, the selected perceived value and stakeholders’ pairwise comparison calculation are the key factors in the results generated by the decision making tool.

5.11 Discussion

This section provides an overview of the results presented in Chapters 3, 4 and 5 in relation to the existing knowledge in Chapter 2. This section is organised in relation to the research questions and objectives. It indicates the relationship between the previous study on OSM and the research results. This leads to the discussion of contributions made by this study and the paper’s conclusion in Chapter 6.

5.11.1 Research questions and objectives

With respect to the research questions and objectives, this section discusses the stakeholders’ perceived values in selecting OSM and the traditional method of construction. It also explains the decision making tool that guided the stakeholders in the decision process, discusses the current state of OSM in Australia, and identifies the core stakeholders involved in decision making between OSM and the traditional method of construction. The discussion is based on four scenarios: (i) the results’ capacity to fit the existing body of knowledge, (ii) the consistency of the results with the current theories, (iii) the suggestion of new results, and (iv) the suggestion of new insights (Wolfe, 1996).

This study furthers previous studies on the decision making process for choosing between OSM and the traditional method of construction by providing the stakeholders’ perceived value parameters using a combination of sustainable values and facilities management factors, which previous studies omitted. It also presents tool development based on the benefit to cost ratio, rather than the perceived values or drivers, as seen in Pan (2006) and other decision making studies.

5.12 Current state of OSM and traditional method of construction in Australia

The goal of this study is to understand the current trends in Australia of OSM in comparison to the traditional method of construction. This study indicates that there is a limited uptake of OSM in Australia and other developed countries, compared to the traditional method of construction. This is due to the lack of understanding of the benefits of OSM over the traditional method of construction, and limited knowledge of the decision criteria and a decision making
tool to assist stakeholders in selecting an appropriate construction method based on the benefit to cost ratio.

Further, this study reveals the significance of knowledge of stakeholders’ management during decision making for OSM and the traditional method of construction. There are limited studies examining stakeholders’ management, which entails identifying the core decision makers and decision variables. This study contributes to the existing research knowledge on OSM by presenting a method of stakeholder identification and their perceived values, and how to capture these perceived values.

5.13 Stakeholders’ perceived values

The result of the critical literature review revealed that previous studies on OSM and the traditional method of construction only considered the drivers as the parameters for stakeholder perceived values, and ignored the sustainability values, facilities management parameters, and whole-life costing. This is one of the problems identified in the decision making process and decision tool when choosing between OSM and the traditional method of construction. In contrast, this study’s results presented stakeholders’ perceived values as parameters for decision making. This is a contribution to the body of knowledge on OSM and the traditional method of construction because the previous limited studies on OSM only highlighted the barriers to OSM, and did not explore value classification based on stakeholders’ perspectives.

This study also identified the core stakeholders in the decision making process of OSM and the traditional method of construction, based on an extensive literature. In the decision process, it is imperative to identify the core decision makers that influence the decision making. This study presented the core stakeholders when choosing between OSM and the traditional method of construction via an extensive literature review.

There are numerous methods of capturing stakeholders’ perceived values in the decision making process. The results from this study explained the various types of value-capturing methods, and justified the selection of an appropriate method. Ultimately, this study employed the concept of ANP and demonstrated how the ANP concept can assist in the decision making process and developing a network of the perceived values.
5.14 Development of decision making tool using VBA

As part of the research aims, this study developed a decision making tool to help stakeholders choose between OSM and the traditional method of construction. The tool was developed using the ANP procedure in conjunction with the VBA process. The tool consisted of 11 stakeholders’ perceived values. The values encapsulate sustainability value, facilities management parameters, and the whole-life costing of a building. The tool further considered the benefits of the perceived values.

The mechanism behind the functionality of the decision making tool was the pairwise comparison of the perceived values, benefits of the perceived values, and the costs. The relative weight of the perceived values was displayed on the decision tool for the stakeholders to see the rank of the selected value. In addition, the relative weight of the benefits of the stakeholders’ perceived values was calculated alongside the costs associated with the development of OSM and the traditional method of construction.

The benefit to cost ratio was calculated to determine the construction method that was capable of generating the best value that was most cost effective to the stakeholders. The results from the study add to the existing body of knowledge by considering the benefit to cost ratio in the decision making process between OSM and the traditional method of construction.

5.14.1 Discussion of validation of the decision making tool

Validation of the decision making tool provides the outcome of the tool while conducting the test on hypothetical scenarios. The main reason for the validation of the tool is to check the workability of the tool. The hypothetical scenario A was based on six criteria: Time, Cost, Quality, Safety, Lifecycle Cost and Return of Investment. The criteria were pairwise compared to determine the relative weight of the perceived values. The results in Table 0-7 and Figure 0-8 justify the validity of the tool because the manual calculations of the relative weights of the stakeholders’ perceived values, relative weights of OSM and the traditional method of construction, and benefit to cost ratio of OSM and the traditional method of construction were the same as the output of the decision making tool.

Hypothetical scenario B was based on six criteria: Time, Cost, Quality, Lifecycle Cost, Energy Consumption and Sick Building Syndrome. The criteria were pairwise compared to determine the relative weights of the selected perceived values. The results in Table 0-12 and
Figure 0-18 justify the validation of the tool. Similar to hypothetical scenario A, the decision making tool output for the relative weights of the stakeholders’ perceived values, relative weights of OSM and the traditional method of construction, and benefit to cost ratio of these two construction methods was similar to the results from the manual calculation.

5.15 Characteristics of decision making tool

The decision making tool in this study provides new insight to the decision making process by considering the benefit to cost ratio and the network of perceived values. Some questions might emerge from stakeholders regarding the validity of the tool and its contribution to the body of knowledge about decision making between OSM and the traditional method of construction. For example: What is the advantage of using a decision making tool? What is the difference between the tool and other developed decision making tools in OSM? These questions are addressed with the following points:

- The decision making tool established stakeholders’ perceived values’ relative weights and ranks, based on stakeholders’ needs, in order of the significant outcomes in the decision making process in order to choose between OSM and the traditional method of construction.
- The decision making tool can be used in the construction industry to improve the quality of information upon which decisions in construction projects are based. Further, it can help construction professionals or industries make decisions based on adequate and robust perceived values, rather than the time, cost, quality, or function and cost.
- The decision making tool was developed based on stakeholders’ perceived values, whole-life costing parameters, and the facilities management concept, which need to be considered when choosing between adopting OSM or the traditional method of construction as a construction strategy.
- The decision making tool considers the lifecycle cost in project evaluation as a factor in decision making, which other models fail to consider. It considers costs beyond the total construction cost, which is common practice in the construction industries.

5.16 Limitations of the decision making tool

This study’s decision making tool has numerous advantages and features in its operation, which have been highlighted in the previous chapters of this thesis. Nevertheless, there are limitations in the application of this decision making tool, as follows:
• The tool does not take into account the opportunities and risk in the decision making process, in contrast to the ANP software by Saaty (1990). This was avoided to allow simplicity in the operation of the tool.

• The tool was not designed to generate sensitivity analysis graphs of the perceived value, as seen in the ANP software by Saaty (1990). The user needs to calculate this based on the relative weights of the benefits of the stakeholders’ perceived values, and the weights of the benefits of the alternatives.

• The tool does not provide a means to draw the network of the selected values, in comparison to the ANP software, which provides symbols to draw the network of the perceived values and costs.

5.17 Chapter summary

This chapter has presented the validation of the study to check whether the tool output conformed to the manual calculations of ANP in choosing between OSM and the traditional method of construction. The study employed hypothetical scenarios to validate the tool. The results of the hypothetical scenarios substantiated the robustness of the tool, and indicated that the tool can be adopted to choose between OSM and the traditional method of construction.

Finally, this chapter explained how the research questions and objectives were achieved through the tool validation process. In addition, this chapter discussed the characteristics and limitations of the decision making tool.
Chapter 6

Conclusions

This final chapter concludes the study by addressing the research gaps, questions, objectives and aims. It also presents the key research findings and outcomes of this study, after discovering the stakeholder perceived values and developing the decision making tool. Further, it highlights the study’s contributions to the body of knowledge, and discusses the research limitations and recommendations for future research work.

6.1 Research questions discourse

The research questions for this study were as follows:

- **RQ1**: What are stakeholders’ perceived values in OSM over the traditional method of construction in Australia, and how can they be captured?
- **RQ2**: How can a decision making tool be developed to assist construction stakeholders to select between OSM and the traditional method of construction?

This study presented stakeholders’ perceived values through an extensive literature review. It used a combination of sustainable value parameters, the facilities management concept, and whole-life costing factors. The research emphasised that capturing stakeholders’ perceived values consists of identifying the core stakeholders and their perceived values. The research presented 11 stakeholders’ perceived values for the decision making tool.

While previous studies have focused on drivers and barriers as the motivating factors for stakeholders in the decision making process, this study developed this principle to determine 11 stakeholders’ perceived values that encapsulated sustainability value, facilities management, and whole-lifecycle cost parameters.

6.2 Achievement of research aims and objectives

*The aims of this research were to capture stakeholders’ perceived values and develop a decision making tool for construction industries to use during the decision making process of*
selecting between OSM and the traditional method of construction. The literature review presented in Chapter 2 provided an overview of the stakeholders’ perceived values in total, while Chapter 4 presented the tool development for choosing between OSM and the traditional method of construction. The research achieved its aims through the objectives presented in Section 1.3. In response to the outline of the research objectives provided in Chapter 1, this section discusses the achievement of the research objectives through this study.

6.2.1 Objective one

The first objective was to explore the current state of OSM in Australia and other international developed countries. To achieve this objective, this study used a critical review of the literature to analyse the previous and current knowledge of state-of-the-art OSM and the traditional method of construction in Australia and international developed countries. To begin, the research reviewed understandings of OSM and the traditional method of construction to establish the concepts of these two types of construction, as seen in Section 2.3 in Chapter 2. In addition, Section 2.3 provided a comparison of the percentage use of OSM and the traditional method of construction. Lastly, Sections Error! Reference source not found. and 2.6 identified the rate of adoption of OSM in Australia and other international developed countries, compared to the traditional method of construction.

6.2.2 Objective two

The second objective was to identify the core stakeholders and the values that influence their decisions towards the uptake of OSM over the traditional method of construction, or vice versa. The objectives were achieved through an extensive literature review and industrial project consultation in Section 2.9. The results from the study indicated the need for stakeholders’ management in the decision making process. They also highlighted the core stakeholders in the decision making process. Further, the study examined the concept of value and the parameters that drive stakeholders’ motivation to choose OSM over the traditional method of construction. The results presented the definition of values and their parameters in Section 2.10. The results of the study considered having a holistic and relative measure that covered the entire life of the selected construction strategy.

6.2.3 Objective three

The third objective was to develop a robust and user-friendly decision support tool for stakeholders to select between OSM and the traditional method of construction. To achieve
this objective, the stakeholders’ perceived values and benefits in Section 2.10 were used as the parameters for the decision tool. The tool was developed via VBA in Excel using the ANP concept. The tool calculated the relative weight of the selected stakeholders’ perceived value and the benefit to cost ratio.

The decision making tool can be used in the construction industry when choosing between OSM and the traditional method of construction. Thus, objective three was achieved because the decision making tool is capable of generating the relative weights of the decision criteria and the benefit to cost ratio needed for decision making.

6.2.4 Objective four

The fourth objective was to validate the decision support tool via inputting the stakeholders’ data into the VBA tool. This study has provided a decision making tool comprising six major processes, as shown in Section 4.1. The process was derived through an extensive literature review, as well as through industrial consultation and information technology knowledge. This research validated the tool through hypothetical scenarios. The findings revealed that the use of OSM is the best option compared to the traditional method of construction. However, it is difficult to generalise the result as stakeholders’ needs and preferences change with time. Regardless, the result is valid and can be used by stakeholders during the decision making stages.

6.3 Contributions of the study

This study contributes to the body of knowledge by developing a decision making tool to choose between OSM and the traditional method of construction. Limited studies have designed decision making tools to select between OSM and the traditional method of construction. This decision making tool will help stakeholders during decision making regarding the adoption of OSM or the traditional method of construction.

Further, this research contributes to the existing knowledge on OSM and the traditional method of construction in four ways. This study:

1. established the 11 core stakeholders’ perceived values for the decision parameters when selecting between OSM and the traditional method of construction
2. incorporated the benefits of the stakeholders’ perceived values as the sub-criteria for the decision making process
3. adopted the benefit to cost ratio as a determinant factor in selecting between OSM and the traditional method of construction
4. established the stakeholders involved in the decision making process of OSM and the traditional method of construction, and shed light on the significance of stakeholders’ management and the need to involve stakeholders in the predesign stage of project development.
5. Establishment of the current state of arts of OSM in Australia and other developed countries through a critical review of the literature
6. Development of a tool that assist in the decision making process in the selection between OSM and traditional method, which previous studies did not considered
7. The identification of the stakeholders’ perceived values

To conclude, in terms of methodology and practical understanding, this study contributes to the body of knowledge in relation to stakeholders’ perceived values and the decision making tool.

6.4 Study implications for construction industry

This study provides a practical contribution to the construction industry and other stakeholders during the decision making stages. It provides a robust decision making tool that enables the stakeholders to make a critical judgement based on their perceived values, the benefits of the perceived values, and the lifecycle costs. The decision making tool is simple, with solid perceived values parameters from Pan (2006) and Blismas and Wakefield (2009) that cover the whole life of the building. The construction industry can use the decision making tool during the feasibility stage, decision making process and mapping of the decision criteria.

In conclusion, the practical implications of this study are twofold. First, in the construction industry, the outcome of decision making can be incorporated into the development process of the company’s construction project. This will enable the production of construction services that generate value to stakeholders. Second, for individual companies, the outcome of the decision making tool can assist in shaping the decision making process. This will improve customer satisfaction and the profitability of the company.
6.5 Limitations of the study

Despite the critical literature review and rigorous data analysis, this study had a number of limitations identified during the research, as follows:

- The decision making tool does not provide a means to network the selected perceived values or the benefits of the stakeholders’ perceived values and costs.
- The decision making tool uses hypothetical scenarios for tool validation due to limited case studies on choosing between OSM and the traditional method of construction.
- The decision making tool only uses the benefit to cost ratio output as a yardstick for selecting between OSM and the traditional method of construction. It does not consider the opportunities and risks, as seen in the ANP software by Saaty (2008).
- The decision making tool does not undertake sensitivity analysis automatically; thus, users need to complete this analysis manually.

6.6 Recommendations for future research

This study was undertaken in response to the current trends and major challenges in decision making regarding the adoption of OSM and the traditional method of construction. To continue to benefit from the decision making tool, it is important to develop the present study. This led to the following recommendations for future research:

- This study developed a decision tool without providing a means to network the stakeholders’ perceived values and benefits of the stakeholders’ perceived values and costs. Thus, it is recommended that future studies incorporate a tool for networking using either C++ or Java programming language. Networking is important in ANP because it helps stakeholders view the interaction between the selected perceived values and benefits of the perceived values and costs.
- Hypothetical scenarios adopted to validate the tool in this study. Although the use of hypothetical scenarios does not restrict the validity of the tool, future studies should use case studies to validate the tool in order to reveal the real perspectives of different stakeholders on selecting between OSM and the traditional method of construction. By doing this, the construction industry will understand the perceived values required by stakeholders, which will assist them in the development of OSM.
- The benefit to cost ratio used as a yardstick for selecting between OSM and the traditional method of construction. It is recommended that future studies include risk in
their decision making tool. This is because risk is inevitable in any construction development. Thus, by including risk, stakeholders can select the construction method with the least risk.

- Sensitivity analysis calculation was not included in this study’s tool development due to the limitation in the scope of VBA. Thus, it is recommended that future studies include sensitivity analysis because it enables stakeholders to view the effect of changes via the relative weight of one perceived value over others.

6.7 Conclusion

This study was conducted in response to the need to improve the uptake of OSM in Australia through comparing the perceived value attributes of OSM and the traditional method of construction. Specifically, this study aimed to capture stakeholders’ perceived values and develop a decision making tool for choosing between OSM and the traditional method of construction. To achieve the aims of this study, a critical review was undertaken to capture the stakeholders’ perceived value attributes. In addition, a decision making tool was developed. The tool was developed using 11 stakeholders’ perceived values attributes, ANP principles and VBA. For study completeness, hypothetical scenarios were employed to validate the tool. The results from the tool provided support for the tool validity, as derived from the hypothetical scenarios.

Underpinned by the research findings mentioned herein, this study sheds more light on stakeholders’ management by explaining the importance of stakeholders in the selection of construction methods, and the motivating factors that drive their desire to adopt one construction method over another. This study further explains the concept of value and its significance in selecting between OSM and the traditional method of construction. Moreover, this study offers practical implications to the construction industry by offering a decision tool that generates robust outcomes, which can be used to develop construction projects. The tool can also assist end users to select the construction method with the most value.

Finally, this thesis has concluded with recommended future research directions that can pave the way for other researchers and construction professionals who are willing to extend the current findings on value capturing and using this decision making tool to choose between OSM and the traditional method of construction.
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