APPRAISING THE OPPORTUNITIES AND CHALLENGES OF MODULAR CONSTRUCTION IN MALAYSIA

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A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Science (Honours) Quantity Surveying

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

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ABSTRACT

The rising of construction waste, emissions of greenhouse gases, project delays and site accidents have alerted the construction stakeholders to look for alternative construction methods. Modular Construction is a modern construction technology where the building elements are produced in a controlled environment and transported to the site for installation. This study aims to investigate the opportunities and challenges of modular construction in Malaysia and bridge the knowledge gap by developing statistical correlations between the challenges and strategies. Following a comprehensive literature review, 20 opportunities of modular construction, 10 challenges of modular construction and 10 strategies to enhance the implementation of modular construction had been identified. 120 responses were collected from the developers, consultants and contractors within the Klang Valley area. The Mean Ranking showed the five most significant opportunities of modular construction were 1) improve project schedule and productivity; 2) better quality; 3) cost-efficient and effective; 4) sustainable; and 5) better occupational safety and health. Besides, 1) transportation constraint; 2) lack of skilled personnel; time-consuming planning and design; 4) high initial cost; and 5) lack of social knowledge were the five most critical challenges. Meanwhile, the three most effective strategies were 1) government incentives and subsidies; 2) training and education; and 3) research and development. Moreover, the government incentives and subsidies; training and education, establish effective logistic and supply chain management; and research and development were found to be significant correlated with the challenges through Spearman’s Correlations test. Lastly, the Factor Analysis disclosed four underlying factors relating to the opportunities, namely corporate social responsibilities; efficient project control; climate and resources consumption; and competitiveness. The construction industry should promote sustainable development through modular construction to make contribution to the society and natural environments. These findings can serve as a reference point for CIDB to facilitate modular construction in Malaysia and to raise the awareness of sustainable development among the construction stakeholder and public.

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LIST OF SYMBOLS / ABBREVIATIONS

α	Cronbach's alpha reliability coefficient
AI	artificial intelligence
AR	augmented reality
BCA	Building and Construction Authority
BIM	building information modelling
BRI	Belt and Road Initiative
CAD	computer-aided design
CAM	computer-aided manufacturing
CIDB	Construction Industry Development board
CREAM	Construction Research Institute of Malaysia
CO2	carbon dioxide
DOSH	Department of Occupational Safety and Health
DOSM	Department of Statistics Malaysia
ECI	early contractor involvement
ECRL	East Coast Rail Link
GDP	gross domestic product
GFA	gross floor area
GIS	geographic information system
GHG	greenhouse gas
GPS	Global Positioning System
IBS	Industrialised Building System
IBSMS	Industrialised Building System Modular System
IoT	Internet of Things
JIT	Just-in-Time
IR 4.0	Fourth Industrial Revolution
LCC	life cycle cost
MBAM	Master Builders Association Malaysia
MBPP	Penang Island City Council
MMC	modern method of construction
MiC	modular integrated construction

MyCREST	Malaysian Carbon Reduction and Environmental Sustainability Tool
OSM	off-site manufacture
PPVC	prefabricated prefinished volumetric construction
RFID	radio frequency identification
SPSS	Statistical Package for the Social Sciences
UK	United Kingdom
US	United States
VOCs	volatile organic compounds

CHAPTER 1

INTRODUCTION

1.1 General Introduction

Chapter 1 introduces the study background and problem statement. The research questions are drawn out and the aims and objectives are identified. The methodology used and the scope of study are also provided as well. Next, the abstracts of the following chapters are briefly described, with a summary of Chapter 1 is provided.

1.2 Background of Study

The construction industry is an important economic sector in both developed and developing countries. According to Statista (2022), construction industry had made up about 8% of global GDP which accounting to 7.3 trillion United States (US) dollars in 2021. Since the construction industry is labour-intensive, it creates various jobs for people such as architects, engineers, quantity surveyors and labours. In the US, the number of employees played in the construction industry was 8.35 million people (Yoders, 2022) out of 333 million people as of 2021 (Macro Trends, 2022). Obviously, the construction industry is a major driver of economies and household income in the country.

Similarly in Malaysia, the construction industry is a significant economic sector. According to the Department of Statistics Malaysia (DOSM) (Mahidin, 2022), the gross domestic product (GDP) contributed by the construction sector was 6.4% in the fourth quarter of 2021. Compared to the mining and quarry sector with a contribution of 3.4%, the construction industry plays a more crucial role to the development of Malaysia. Besides, there were 12,893 construction projects had been awarded in 2021, with a total value of RM 128.37 billion (Construction Industry Development Board, 2022a). On the other hand, the Department of Statistics Malaysia (2022) also showed that there are 1.16 million people employed in the construction industry, which accounting to 7.7% of workforce among all sectors in 2021. More importantly, the construction industry has become a hotspot to attract the investment of foreign capital. Meanwhile, Malaysia is one of the beneficiaries of the Belt and Road Initiative (BRI) with the investment in mega projects such as the East Coast Rail Link (ECRL) and Bandar Malaysia (Grassi, 2020).

From then till now, the industrial revolutions are shifting every industry from manual to machines. The acceleration of technological innovation brings a massive change in technical, cultural and socioeconomic aspects, and the world is in Fourth Industrial Revolution (IR 4.0) today. To prevent falling behind other industries, the construction industry should combine the concept of IR 4.0 and connect it with the rapid development of more intelligent technologies and systems. Hence, the Construction Industry Development Board (CIDB) establishes the Construction 4.0 Strategy Plan (2021-2025). It provides a roadmap for the transformation of the Malaysian construction industry into a more innovative, productive and sustainable sector (Construction Industry Development Board, 2020a). Twelve “disruptive technologies” with the potential to shift the future of construction industry have been identified. This includes the Prefabrication and Modular Construction, Building Information Modelling (BIM), Autonomous Construction, Augmented Reality (AR) and Virtualisation, Cloud and Real Time Collaboration, 3D Scanning and Photogrammetry, Big Data and Predictive Analysis, Internet of Things (Iot), 3D Printing and Additive Manufacturing, Advanced Building Materials, Blockchain, as well as the Artificial Intelligence (AI). From this, prefabrication and modular construction become the drivers to transform the construction industry.

Since 2003, the CIDB has promoted prefabrication construction method in the construction industry through the Industrial Building System (IBS) (Mydin, Sani and Taib, 2014) after Malaysia first explored prefabrication in 1960 (Construction Industry Development Board, 2016). IBS is the construction technique where the building components are mass prefabricated under a controlled environment with little additional site work for their installation. For instance, landmark buildings such as Petronas Twin Tower adopted the IBS solution by utilising the prefabricated component when constructing the building. Prefabricated construction can benefit the construction industry with shorter construction time, safer working conditions and waste reduction if compared to conventional construction method (Murali and Sambath, 2020; Khahro, et al., 2019; Navaratnam, et al., 2019; Jagtap and Dhawade, 2015).

Meanwhile, prefabrication and modular construction are waving in the industry. A report from McKinsey defined modular construction as a structure with standardised components produced in the off-site factory before assembling them on-site (Bertram, et al., 2019). According to Modular Building Institution (2022), modular construction is the process by which the building's elements, components and modules are produced under a controlled factory environment and are ready to assemble on the site. The concept of modular construction can be dated back to the early 18th century when prefabricated house was shipped in pieces from England to Australia for assembly. By 1853, hundreds of these modular builds were sent to Australia, and they became quickly appeared globally (Thurston Building Innovation, 2018). In the mid-19th century, the "kits homes" that consisted of all building materials needed were promoted to the public by the American manufacturers. After buying the home kits, the buyers can build the house themselves or hire the construction team to help them make the house following the instructions. This formed the basic idea of modular construction. Then, these manufactured houses gained popularity to fulfil housing demands after World War 2 due to their speed and efficiency of erection (Hannah, 2020).

Modular construction is also known as off-site prefabrication or modern method of construction (MMC). It is a popular construction method in developed countries such as the United Kingdom (UK), US and Japan (Musa, et al., 2016a). Many projects in the neighbourhood country, Singapore, also implemented the modular construction method. For example, the Crowne Plaza Changi Airport, NTU North Hill Residence Hall and The Clementi Canopy Condominium (Liew, Chua and Dai, 2019). In Malaysia, the terminology that represents prefabrication is IBS. There are six IBS classification which are the blockwork system, formwork system, timber framing system, precast component system, steel frame system and other prefabricated components (Construction Industry Development Board, 2023). Meanwhile, local researchers such as Musa, et al. (2016) have explored the organisational readiness framework for the Industrialised Building System Modular System (IBSMS). It advised that the IBS approach should be adapted to effectively implement the modular construction in Malaysia. The researcher further claimed that modular construction could significantly promote environmental, economic and social sustainable. Therefore, the Malaysian construction industry needs to explore modern methods of construction such as modular construction to move Malaysia towards the status of a developed country.

1.3 Problem Statement

The human population is increasing year by year. Therefore, urbanisation tends to become more significant when people move to the cities from the rural areas to enjoy the benefits of the cities, including better education, jobs, entertainment and facilities. In 2020, around 78% of the total population of Malaysia stayed in the cities or urban areas (O'Neill, 2022). Cities are becoming denser as the population continues to increase. However, the trend of urbanisation can benefit the construction industry as people demand housing, transportation, workplace, etc., to survive in the urban areas. To meet and manage the needs of this huge population, the construction industry should be more innovative and sustainable in setting up the building structures such as houses, hospitals, schools and hotels.

However, the construction industry faces various problems that will negatively impact the construction stakeholders, society and the environment. According to the mayor of Penang Island City Council (MBPP), MBPP receives 235 tonnes of construction waste daily which is around 20% of the total waste (Lo, 2021). This will lead to environmental issues as the land will be polluted, greenhouse gas (GHG) will be emitted and post public health at dangerous when the waste goes for landfilling (Mah, Fujiwara and Ho, 2018). Besides, long construction time is one of the basic characteristics of the construction project. Poor productivity and project delay become the major problem faced by the Malaysian construction industry because various uncertainties can occur on site due to the lengthy construction period. Ullah, et al. (2018) highlighted that the poor weather condition will force the construction work to stop and cause the schedule to be delayed, which in turn leads to cost overrun and dispute between the parties. With a heavy reliance on low-skilled foreign workers, Malaysia's construction industry has been sluggish with low wages and low productivity traps. Najib, et al. (2019) pointed out that the problem facing the Malaysian construction industry is not only the lack of local workforce, but also the drastically reduction of local workforce due to the flight of human capital to foreign countries for better job opportunities. In addition, the construction workers are always at risk due to the dangerous on-site working condition. According to the Department of Occupational Safety and Health (DOSH) (2022), the site incident reported to DOSH from the construction sector in 2020 was 137 cases. Hamid, et al. (2019) found that falling from a high level and falling objects are the leading causes of site accidents.

Meanwhile, the construction industry is having a poor image from the public. Because of the unique nature of the sector, the construction industry has been accused of being dirty, dangerous and unsustainable. Unfortunately, these poor images are the real reflection of the construction industry especially when a construction project is carried out with the conventional construction method. While receiving criticism from the external environment, the construction practitioners should consider how the construction industry can minimise the GHG emission throughout the project lifecycle? How to reduce the construction waste production? How to speed up the construction progress and increase the productivity? Yet, the modular construction method can be a good alternative to answer these questions by replacing conventional construction to offer sustainability. However, the construction players found that it is challenging to take the risk of adopting this construction method (Schoenborn, et al., 2012). Yet, among the new technologies identified by CIDB to transform the construction industry in the era of IR 4.0, modular construction owns the same level of importance as other technologies, which also can make an outstanding contribution in leading the industry to stay competitive in the new transformation (Construction Industry Development Board, 2020b).

Previous studies have emphasised the importance of modular construction. In the US, the identification of factors affecting the decision-making in the modular construction project was conducted by Nabi and El-adaway (2020). Fifty factors were categorised into eight groups, which were cost and profitability, time-related issues, quality-related issues, safety-related issues, environmental-related issues, design and engineering, resources and technology, and regulatory and organisational aspects. Besides, Wang, et al. (2020) from Australia evaluated the digital technologies applied in the modular construction. The researcher had discussed fifteen technologies which included the Geographic Information System (GIS), BIM, Global Positioning System (GPS), IoT and Radio Frequency Identification (RFID). These digital technologies are perceived as the key to enhance the productivity in modular construction. In Hong Kong, Wuni and Shen (2020b) studied the critical success factors for modular construction such as improved supply chain management, good working collaboration and accurate design. By identifying the critical success factors, guidance and improvements can be provided for the successful implementation of modular construction.

In addition, Paliwal, et al. (2021) carried out a study towards the benefits of modular construction in hospitality building project in Las Vegas. The top five benefits of modular construction were schedule improvement, lowest cost, better quality, productivity improvement and better predictability. Furthermore, Nazir, et al. (2021) from UK assessed the advantages and disadvantages of modular construction. This included better durability, cost-effective and speedy construction as the advantages, with lack of flexibility, skills and experiences as the disadvantages. In Singapore, Hwang, Shan and Looi (2018) discussed the constraints and mitigation strategies of modular construction. The main constraints highlighted were the design flexibility, unsupportive decision making and transportation restrictions. With this, the researchers had proposed strategies such as encouraging close collaboration, applying Just-In-Time (JIT) delivery and offering training courses to mitigate the constraints.

Moreover, there are also Malaysian researchers that studied the area of modular construction. El-Abidi, et al. (2019) assessed fifty critical success factors and fifteen sub-factors of modular construction in Malaysia. It found that the government leadership, national policy and corporate leadership were the most vital factors that affected the success of the modular construction project. On top of that, Teh and Zainal (2021) appraised the challenges and strategies to improve the implementation of robotic technology in Malaysian modular construction. The study showed that the investment tax allowance, cooperation and incentives were the most effective strategies to enhance the adoption of robotic technology in modular construction. Apart from these, Rahim and Qureshi (2018) studied the benefits and constraints of modular construction. For instance, time saving, quality improvement and labour reduction were the benefits, while skill shortage, high initial cost and lack of awareness were the constraints. Meanwhile, Aziz and Abdullah (2015) also had reviewed the challenges of modular construction in Malaysia which involved the lack of expertise, lack of coordination and high production cost.

To conclude, many researchers have conducted a study on modular construction. However, most of the studies emphasised on the opportunities of modular construction (Paliwal, et al., 2021; Nazir, et al., 2021; Rahim and Qureshi, 2018) and the challenges of modular construction (Nazir, et al., 2021; Hwang, Shan and Looi, 2018; Rahim and Qureshi, 2018; Aziz and Abdullah, 2015). Besides, the studies that based in Malaysia are still limited. It is needed for the construction stakeholder to realise the advantages of modular construction and adopt this practice in real projects to achieve the core value of the Construction 4.0 Strategy Plan (2021-2025).

Furthermore, it is also noting that little research has focused on the strategies to enhance the implementation of modular construction. The researchers focused primarily on identifying factors individually without demonstrating the relationships between the variable groups. Therefore, this study aims to appraise not only the opportunities and challenges of modular construction, but also to evaluate the strategies to enhance the implementation of modular construction. To bridge the research gap, this study tends to develop a correlation between the challenges of modular construction and the strategies that can improve the adoption of modular construction to demonstrate the effectiveness of a particular strategy as a solution to a particular challenge. The opportunities, challenges and strategies are assessed with the motivation to raise the awareness towards modular construction, hoping to enlighten the Malaysian construction stakeholders.

1.4 Research Question

The following are the research questions of this study:

1. How can modular construction benefit the Malaysian construction industry?
2. Why modular construction is challenging to implement in Malaysia?
3. How to improve the implementation of modular construction in Malaysia?

1.5 Aim

This study is conducted for the purpose to appraise the opportunities and challenges of modular construction in Malaysia.

1.6 Objectives

In this study, the following objectives are set to accomplish the research aim:

1. To evaluate the opportunities of modular construction in Malaysia.
2. To examine the challenges of modular construction in Malaysia.
3. To appraise the strategies to enhance the implementation of modular construction in Malaysia.

1.7 Research Methodology

This study begins by defining the research problem and reviewing the previous research on modular construction. The quantitative research approach was adopted to explore the opportunities, challenges and strategies to enhance the implementation of modular construction in Malaysia. The questionnaire survey was conducted with the potential respondents to collect the data. Besides, the Cronbach's Alpha Reliability test, Mean Ranking, Kruskal-Wallis test, Spearman's Correlation test and Factor Analysis were employed to analyse and interpret the data collected.

1.8 Research Scope

The scope of the study focused on the perceptions of the construction practitioners on the opportunities, challenges and strategies to enhance the implementation of modular construction in Malaysia. The construction stakeholders in the groups of client, consultant and contractor within the Klang Valley area with the knowledge of modular construction were targeted as the respondents in this study. These include a variety of professions such as architects, engineers and quantity surveyors.

1.9 Chapter Outline

This study comprises of five chapters. Chapter 1 provided the reader with a broad background of the study. It included delivering the problem statement and identifying the research gap between the previous studies and current study. This chapter also highlighted the research aims, objectives, methodology, scope and chapter outlines.

Chapter 2 is the literature review part. The definitions and the systems of modular construction were provided. Besides, the opportunities and challenges of modular construction were discussed in detail. Consequently, the strategies to enhance the implementation of modular construction had also been assessed.

Chapter 3 describes the quantitative research methodology employed in this study which involved the use of questionnaire survey. Besides, the research design, sampling design as well as the data collection method were discussed. Also, the data analysis methods that used in this study were defined and described.

Chapter 4 interprets the result of the questionnaire survey. The data collected were analysed with Cronbach's Alpha Reliability test, Mean Ranking, Kruskal-Wallis test, Spearman's Correlation test and Factor Analysis to derive the results. The findings were discussed and compared with the previous research.

Chapter 5 provides a conclusion based on the findings and study objectives. The limitations of current study were discussed with recommendations established for future work.

1.10 Summary of Chapter

Chapter 1 delivers the study background and identifies the research gap. The research questions, research aim, and research objectives are designed to address the problems. Thus, it leads to assess the opportunities, and challenges of modular construction, with the strategies will be explored to enhance the implementation of modular construction. Besides, the research methodology, research scope and chapter outline are included in this chapter as well.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Chapter 2 represents the literature review section of the study. It gathers the information and insights from previous studies to offer a comprehensive summary of the modular construction. First, the definitions of modular are provided and the types of modular construction systems are identified. By reviewing the previous studies on a similar topic, this chapter defined and discussed the opportunities of modular construction. In the following, the challenges of modular construction are assessed to highlight the key aspect that required careful considerations when implementing the modular construction. Then, the strategies to encourage implementation of modular construction are also discovered to disclose effective solution in motivating the application of modular construction.

2.2 Modular Construction

The definition of modular construction is different across different nations. Table 2.1 demonstrates the interpretations of modular construction based on the journals, reports, organisation websites and handbooks.

Table 2.1: Definitions of Modular Construction

Country	Definition	Source
US	"In broad terms, modular construction involves producing standardized components of a structure in an offsite factory, then assembling them onsite. Terms such as offsite construction, prefabrication, and modular construction are used interchangeably and cover a range of different approaches and systems."	Bertram, et al. (2019, p.7)
US	"Modular construction is a process in which a building is constructed off-site, under controlled plant conditions, using the same materials and designing to the same codes and standards as conventionally built facilities – but in about half the time. Buildings are produced in modules that when put together on site, reflect the identical design intent and specifications of the most sophisticated site-built facility – without compromise."	Modular Building Institution (2022)
UK/ Europe	"Modular construction is a process where a building is constructed offsite using controlled plant conditions before being transported and assembled at a final location. This type of construction can incorporate a range of different building types and floor plans."	TWI Ltd. (2022)
UK/ Europe	"Modular construction comprises prefabricated room-sized volumetric units that are normally fully fitted out in manufacture and are installed on-site as load-bearing building blocks."	Lawson, Ogden and Bergin (2012, p.148)
Australia	"Any method where on-site work is minimised and prefabrication is maximised is considered Modular Construction."	Monash University (2017, p.13)
Singapore	"Modular is a general construction term to describe the use of technology that facilitates off-site manufacturing. Complete modules made of multiple units complete with internal finishes, fixtures and fittings are manufactured in factories, and are then transported to site for installation in a Lego-like manner."	Building and Construction Authority (2022b, p.7)

Modular construction is also known as prefabrication, off-site construction, off-site manufacture (OSM), off-site prefabrication, modern method of construction, volumetric construction, volumetric prefabrication, standardisation and pre-assembly, modular integrated construction (MiC), prefabricated prefinished volumetric construction (PPVC) and IBS (Building and Construction Authority, 2022b; Architecture for London, 2020; Bertram, et al., 2019; Navaratnam, et al., 2019; Shan, et al., 2019; Musa, et al., 2016a; Gibb, 2001). The concept of modular construction may be different across countries and nations. It can be the components that are prefabricated off-site, which includes a single element, structure, module and a fully finished 3D unit. As mentioned in the report published by McKinsey, modular construction covers a wide range of methods and systems, from individual elements that connected by standard connections and interfaces to the fully equipped 3D volumetric units (Bertram, et al., 2019). Besides, Monash University (2017) indicates that construction methods that minimise on-site work while maximise off-site prefabrication are modular construction.

In more detail, Lawson, Ogden and Bergin (2012) defined modular construction as a volumetric unit which fully prefabricated into room-sized building blocks that prepared to install on the site. This is compatible with the definition provided by Modular Building Institution (2022) which the buildings are produced in modules under the controlled factory condition and delivered to the site for assembly. It further explained that the modules are prefabricated using the same materials, standards and codes as the conventional construction. However, modular construction only uses up half the time compared to traditional construction. Yet, there are also modular construction organisations that further claimed that to define "module", the assemblies shall prefabricate 60% to 90% in the factory before assembling them on the construction site (TWI Ltd., 2022).

In Singapore, modular construction is known as PPVC. It is an advanced construction method from modular construction in which the 3D modular units are fully finished with the frame, floor, wall, ceiling and necessary fittings (Kyjaková and Bašková, 2016). The volumetric units are then transported to the site and stacked together to form a complete building. High-rise buildings such as condominiums and hotels can be built with modular construction as the standardised and repetitive modules can effectively produce in the factory. Currently, Singapore is developing the world's tallest modular building, Avenue South Residences, which consists of two 56-storey towers (Harrouk, 2020).

According to Thai, Ngo and Uy (2020), the degree of prefabrication can be divided into 1D single element, 2D panellised system and 3D volumetric system. Modular construction primarily refers to 2D and 3D systems because these two systems are efficient enough for the buildings to be manufactured 70% to 90% in the factory before assembling on the site. In the interview between Edge Malaysia and Master Builders Association Malaysia (MBAM), the president explained that the 2D precast components which casted off-site, transported and installed at the final location are the common modular construction system used in Malaysia. In addition, there is also the 3D volumetric precast component that assembled around 80% in the factory before transport to the site. However, these 3D precast components are currently limited to the cabins converted from the steel containers in Malaysia. Besides, the prefabricated concrete bathroom unit is another example of 3D system available in Malaysia (Lee, 2022).

The differences between IBS and modular construction are that modular construction is type of IBS, but not all IBS systems are modular construction (Properly, 2020). IBS is the term used to describe the prefabrication of building component in the factory prior to the final assembly on the site. On the other hand, the project should be around 60% to 90% completed in the manufacturing plant before delivery to the site for modular construction (Lee, 2022; TWI Ltd., 2022; Properly, 2020; Thai, Ngo and Uy, 2020). Overall, modular construction can be explained as the components or modules of a building that manufactured at least 60% under a controlled environment. However, it follows the approved standards and specifications and is ready to install on the site. It can be the precast components, structures and frames as well as a complete 3D modular unit that manufactured off-site, which can minimise the on-site construction activities.

2.3 Modular Construction System

Figure 2.1. illustrates the level of modular construction released by McKinsey (Bertram, et al., 2019). The two primary categories of modular construction are 2D elements which require more on-site assembly, and 3D volumetric units which are more extensively fitted off-site. Besides, a hybrid model also can be formed by combining these two approaches.

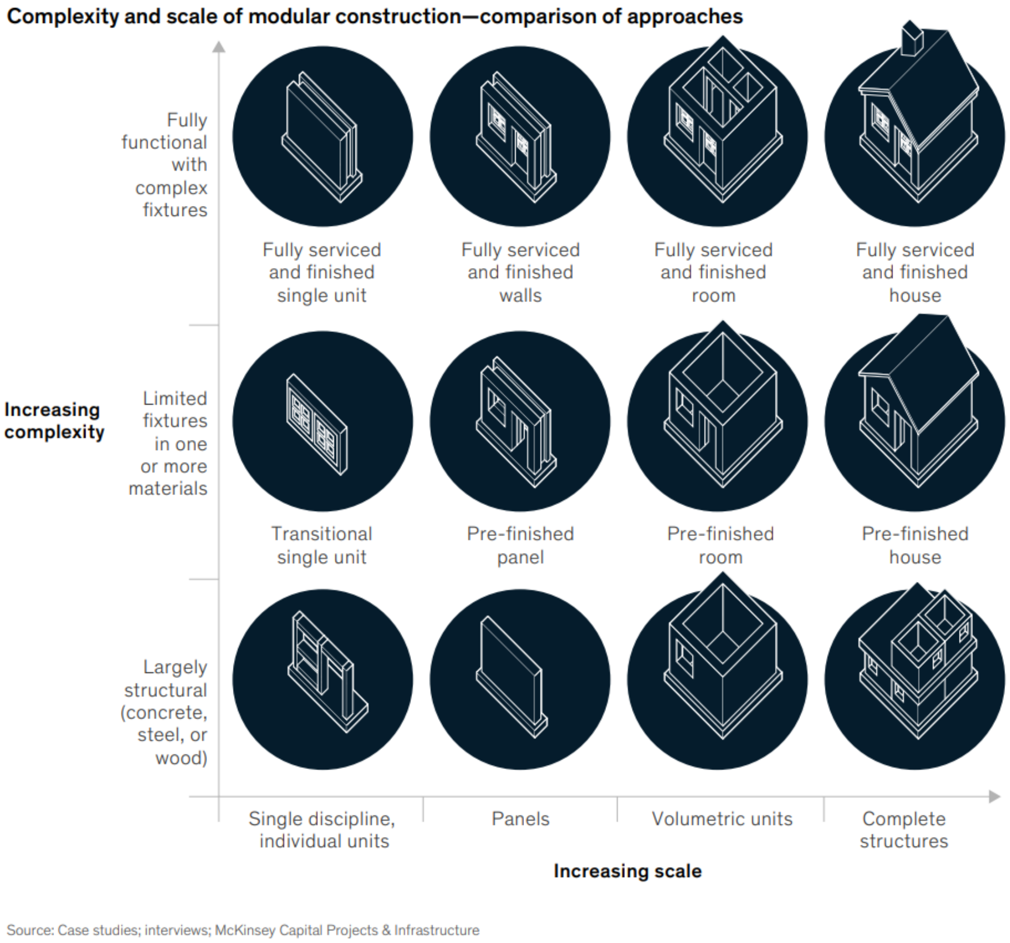

Figure 2.1: Level of Modular Construction

Source: Bertram, et al.(2019)

2.3.1 3D Volumetric System

The 3D volumetric system includes the modules that are fully fitted with the services, fixtures and fittings under the controlled factory environment. After the modules are produced in the factory, they are then transported to the construction site and stacked together to form the building. Since the units are pre-assembled and pre-engineered in the off-site environment, the on-site construction activities can be minimised. Besides, timber, steel and concrete are the common materials used to manufacture the modules. This system offers the greatest efficiencies and time savings but trades off with the logistic costs and size limits. In addition, it suggests that the projects with a high degree of repeatability are most suitable to use the 3D volumetric system. However, the repeatability does not require all products to have the same appearance. This is because a number of standardised modules may be assembled in various ways to create a unique final product (Tzourmakliotou, 2021); Bertram, et al., 2019; Hyams, Mccann and Ferguson, 2018).

2.3.2 2D Panelised System

A panelised system is also known as non-volumetric preassembly. In this system, the panels such as walls and ceilings are manufactured in the factory, delivered to the site, craned into site position and installed to connect together to form the structure. There are two types of 2D panelised system which are the open system and the closed system. In the open system, the panels are served as structural elements. After the panels are manufactured in the production facility, they are then transported to the site and the services such as plumbing, with finishes such as painting will be equipped to the panels on the site. On the other hand, the closed system involves a more furnished panel. This is because the services and finishes in a closed system will be installed to the panels in the factory before being delivered to the site. Moreover, the 2D panelised system is having the transportation advantages. The reason for this is that the panels are easier to transport than the 3D modules due to the flexibility in sizes and the transportation cost (Tzourmakliotou, 2021; Bertram, et al., 2019; Hyams, Mccann and Ferguson, 2018).

2.3.3 Hybrid System

The hybrid system combines 3D modules and 2D panels to deliver the project. On the other hand, the hybrid system is also explained as the combination of 3D modules or 2D panels, with other precast elements or structural frames. This approach consists of both the flexibility and logistic benefits of 2D panelised systems and the productivity benefit of 3D volumetric systems. Under this system, it is typically for the kitchen or bathroom to use 3D modules with the rest of the building formed by 2D panels. However, the hybrid system is more complex as the project team needs to deliver two different solutions (Tzourmakliotou, 2021; Bertram, et al., 2019; Hyams, Mccann and Ferguson, 2018).

2.4 Opportunities of Modular Construction in Malaysia

The construction industry can benefit from modular construction in several ways. This section tends to explore the opportunities of modular construction from three perspectives, which are the economic, social and environmental aspects as shown in Table 2.2.

Table 2.2: Opportunities of Modular Construction

Ref	Opportunities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
	Economic Aspect															
O1	Improve project schedule and productivity	√	√	√	√	√	√	√	√	√	√	√	√	√	√	14
O2	Better quality		√	√	√	√	√		√		√		√	√	√	10
O3	Cost efficient and effective	√	√	√	√	√	√	√	√	√	√	√	√	√	√	14
O4	Lesser weather disruption	√		√		√		√	√	√				√	√	8
O5	Minimise material wastage	√			√				√	√			√			5
O6	Reduce site labour					√				√	√			√	√	5
O7	Flexible and removable		√			√				√				√		4
O8	Reduce rework					√	√				√		√			4
O9	Reduce life cycle cost						√				√			√	√	4
O10	High potential for market share												√			1
	Social Aspect															
O11	Better occupational safety and health	√	√	√		√	√	√	√	√	√	√	√	√	√	13
O12	Noise reduction on site	√	√		√	√	√	√		√		√		√		9
O13	Lesser site disruption			√		√			√					√	√	5
O14	Reduce disturbance to surrounding community		√	√		√	√		√					√		6
O15	Decrease transportation and traffic movement				√							√				2
O16	Job creation						√		√							2
	Environmental Aspect															
O17	Sustainable	√	√	√	√	√	√	√		√			√	√	√	11
O18	Waste reduction	√	√	√	√	√	√	√	√	√		√		√	√	12
O19	Reduce pollution					√	√		√	√		√		√		6
O20	Reduce embodied energy and energy efficient				√	√	√			√	√			√	√	7

Table 2.2: (Continued)

Ref	Opportunities	15	16	17	18	19	20	21	22	23	24	25	26	27	Total
	Economic Aspect														
O1	Improve project schedule and productivity	√	√	√	√	√	√	√	√		√	√		√	11
O2	Better quality	√	√	√		√	√	√	√	√	√	√		√	11
O3	Cost-efficient and effective			√		√		√	√						4
O4	Lesser weather disruption		√	√		√	√					√			5
O5	Minimise material wastage		√	√		√		√	√	√					6
O6	Reduce site labour		√	√		√	√		√						5
O7	Flexible and removable	√	√					√			√			√	5
O8	Reduce rework						√								1
O9	Reduce life cycle cost													√	1
O10	High potential for market share													√	1
	Social Aspect														
O11	Better occupational safety and health	√	√		√	√		√	√	√		√	√		9
O12	Noise reduction on site	√	√			√			√		√		√		6
O13	Lesser site disruption	√	√		√	√		√							5
O14	Reduce disturbance to surrounding community				√										1
O15	Decrease transportation and traffic movement	√					√								2
O16	Job creation						√								1
	Environmental Aspect														
O17	Sustainable	√	√			√		√	√		√	√	√	√	9
O18	Waste reduction	√			√				√	√	√		√		6
O19	Reduce pollution					√			√	√			√		4
O20	Reduce embodied energy and energy efficient							√	√						2

Table 2.3: Summary of Opportunities of Modular Construction

Ref	Opportunities	Total
	Economic Aspect	
O1	Improve project schedule and productivity	25
O2	Better quality	21
O3	Cost-efficient and effective	18
O4	Lesser weather disruption	13
O5	Minimise material wastage	11
O6	Reduce site labour	10
O7	Flexible and removable	9
O8	Reduce rework	5
O9	Reduce life cycle cost	5
O10	High potential for market share	2
	Social Aspect	
O11	Better occupational safety and health	22
O12	Noise reduction on site	15
O13	Lesser site disruption	10
O14	Reduce disturbance to surrounding community	7
O15	Decrease transportation and vehicular traffic	4
O16	Job creation	3
	Environmental Aspect	
O17	Sustainable	20
O18	Reduce waste	18
O19	Reduce pollution	10
O20	Reduce embodied energy and energy efficient	9

Authors: **1**-Prajapati, Pitroda and Raichura (2022); **2**-Hořínková (2021); **3**-Paliwal, et al. (2021); **4**-Nazir, et al. (2021); **5**-Tzourmakliotou (2021); **6**-Veiskarami (2020); **7**-Subramanya, Kermanshachi and Rouhanizadeh (2020); **8**-Wilson (2019a); **9**-Navaratnam, et al. (2019); **10**-Bertram, et al. (2019); **11**-Ferdous, et al. (2019); **12**-Kisi, et al. (2019); **13**-Wuni and Shen (2019); **14**-Hyams, Mccann and Ferguson (2018); **15**-Musa, et al. (2018); **16**-Ho, Lam and Shea (2019); **17**-Rahim and Qureshi (2018); **18**-Davies (2018); **19**-Kamali and Hewage (2016); **20**-KPMG (2016); **21**-Musa, et al. (2016b); **22**-Boafo, Kim and Kim (2016); **23**-Kyjaková and Bašková (2016); **24**-Musa, et al. (2014); **25**-Schoenborn, et al. (2012); **26**-Lawson, Ogden and Bergin (2012); **27**-Goodier and Gibb (2007).

2.4.1 Economic Aspect

In construction projects, economic issues are one of the most important considerations. This is because every construction project requires sufficient capital and cash flow to allow the construction activities to proceed as planned (Wuni and Shen, 2020a). Hence, it is needed to ensure that the cost overrun and schedule delay problems are eliminated in the construction project. Because construction projects have a long project cycle, economical construction can help project stakeholders to reduce the construction cost, life cycle cost and achieve added value (Wu, et al., 2021). Meanwhile, modular construction can bring economic benefits and potentials to the industry over conventional construction.

2.4.1.1 Improve Project Schedule and Productivity

In every construction project, the project schedule is crucial to allow a construction project to be delivered successfully without delay. Previous studies found that project schedule and productivity can be improved in modular construction (Prajapati, Pitroda and Raichura, 2022; Hořínková, 2021; Paliwal, et al., 2021; Veiskarami, 2020). Since most of the building activities are transferred off-site, external environments such as inclement weather have less impact on the manufacturing activities of modular construction (Hořínková, 2021; Paliwal, et al., 2021). Besides, the incorporation of BIM into modular construction during the design and planning stage can efficiently reduce the time and cost of the project (Veiskarami, 2020; Ferdous, et al., 2019).

In modular construction, the factory production can incorporate advanced technologies such as automation and robotics into the production line. Generally, two eight-hour shifts are adopted, but three eight-hour shifts can be possible when appropriate labours are sourced (Bertram, et al., 2019). With this, the productivity is significantly improved as the technologies can operate 24/7 to boost productivity which is different from the slow labour processes on the site (Veiskarami, 2020). Subramanya, Kermanshachi and Rouhanizadeh (2020) and Veiskarami (2020) revealed that multiple activities could be carried out simultaneously in modular construction and contribute to a better project schedule. This is because the foundation construction works on the site and the manufacturing works of the building components or modules in the factory are able to carry out at the same time. Even in the off-site plant, different components such as wall panels and floors can produce parallelly, unlike the linear construction processes in conventional construction (Navaratnam, et al., 2019).

According to the report released by McKinsey (Bertram, et al., 2019), the planning and design phases of both traditional and modular constructions almost have the same duration, and modular construction can spend longer time than traditional construction. Besides, the foundation constructions of both methods also take the same duration as they are both on-site foundation construction activities. However, the off-site manufacturing process in modular construction can start simultaneously with foundation construction. On the other hand, the on-site construction activities for traditional construction only occur after the foundation was fully completed. More importantly, the manufacturing process of components in modular construction is much faster than the on-site construction activities, which only take half the time if compared to traditional construction. After the components are produced, their final assembly on the site is also speedy. As a result, modular construction can decrease the project duration up to 50% when compared to conventional construction (Bertram, et al., 2019). Meanwhile, the case study conducted by Ho, Lam and Shea (2019) claimed that The Changi Town Plaza Hotel in Singapore that utilities the PPVC have reduced the construction time by around 17%.

Bertram, et al. (2019) revealed that a team with five labourers could assemble six modules in a single day, which equivalent to 270 square meters of finished floor area. Therefore, the on-site assembly process of the modular construction is said to be speedy. Since modular construction contributes to a shorter project schedule, it is an effective method to address the crisis in the rising housing demand of the inhabitant (Khan, et al., 2022). Apart from these, this fast construction solution can be a great option in emergencies such as Covid-19 where portable cabins are required for large-scale medical isolations. As an illustration, the Huosheshan and Leishenshan hospitals in Wuhan that built with modular construction were completed within ten days to respond to the pandemic (The Star, 2020). Years of construction tasks that were delivered within half a month time has proved the effectiveness of modular construction in time aspect.

2.4.1.2 Better Quality

According to Subramanya, Kermanshachi and Rouhanizadeh (2020), modular construction can achieve better product quality. This is because the materials used in modular construction are less explored to adverse weather such as rain and wind. Since the production processes take place in an indoor environment, the damages related to moisture, such as mould growth that can harm the health of the occupants can be minimised (Wilson, 2019a). This allows for better durability and contributes to better finished building quality. Besides, the components or modules are produced follow the codes and standards under the controlled factory environment. Meanwhile, the manufactured components are designed to withstand vibration during transportation and have the load bearing capacity to stand on the site. Therefore, the components or modules are considered durable, lightweight and weather resistance which improves the total quality (Tzourmakliotou, 2021).

In addition, a monitored manufacturing environment with automated processes and precision manufacturing tools such as Computer-Aided Manufacturing (CAM) or Computer-Aided Design (CAD) enables higher levels of quality control and consistency (Wilson, 2019a). According to Hyams, Mccann and Ferguson (2018), the airtight and thermal efficiency of the building components can be delivered consistently under a controlled factory environment. Furthermore, using technologies such as robotics allow precision manufacturing process to occur in producing high-quality components and interfaces (Bertram, et al., 2019). Subsequently, modular construction offers better air-tightness and thermal performance because it allows for tighter joint tolerances and fewer air leaks between the building components (Wilson, 2019a; Lawson, Ogden and Bergin, 2012).

Apart from these, the manufacturing facilities have independent inspection through the quality assessment and quality control program (Musa, et al., 2018). The consistent quality of the product are achieved by introducing a fully automated and digitalised production system to effectively check all stages of the component productions (Hořínková, 2021). With the precise machine, quality control can conduct efficiently as the components or modules are checked and tested regularly. When defects are found during the quality assessment process in the factory, rectification can be done immediately before the components are put into assembly processes. Hence, the quality of building is secured due to the strict and intelligent manufacturing process in the factory (Khan, et al., 2022; Ho, Lam and Shea, 2019).

2.4.1.3 Cost-Efficient and Effective

Project costing is another key factor in the success of a construction project. However, cost overruns is a frequent problem in the Malaysian construction industry. Kamaruddeen, Sung and Wahi (2020) highlighted that cost overruns of 10% to 15% from the total contract sum are experienced by most construction projects in Malaysia. For example, a mistake during construction and changes in scope can cause the project cost to overrun.

The famous saying of “time is money” holds great significance in the construction project. As discussed, the modular construction process is fast because the project progress is less likely to be affected by the weather condition, and multiple tasks can be carried out parallelly. Shorter construction time means a significant cost reduction through the savings in interest charges, labour wages and accommodation expenses (Kamali and Hewage, 2016). Because of the reduction in on-site activities and faster project schedule, lesser site labour and machinery are required. This cuts the labour costs and machinery costs in term of wages, lease and fuels. As a result, a lower site overhead costs and construction management cost are also resulted in the modular construction. Furthermore, the project team can enjoy the cost savings on the margins in the quotation of the subcontractors. This is because most of the subcontractors will be removed due to the integrated process of modular construction (Bertram, et al., 2019).

In addition, each building’s components or modules can be mass produced in the factory. This allows the manufacturer to order the materials in bulk at a lower price and enjoy a discount on material costs (Veiskarami, 2020). The reduction in labour and transportations needed for material supply also save the labour and transportation costs (Navaratnam, et al., 2019). Even if the materials are not fully utilised in the current project, they can be used to manufacture the component for future projects and prevent material wastage. Also, the poor quality of structures constructed on the site may cause rework and lead to additional time and cost. Yet, the quality of components or modules produced under the controlled factory environment is high with the use of technologies and machines. Therefore, this can reduce rework and allow cost efficiency with modular construction (Veiskarami, 2020).

From the investor or client point of view, modular construction is cost-effective because it allows the investor to enjoy a faster investment return when the project timeline is short (Hořínková, 2021). Bertram, et al. (2019) highlighted those investors who invest in modular properties could enjoy a fast revenue by selling or renting out the properties earlier than other projects. On the other hand, the client who needs the building for a commercial purpose also can operate the business earlier by eliminating the long construction time of traditional construction. Meanwhile, the self-builders who built their own homes with modular construction also can save the rental costs on alternative accommodation while waiting for the handover of the building.

2.4.1.4 Less Weather Disruption

The labour productivity will be disrupted by inclement weather such as storms. This is because the works may force to stop and the project schedule will be affected. However, the project schedules in modular construction are less dependent on the weather condition as most construction activities take place in the factory (Paliwal, et al., 2021; Rahim and Qureshi, 2018; Kamali and Hewage, 2016). The material will also be protected from rain as there are lesser material on site when the on-site activities are minimised. In the construction industry, building materials such as cement needs to store appropriately. This is because cement is sensitive to moisture, and it becomes harden when exposed to damp. Therefore, modular construction is able to minimise the material damage due to weather condition and sufficient materials are secured to incorporate into the manufacturing process of the components. With this, the delay problem due to weather conditions is less likely to happen in modular construction and the machines can operate 24/7 under a controlled environment. In addition, labour safety can be guaranteed because they work indoors instead of outdoors. The risks of site accidents such as slip is eliminated and sufficient number of labour will be available to deliver the project (Tzourmakliotou, 2021).

2.4.1.5 Minimise Material Wastage

Under the controlled plant, the materials used to produce the prefabricated components can be easily managed due to repetitive processes (Hořínková, 2021). This is because the product quality is secured when the components are produced following the codes and standards in a factory environment. As machine is more intelligent than people, the error when producing the building components or modules are minimised. The allocation of precision manufacturing machines also allows high-quality and standardised components to produce with the efficient use of materials (Tzourmakliotou, 2021). Therefore, the rework as a result of error or unapproved quality is eliminated to decrease the material wastage. In addition, it also minimises the possibilities of material wastage caused by site theft and weather-related damage. This is because fewer materials and machinery being allocated on the site while most of the raw materials are stored in a dry and safe place in the factory (Meyers, 2016).

Furthermore, the excess materials of one component can be allocated to the manufacturing process of other components under same project. Hence, it reduces the amount of material that need to be sourced in a modular construction project (Wilson, 2019a). Likewise, since the company can work on multiple modular projects in the same location, the unused material for one project can be easily transferred to another project to minimise material wastage (Marrison, 2022). Besides, the reduction in materials wastage is also achieved when the materials or modules of the modular building are able to recycle and reuse to form a circulation economy (Khan, et al., 2022). Bertram, et al. (2019) found that the factory production process in modular construction can reduce the wastage cost by 10% over conventional construction.

2.4.1.6 Reduce Site Labour

Since most of the construction works are transferred to an off-site environment, the labours needed on the site are greatly reduced. The site activities may only require during demolition, pilling, foundation construction and assembly stage.

Besides, there are fewer subcontractors employed on the site, which contributed to a better work sequence and a less crowded site during the project peak period (Ho, Lam and Shea, 2019). With this, it minimises the idle and downtime caused by weather conditions such as rain. Moreover, the productivity is doubled when the activities are conducted under the controlled working environment that equipped with standardised and automated processes (Bertram, et al., 2019). Therefore, reducing the site labour not only save the idle time, but also enhance the productivity by transferring site labour to factory.

In addition, the probability of site incidents will also be minimised when there are fewer on-site construction activities (Kamali and Hewage, 2016). The labour cost is expected to reduce by 15% and an additional 10% saving is also possible when the installation works of mechanical, electrical and plumbing are conducted in the factory (Tzourmakliotou, 2021). This is because service installation tasks are conducted in the factory and can reduce the on-site worker and labour costs. Moreover, the client does not need to provide the site facilities such as temporary accommodation and canteen throughout the project progress. Hence, the operational expenses on site in terms of water and electricity are reduced as well.

2.4.1.7 Flexible and Removable

Building modules or components are produced off-site and assembled on the site to form the building. According to Hořínková (2021), modular construction can respond to the client’s needs and financial capabilities, which the building can be expanded or the modules can be removed. The researcher provides an example where a young couple may have financial constraints during an early age when the modular building is brought. The required living space and financial capabilities will increase over the years, and modules can be added to join with the current building when needed. In contrast, the modules can be removed when a reduction of usable area is required. Meanwhile, the removed modules are reusable by allocating to other buildings or serving for another usage such as storage. Ho, Lam and Shea (2019) also mentioned that the modules could be easily detached to ease the demolition work.

Besides, Vertis Buildings (2022) suggested that modular construction can minimise the impact of renovation work to the operations of the building and businesses of the client. It claimed that the renovation of school buildings is often scheduled on the school holidays as construction activities will affect the teaching environment (Davies, 2018). With modular construction, the modules can be moved to factory for reconfiguration and reinstall back to the school building. Therefore, it eases the construction or renovation work as the modules allow the building to be easily relocated, expanded, reconfigured and reduced (Portakabin, 2022).

2.4.1.8 Reduce Rework

According to Santoshi (2021), rework in construction activity refers to repeating a process or activity that was initially implemented incorrectly. It should be managed effectively because rework can adversely affect the schedule and cost of a construction project. Yet, the modular construction method requires a more standardised, automated and controllable operating environment in the factory. Due to the repetitive production processes in the factory, the mistake in production can be eliminated from human error to offer a quality product. Hence, the great majority of rework expenses can often be avoided and standardisation can be easily achieved in modular construction (Bertram, et al., 2019). As a result, the condition of rework in modular construction is less likely to occur if the design is well proposed and the machines are well functioned.

As discussed earlier, the incorporation of precise manufacturing plants allows for better product quality (Wilson, 2019a). Furthermore, the quality assurance and quality control programme available in the manufacturing facilities can strictly control the quality of manufacturing components. This can reduce the need for rework as a predelivery check will be conducted in the factory (Tzourmakliotou, 2021). In addition, the designs are fully developed during the design stage with inflexibility changes in the manufacturing stage (Kazem-Zadeh and Issa, 2020). This is because changes occur during the manufacturing and construction stages are costly and timely (Wilson, 2019a). Therefore, the project team will avoid making changes in later stage to reduce the potential of rework. As a result, the project schedule will not be affected, with the cost and materials being spent effectively to the critical project activities.

2.4.1.9 Reduce Life Cycle Cost

One of the essential considerations during the design and construction phase of a project would be the life cycle cost. According to Dwaikat and Ali (2018), the life cycle cost (LCC) is the total cost of the building, including design, construction, operation, maintenance and disposal. People always focus on the construction cost but overlook the operation and maintenance cost of the building. In fact, operation and maintenance costs can be very costly to the client if the quality of construction is poor. Since modular construction can offer better quality building, it can minimise the defect during the occupancy stage. Besides, the potential to incorporate green materials and technologies when manufacturing the building components allows the building to perform more sustainably than other buildings (Prajapati, Pitroda and Raichura, 2022).

Consequently, the building is durable, with limited maintenances are required to preserve the building. Wilson (2019a) revealed that the thermal performance of the modular building is better as the air leakage is minimised through the precise interface between the components. Hence, the operation cost is also able to reduce by consuming lesser energy. According to KPMG (2016), the client responded that there is a reduction in whole life cost with modular construction. Besides, the feedback from one client to McKinsey told that the energy bills of the building had decreased by 25% after transitioning to modular construction (Bertram, et al., 2019).

2.4.1.10 High Potential for Market Share

Kisi, et al. (2019) suggested that modular construction has a high potential for market share. The lack of modular manufacturers in the market allows the initiative company to lead the modular construction in competing with conventional construction. Today, people are dealing with affordable housing and the government serves affordable housing as national priority (The Star, 2022a). Apart from affordable housing, the demand for hospitality and healthcare markets also creates the potential for implementing modular construction (Wilson, 2019a). As pointed out in this study, modular construction is cost-efficient, can construct within a shorter time and can promote sustainable features over traditional construction. Therefore, this construction method can meet the needs for fast and affordable housing. With this, the construction organisation can take the initiative by shifting into modular construction to win a large proportion of market share in the housing market.

2.4.2 Social Aspect

Modular construction also can contribute benefits in terms of the social aspect. It is essential because construction activities can lead to a range of social problem such as noise, accident and impact on living quality (Wu, et al., 2021; Ghani and Zawawi, 2018). Yet, modular construction can offer better occupational safety and health, reduce the noise on site, site disruption, disturbance to the surrounding community, transportation and traffic movement, and create jobs.

2.4.2.1 Better Occupational Safety and Health

The construction industry is having a higher level of danger compared to other sectors. The degree of occupational incidents contributed by the construction industry is very high. According to Hořínková (2021), most of the incidents are caused by falls from height, crushed by the falling object, machine and electric shock. The rising of fatal and non-fatal injuries has prompted the industry practitioners to improve the job safety. Yet, modular construction can provide a better occupational safety and healthy working condition to the construction players (Kisi, et al., 2019; Musa, et al., 2018; Kamali and Hewage, 2016). Hořínková (2021) signalled that construction incidents can be reduced by 80% in modular construction over traditional construction. As there are lesser construction activities on the site, the probability of site incidents will be reduced by minimising the risk of slips, trips, and falls as well as work at height (Veiskarami, 2020). Furthermore, labours are now transferred to the factory environment where the safety plan can be efficiently allocated and managed indoors.

Also, modular construction offers a healthy working environment to the labours (Wilson, 2019a). This is because the labours can move away from the noisy construction site with various heavy equipment and construction processes that caused ear illness. Besides, the well-being of labours is improved by eliminating the need to work outdoor under changeable weather conditions and the transient lifestyle that come with the projects (Bertram, et al., 2019). Meanwhile, the air quality, lighting, firefighting, access to tools, etc., are better in the factory. By moving on-site activities to off-site facilities, modular construction enhanced the working culture of the industry by offering better job security and flexible working shifts as highlighted by Wilson (2019a).

2.4.2.2 Noise Reduction on Site

The noise produced by the construction site activities can negatively impact site personnel and the neighbourhood. By transferring construction activities to the factory, noise and vibration on site are significantly reduced (Hořínková, 2021). Therefore, modular construction is highly suitable to implement by the project such as hospital and school as well as the site that closed to such buildings (WillScot, 2021). This is because modular construction will not affect the patients' resting and students' studying environment as it allows the project to be carried out with lesser noise. The living quality of the nearby residents also will not be much affected by modular construction compared to conventional construction when on-site construction works are decreased. Likewise, it reduces the impact on health of the construction labours due to the reduction of working time in the noisy site environment.

2.4.2.3 Lesser Site Disruption

The issues of theft and site vandalism have raised the awareness of project stakeholders to provide better security on the construction site. If valuable materials or machinery are stolen, the project stakeholders will suffer massive losses, leading to financial constraints and disputes. However, modular construction can minimise site disruption by moving the site activities to the factory (Paliwal, et al., 2021). There will be lesser materials to store on the construction site as the manufacturing processes are conducted in the factory (Hyams, Mccann and Ferguson, 2018). As a result, the site can remain clean and safe by providing a more expansive space for labour or plant to move freely.

Besides, the problem of a congested site that caused the plant to move difficultly on site and that affected the site performance will be eliminated. It used to be a common problem for conventional construction due to the massive materials, plant, equipment, site labour and subcontractors to compete for the space on the site (Bertram, et al., 2019). In modular construction, the amount of transportation is drastically reduced (Davies, 2018). Hence, the disruption to site activities is decreased as there is no need for frequent material transportation and subcontractor to enter the site (Ho, Lam and Shea, 2019). Now, most of the building activities are conducted in the factory and the subcontractor works can be replaced by automation processes to cut off the subcontracting cost. Lesser transportation will also eliminate the traffic congestion on the site and reduce the disruption to the surrounding neighbourhoods (Wilson, 2019a).

2.4.2.4 Reduce Disturbance to Surrounding Community

One of the important opportunities of modular construction in terms of social dimension is it can reduce the disturbance to the neighbourhood during the construction stage (Paliwal, et al., 2021; Wuni and Shen, 2019). Lawson, Ogden and Goodier (2014) highlighted that this is essential for the adjacent building to operate without interruption when the construction site is closed to the residential area, hospital and school. In conventional construction, noise and dust generated on the construction site will affect the surrounding community. This is reported by Malay Mail in which the residents protested to complain about the loud construction noise caused by the ongoing condominium project (Lim, 2017). The construction site is located near to the residential areas and three schools. Meanwhile, the reporter found that the residents were seriously disturbed by the construction noise and the construction dust, which had severely hampered their daily lives.

Obviously, on-site construction activities can affect the living quality of the surrounding community. With this, modular construction serves as a good alternative to reduce these negative impact due to lesser on-site construction activities (Wilson, 2019a). Although the foundation construction and assembly stage will still take place on the site, the overall on-site construction period is significantly shorter than the conventional construction. Besides, the prefabricated elements or modules can be assembled quickly on the site, which cuts down the construction time and decreases the impact on the surrounding community (Paliwal, et al., 2021). The surrounding traffic also will not be much affected as no frequent heavy vehicle travel to and from the site.

Apart from these, the Malaysian construction industry is highly dependent on foreign labour due to the shortage of local labour and the intensive nature of site activities. Ashaari, Razak and Siow (2018) claimed that the existence of foreign labour had affected the public safety and security due to crime issues. Yet, the adoption of modular construction can reduce the site labour by transferring the site activities to the off-site factory. This reduces the dependency on foreign site labour and the possibility of criminal activities caused by those labours (Rahim and Qureshi, 2018). Therefore, the living environment and quality of the surrounding community are secured when modular construction is implemented.

2.4.2.5 Decrease Transportation and Traffic Movement

In traditional construction, the construction activities on site require workers and materials to arrive at and leave the site during the construction phase. These movements happened throughout the workday and led to local traffic disruption (Krug, 2013). According to Ferdous, et al. (2019), the transport activities in modular construction are decreased because most on-site activities are conducted in the off-site manufacturing environment. Therefore, no frequent material deliveries to the site are required throughout the construction period. By developing efficient traffic management, the site deliveries traffic can be reduced and decrease the disturbance to the surrounding communities (Nazir, et al., 2021). This is because frequent vehicles going in and out of the site may lead to traffic congestion. Lesser heavy traffic of construction vehicles also decreases the danger to the residents.

The same concept is also applicable to the site staff’s vehicle. Since there are lesser on-site activities, the number of travel trips to the site is also reduced (Paliwal, et al., 2021). This decreases the vehicular activities for the site staff to travel to and from the site (Musa, et al., 2018). As a result, the residents have fewer days to compete with delivery trucks and commuter construction workers (Morrison, 2021). Meanwhile, it not only reduces the influences on the surrounding neighbourhood, but also decreases the environmental impact of air pollution. This is because modular construction can reduce the carbon dioxide (CO2) emissions when fewer vehicles are running on the road compared to conventional construction (Tzourmakliotou, 2021). Obviously, transferring most of the on-site activities to off-site can result in a reduction in traffic movement which in turn reduces the impact of traffic congestion and environmental pollution.

2.4.2.6 Job Creation

The construction industry faces labour shortage problems especially when the project is site-based. This is because construction activities are labour-intensive and people refuse to join the construction industry due to poor working conditions (Khan, et al., 2022). Aside from this, the ageing workforce is also the major problem facing the construction industry and it is critical to bring new people into the industry (Bertram, et al., 2019). Yet, transferring site activities to the factory can eliminate this problem and create jobs for the public. According to KPMG (2016), off-site manufacturing can attract non-skilled workers and develop them. Besides, the skilled workers from other industries also can be transferred to the off-site industry. This is because the working condition in the factory is better than the construction site as contributed by the safer and cleaner environment.

KPMG (2016) also revealed that modular construction could change the image of the construction industry. This is because the existing stereotypes of society toward the industry include dirty, dangerous and uneducated. With a safer, cleaner and more advanced working environment, people will become more willing to join the construction industry and students will be attracted to enrol in construction-related courses at the university. Moving forward, advanced technologies such as automation and robotics are adopted in the modular construction processes. Wilson (2019a) claimed that this scenario creates attractive opportunities for new professionals, especially the younger generation to join the construction industry. However, the stakeholders may argue that the risk of job loss will increase when more automation systems are adopted into the industry. Yet, an analysis by World Economic Forum (2018) said that automation can create 58 million new jobs in 2025. Hence, the adoption of advanced technologies in modular construction can create jobs and attract new players to enter the industry.

2.4.3 Environmental Aspect

Climate change is one of the hot topics as it seriously affects every living creature (Pourmokhtarian, et al., 2022). Therefore, it is urgent for the industry to act sustainably by complying with the Sustainable Development Goals (Wuni and Shen, 2019). The implementation of modular construction can provide advantages in the environmental aspect by promoting sustainability, reducing waste, pollution, and embodied energy.

2.4.3.1 Sustainable

Sustainable construction is one of the common goals of the construction industries in every country. In Malaysia, CIDB has taken the initiative to help the construction players incorporate sustainability such as developing the Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST) to guide the built environment towards sustainable development (Construction Industry Development Board, 2022b). Meanwhile, modular construction is one of the construction methods that can promote sustainability (Pervez, Ali and Petrillo, 2021; Kazem-Zadeh and Issa, 2020). Under the factory environment, the energy consumption, material utilisation, quality, etc., can control better than the conventional construction. Moreover, the adoption of precise design and manufacturing machines allows the creation of durable and high-quality building components. For instance, the earlier mentioned air tighter and thermal performances of the modular building can improve the life cycle performance of the building (Wilson, 2019a). This can minimise the maintenance cost and energy consumption during the occupancy phase.

Besides, the materials and modules can be recycled and reused during the manufacturing and demolition stage, which is known as the circular economic movement (Khan, et al., 2022). As a result, the demand for raw materials to produce new building elements is significantly decreased to slow the extinction of natural materials. Furthermore, eco-friendly materials are incorporated into the building to enhance the building performance. Materials with low or no volatile organic compounds (VOCs) such as low VOCs timber and paint are to apply in the building to minimise the danger to occupancy health. In addition, renewable energies and advanced technologies such as solar panels, sensors and LED lights can be equipped in the modular building to allow energy efficiency (Kamali and Hewage, 2016). Hence, the life cycle performance especially during the occupancy phase is optimised since the building is sustainable and durable.

2.4.3.2 Waste reduction

According to Tzourmakliotou (2021), the construction and demolition waste is higher as 60% of the total solid waste. Dealing with the massive waste produced by the construction industry, modular construction can effectively combat this issue (Nazir, et al., 2021; Musa, et al., 2018; Boafo, Kim and Kim, 2016). Since the manufacturing processes in modular construction employed precision and automation machine, optimal control of the material usage resulted in lesser material input and waste (Wilson, 2019a). As aforementioned, the surplus materials can be allocated to another project to prevent wastage. With this, waste management can be applied effectively in modular construction by reducing waste during the production process and reusing and recycling the modular components into new projects.

According to Hořínková (2021), the circulation design can be adopted in modular construction which the building are designed to reuse the materials or components into another new structures. It is also mentioned by Khan, et al. (2022) that the circular economy movement is supported by modular construction as the materials, modules and other items are able to be recycled and reused. In addition, the modules can be dismantled and reused for another building (Paliwal, et al., 2021). This is because the modules are able to move for joining with other buildings instead of deconstructing the units (Kamali and Hewage, 2016). The consumption of new raw materials is also reduced when the modules are reutilised rather than manufactured the new modules. As a result, waste management in modular construction can decrease the amount of disposal waste that goes for landfill or incineration. Also, there is a saving in the disposal cost due to the waste reduction.

The case studies carried out by Loizou, et al. (2021) proved the waste reduction in modular construction. Two buildings were used to study in which Case A was a 63m2 single-storey granny flat, while Case B was a 2,220m2 three-storey school building. Both cases were applied to both the conventional and modular construction to calculate the waste generated. The researcher adopted the Material Loss Rate (MLR) and gross floor area (GFA) to estimate the waste generation. At the end, the results showed that modular construction could reduce the waste generated over the traditional construction, which Case A reduce the waste by 81.3% and Case B reduce the waste by 83.2% on average.

2.4.3.3 Reduce Pollution

The construction industry can cause air, land, and noise pollution (Tzourmakliotou, 2021). The construction project is a major pollution contribution to the air because the construction process, from the material production to the building disposal stage, will release GHG into the environment. Yet, the study found that modular construction can effectively reduce GHG over conventional construction (Veiskarami, 2020).

Pervez, Ali and Petrillo (2021) conducted a case study comparing the GHG emission of traditional and modular construction. The case building used is a single-storey bungalow that built with modular construction technique. Due to the difficulties in obtaining a building with the same characteristic that constructed with traditional construction, the researcher decided to study the GHG emission of the same building constructed using the conventional method for comparison. This was done by obtaining the construction specification from the modular builder who built this modular building. The information is used to collect the material and energy requirements from five traditional builders through surveys. Besides, this case study measured the GHG emission in five stages, which are "embodied GHG emissions of building materials", including the energy usage when manufacturing the material; "GHG emissions from the transportation of building materials" from the warehouse to site for tconventional construction, and to the manufacturing factory for the modular construction; "GHG emissions from resource consumption during the construction of a building" such as the on-site and off-site electricity and fuel consumption; "GHG emissions from module transportation from factory to construction site" that only applicable to modular construction; and "GHG emissions from transportation of construction waste to landfill" from both the site and factory to landfill. It revealed that modular construction could result a 46.9% reduction in GHG emissions than traditional construction.

Furthermore, modular construction reduces the air pollution because there are no frequent material deliveries to the site are required (Gomez, 2021). Lesser on-site labours also decrease the travelling to the site and equipment operation on the site. Moreover, the panels and modules can be installed quickly once they arrive at the site. This reduces the number of site visits, site jobs, commuting of labours, subcontractors and the operation of plants and machinery on site. Therefore, the overall GHG and CO2 emitted by vehicles and equipment are decreased (Tzourmakliotou, 2021). In addition, carbon emission is also declined through the reduction in construction waste achieved by modular construction. This is because fewer wastes are going for incineration and landfilling, thus diminishing the GHG emission and land pollution (Kamali and Hewage, 2016). On the other hand, noise pollution is reduced in modular construction as the modular construction process will generate lesser noise than conventional construction (Ferdous, et al., 2019).

2.4.3.4 Reduce Embodied Energy and Energy Consumption

According to Crawford (2020), embodied energy is the total energy consumed by the material that makes up a building. It includes the energy consumed to produce building materials from the extraction of raw material, processing, manufacturing, to the transportation of materials to site. Besides, the energy consumptions during the construction and renovation are also served as the embodied energy. Yet, modular construction can reduce the embodied energy because there are lesser site works for which no frequent material transportation to the site is required. The on-site energy consumption also can be reduced by minimising the on-site plant and equipment (Wilson, 2019b). Moreover, the client can incorporate energy-efficient machines in producing the building components in the factory that allow better control over the energy utilisation and emission. The interviews conducted by Veiskarami (2020) showed that the energy consumption during the manufacturing and construction stage was reduced by 50% due to the faster project schedule in modular construction.

Besides, sustainable materials incorporated in the building components contribute to energy efficiency during the occupancy phase. Kamali and Hewage (2016) pointed out that the energy consumption during the occupancy stage accounts for more than 70% of the total energy consumption, from the material production to the end-of-life period of a building. Therefore, an energy-efficient building can help the client to reduce the energy consumption during the occupancy stage. Also, smart designing components and modules such as effective insulation performance can save energy utilisation during the operation stage. This is done by incorporating a good design, sustainable material and intelligent production machine into the project. According to Wilson (2019a), the thermal performance of the modular building is better due to the enhancement in the joint interface by minimising the air leakage. In addition, insulation panels and solar panels can be installed in the modular building to reduce the heating, ventilation and air-conditioning requirement along with the reduction of carbon emission throughout the building life. Therefore, the energy consumption for the occupancy phase can be greatly reduced due to the high-quality product produced by modular construction.

2.5 Challenges of Modular Construction in Malaysia

Although modular construction can bring a lot of opportunities over conventional construction, there are also some challenges that hindered its implementation. Therefore, it is important to highlight the challenges of modular construction to raise the awareness of the construction practitioners who tend to employ the modular construction technique. This section will explore the challenges of modular construction as illustrated in Table 2.4.

Table 2.4: Challenges of Modular Construction

Ref	Challenges	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total
C1	Transportation constraint	√	√	√	√	√		√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√		21
C2	Lack of skilled personnel	√	√	√	√		√	√	√	√	√		√		√	√		√	√		√		√		√	17
C3	High initial cost	√	√	√	√	√		√		√		√		√	√	√	√	√	√		√	√	√			17
C4	Need for excessive coordination and collaboration	√		√	√	√	√	√	√		√	√			√			√	√		√		√			14
C5	Low flexibility in design				√		√	√			√	√		√	√	√	√		√		√		√	√		13
C6	Time-consuming planning and design	√			√			√	√				√	√	√				√		√	√			√	11
C7	Client resistance							√	√	√		√			√	√	√		√		√				√	10
C8	Lack of guidance and government support							√		√	√	√			√	√			√						√	8
C9	Expensive				√	√		√						√					√			√	√		√	8
C10	Lack of social knowledge	√							√						√	√	√	√								6

Author: **1**-Prajapati, Pitroda and Raichura (2022); **2**-Hořínková (2021); **3**-Paliwal, et al. (2021); **4**-Nabi and El-adaway (2021); **5**-Tzourmakliotou (2021); **6**-Nazir, et al. (2021); **7**-Kazem-Zadeh and Issa (2020); **8**-Subramanya, Kermanshachi and Rouhanizadeh (2020); **9**-Veiskarami (2020); **10**-Xu, Zayed and Niu (2020); **11-**Wilson (2019a); **12**-Navaratnam, et al. (2019); **13**-Bertram, et al. (2019); **14-** Kisi, et al. (2019); **15**-Ferdous, et al. (2019); **16**-Hyams, Mccann and Ferguson (2018); **17**-Rahim and Qureshi (2018); **18**-Hwang, Shan and Looi (2018); **19**-Davies (2018); **20**-Kamali and Hewage (2016); **21**-Kyjaková and Bašková (2016); **22-**Aziz and Abdullah (2015); **23**-Schoenborn, et al. (2012); **24**-Goodier and Gibb (2007).

2.5.1 Transportation Constraint

One of the major challenges in modular construction is the transportation constraint (Kazem-Zadeh and Issa, 2020; Xu, Zayed and Niu, 2020; Hwang, Shan and Looi, 2018). Since the building components or modules are produced in the factory, they are needed to transport to the site for assembly. However, studies disclosed that the design, dimension and weight of the structures would be limited by the transportation factor (Veiskarami, 2020; Hwang, Shan and Looi, 2018). According to Veiskarami (2020), the architect needs to design the structures that can be transported following the local road regulation. There will be length and height limits for the components or modules to transport on the road. Therefore, design considerations should include the transportation constraint to prevent any transportation issues in the later phase. The project team must ensure that the structure produced can be transported with suitable vehicles, comply with the local regulation and meet the structures' performance requirements.

Besides, the structural designs need to consider the strength and load-bearing capacity during the transportation. If the structures cannot withstand the vibration during transportation, it will cause the structures damage and the intensity of damage can critically increase depending on the roughness of the road surface (Ferdous, et al., 2019). Also, the prefabricated structures are exposed directly to the external environment such as sun, rain and wind during transportation. As a result, possible damage could happen to the structures and may require repairing if the damage is critical (Veiskarami, 2020). With this, additional protections need to provide during the transportation stage. It was suggested to equip the vehicles with the vibration absorber and choose the vehicles that suit the dimension of the structures. Apart from these, the loading and unloading processes should also conduct carefully with the aid of lifting plants and machinery to avoid structural damage (Veiskarami, 2020). As more heavy machines are required to load and unload the components, Hořínková (2021) claimed that this would risk the worker as accidents can easily happen.

Furthermore, the project team needs to get the permit from the authorities before transporting the large-size building components. The police escort may also need to apply to deliver the components (Hořínková, 2021). Yet, there is a risk that the approval of the transportation permit will delay, which in turn affect the progress of the project. Besides, custom delays are likely to happen if the structures are transported to or from oversea countries (Kamali and Hewage, 2016). However, delay in delivery means external cost and time are needed. Hence, it can lead to project cost or time overrun that will negatively affect the project. Furthermore, the project team should consider the transportation route during the planning stage. Attention should pay to the bridge, width of the road and height of the tunnel to ensure a workable route (Kazem-Zadeh and Issa, 2020). Meanwhile, the transportation costs of modular construction are expensive as large-size components are required to delivered to the site. Likewise, the need for the police escort in transporting big modules will incur additional costs to the project (Wilson, 2019a). Yet, the interviewee revealed that extra transportation costs could be offset by the speedy project schedule that allows cost efficiency (Veiskarami, 2020).

2.5.2 Lack of Skilled Personnel

Numerous recent studies have indicated that the lack of skilled personnel is one of the significant challenges in implementing modular construction (Nabi and El-adaway, 2021; Kazem-Zadeh and Issa, 2020; Nazir, et al., 2021; Kisi, et al., 2019).

Modular construction requires skilled personnel because the design and assembly phases demand a high degree of collaboration between experienced contractors, fabricators, architects and installers in delivering the project. However, the industry is still learning how to apply modular construction, and more time is needed for the practitioners to adapt to modular norms (Paliwal, et al., 2021). Besides, proper planning, designing, scheduling, transporting and assembling are the crucial criteria for a successful project. However, this accurate planning requires modular experts with experience and knowledge to enhance the teamwork (Hořínková, 2021). The absence of such an expert prevents the merits of modular construction from delivering thoroughly and causes limitations in implementing the modular construction method.

Also, there is a lack of qualified manufacturers as stated by the interviewee of McKinsey (Bertram, Blanco and Mischke, 2019). The manufacturers face difficulty in obtaining the necessary experience while the industry is still struggling to provide a reliable alternative to deliver the project. Nazir, et al. (2021) pointed out that many construction players only have little or no experience with modern construction methods like modular construction. Since modular construction is not popular as conventional construction, most construction players are more familiar with the conventional method. Nabi and El-adaway (2021) observed that the respondents highly agreed that the shortage of skilled labour in modular construction poses a serious risk to the cost and schedule performance.

KPMG (2016) highlighted the shortage of skilled labour in the construction industry can be overcame by transferring the site-based activities to the factory environment. Off-site activities can attract labour from other industries instead of focusing on the limited pool of skilled resources in the construction industry. However, studies still show that the scarcity of skilled practitioner in modular construction remains a significant challenge. In the university, the students did not have opportunities to gain knowledge about modular construction and continued contributing to this issue. With this, Ferdous, et al. (2019) suggested that the industry can collaborate with the universities to provide necessary training to develop the skills required for implementing modular construction.

2.5.3 High Initial Cost

A high upfront cost is required in modular construction to establish the plan, design and set up the production line (Ferdous, et al., 2019). The client needs to invest in the factory, plant and machinery before the components can be produced in the factory. According to Veiskarami (2020), the drawings and designs are needed to change as the production depends on the factory technologies rather than the traditional on-site activities. The design and production costs for the first attempt are expensive, but the researcher further explained that this high initial cost could be recovered soon. This is because if the design can use repetition in the production line and focus on the standardisation of elements through the integration with modern software, the error can be revised and minimised over time. With this, rework can be minimised and the design can be implemented in multiple projects, saving a lot of cost for future projects (Veiskarami, 2020).

However, the investment in modern technologies again leads to an expensive scenario for the setting up phase. Since the financial institutions are more familiar with the traditional construction method, bank loan approval becomes complicated for modular construction. The problem is that project stakeholders will choose conventional construction if the cost of labour and machinery is lower than the manufacturing facilities of modular construction (Prajapati, Pitroda and Raichura, 2022). Bertram, et al. (2019) claimed that the allocated manufacturing expenses could account for between 5% and 15% of the total project costs but also depending on the setup level. Yet, there is also the previous study that claimed that investment in the manufacturing facilities such as production plants and technologies allows a predictable return of investment (Hořínková, 2021). Besides, investors today tend to invest in expensive innovative construction methods to create a healthy living environment for the public and to minimise the negative environmental impact (Veiskarami, 2020).

2.5.4 Need for Excessive Coordination and Collaboration

Modular construction requires excessive coordination and communication from the design stage to the on-site construction stage (Nabi and El-adaway, 2021). Therefore, multidisciplinary professionals need to work in parallel throughout the project lifecycle at a high level of collaboration (Hwang, Shan and Looi, 2018). Besides, it is important for every project team member to access and get the correct information to ensure smooth project delivery.

Effective communication and coordination are crucial to prevent disputes between the parties (Nabi and El-adaway, 2021). Due to the complexity of the modular construction, accurate scheduling is required in delivering the project to prevent time and cost overrun (Hořínková, 2021). Hence, a high level of collaboration is needed between the parties such as the architect, engineer and manufacturer. The project team should carefully plan the design of the modules, including the mechanical, electrical and plumbing installation before the designs are put into production. However, the fragmented nature of the construction industry puts parties in an adversarial relationship (Nazir, et al., 2021). Therefore, time is needed by each party to transform their attitudes toward each other so that they can collaborate well on the project.

Veiskarami (2020) elaborated on the supply chain-transportation-onsite assembly system to show the importance of effective coordination and communication among the team members. Once the modules are ready to transport to the site, the transportation should synchronise with the factory supply and the on-site assembly demand. This is because the schedule, storage and demand of both the factory and the site will be affected if there is a delay in transportation. The researcher further emphasised that the on-site assembly line must communicate on time with the factory expert to reduce the negative impact on the execution phase. Therefore, the factory, transportation and site should collaborate well to facilitate smooth project delivery. It suggests that modular construction should employ JIT delivery to avoid additional storage costs (Wilson, 2019a).

2.5.5 Low Flexibility in Design

In modular construction, the design is inflexible in the later stage (Abdul Nabi and El-adaway, 2021; Kazem-Zadeh and Issa, 2020; Nazir, et al., 2021). This is because design changes during the manufacturing and construction stages are expensive. In addition, the building parts in modular construction demand good tolerance and interface to allow a better connection among the building components when assembling (Nabi and El-adaway, 2021). As a result, any changes in one component may affect the design of other components, which contribute to redesign, rework, waste of material, waste of productivity, time overrun as well as cost overrun. Therefore, the design team will allow early design freeze and avoid changes during the manufacturing stage.

Moreover, the transportation constraint also contributes to the inflexibility of design in modular construction (Bertram, et al., 2019). Since the components or modules need to transport to the construction site for assembly, their size may be limited by the local road and transport regulations. Wilson (2019a) revealed that modular construction would limit architects' design options and control as believed by some of them. From the architect's view, the design such be innovative and attractive enough to attract the client. Still, manufacturers think the product should be simple to allow time and cost efficiency (Veiskarami, 2020).

The report of McKinsey mentioned that the industry learned to develop repeatable designs to reduce costs (Bertram, et al., 2019). Mass production led to limited variety in module design. However, it also should be clear that repeatable designs do not mean being unable to customise. In fact, modular construction could develop standardisation to provide opportunities for mass customisation and offer design freedom. Yet, economics-of-scale should be achieved to allow cost efficiency and this is another challenge to achieve flexible design as more cost, time and resources are required (Bertram, et al., 2019).

2.5.6 Time-Consuming Planning and Design

Long lead-in time is also one of the challenges of modular construction (Kyjaková and Bašková, 2016; Navaratnam, et al., 2019). The project processes can be complicated because the components should produce off-site and delivered to the site for installation (Hořínková, 2021). Therefore, proper planning is demanded to carefully consider every project process to identify the possible constraints and propose strategies to eliminate them before the problem arises. This is different from conventional construction as a higher level of the decision will take place in the early stage (Wilson, 2019a). In modular construction, accurate planning and scheduling are required before the project implementation because changes especially in the design are difficult to achieve once the project enters the manufacturing phase (Nazir, et al., 2021).

According to Bertram, et al. (2019), the design processes for modular construction will be longer than for conventional construction. This is to allow the design to be aligned with the manufacturing process. The designs for modular construction also have different complexities from the designs of conventional construction. For instance, the capabilities when the components or modules are being lifted, transported, placed and jointed need to take into account during the planning and design stage (Navaratnam, et al., 2019). Therefore, modular construction requires a high level of design at an early stage to allow robust buildability testing of the design before submission for manufacturing (KPMG, 2016). In addition, early design decisions are needed since modifications in a later stage are more expensive and challenging. Hence, more time must be allocated to the planning and design phases to produce a high-quality project proposal before manufacture and construction starts.

2.5.7 Client Resistance

Since modular construction is not well-known in the building market, clients are reluctant to accept the modular concept as its application is low. The lack of knowledge and some clients' bad experiences with off-site construction have created resistance to adopt modular construction (Veiskarami, 2020). Besides, different manufacturers may have different standards as the current supply chain of modular construction is fragmented and undeveloped. Bertram, et al. (2019) claimed that the risk of bankruptcy was high as there are limited track records to prove the interoperability of the modular construction. In addition, the unfamiliarity of financial institutions with modular construction also leads to a higher lending rate (Tzourmakliotou, 2021).

Furthermore, the client may need to revise the financing arrangement when modular construction is implemented (Wilson, 2019a). This is because the project progress of modular construction is faster and may contribute to the unreasonable cash flow of the client. Moreover, the contract and procurement system are also needed to redefine the relationship between the parties. The reason is that the traditional contracting method, such as design-bid-build will cause significant disconnection between the parties and put them into adversarial situations (Veiskarami, 2020). Modular construction required a high level of collaboration between the parties to develop detailed designs instead of creating a gap between the parties. As a result, the client who familiars with the traditional procurement method may refuse to adopt the changes (Hyams, Mccann and Ferguson, 2018).

Moreover, the client can enjoy multiple design options in traditional construction. However, these design options are absent in modular construction due to the possible monotonous architecture (Wuni and Shen, 2020a). This contributes to the adaptability concern as the client may resist adopting such an innovative construction method. Therefore, it leads to a low confidence level of both the clients and contractors to implement modular construction in their development.

2.5.8 Lack of Guidance and Government Support

Sufficient guidance and government support are essential for implementing every new system in the industry. However, there is a lack of information about modular construction, which prevents the contractors or manufacturers from applying this technology. In fact, the government should set the codes and standards for the requirement of modular construction in providing the guideline to the practitioners (Kisi, et al., 2019). Yet, Wilson (2019a) claimed that no special regulation is imposed on modular construction as the practitioners are expected to adhere to the same building codes as traditional structures. The barrier is the differences in the application and approval process between modular and traditional construction which the practitioners are unfamiliar with.

Besides, the lack of incentives or funds cannot attract the construction player to adopt modular construction. Since modular construction requires a high initial cost, small contractors cannot afford the up-front cost due to the lack of funding (Rahim and Qureshi, 2018). Ferdous, et al. (2019) raised their voice towards the unwillingness of financial institutions to fund the modular construction project in Australia. The researcher revealed that the Little Hero Apartment project that implements modular construction in Australia was sourced by Arab Bank rather than the Australian bank due to the challenges accounted for modular construction. The absence of government support and intervention limits the implementation of modular construction. In fact, the government should drive the adoption of modular construction by funding the private-public relationship projects. For instance, all public housing projects in Singapore must implement the PPVC method (Bertram, et al., 2019).

2.5.9 Expensive

Although modular construction is cost efficient due to faster project duration as discussed earlier, it can be more expensive than traditional construction. Modular construction is sustainable, durable and advanced. This means that costly sustainable materials and advanced technologies are to be allocated to the modular construction. Meanwhile, the manufacturing facilities are more automated and hence the tolerances of the materials used require greater precision. According to Bertram, et al. (2019), precision robotics cannot compensate for slightly deformed materials like skilled workers on site. In addition, manufactured components should qualify for the lifting, transportation and assembly loads. To ensure these competencies, high quality materials are required in manufacturing the components and the cost will be driven up.

Apart from these, the high initial costs and logistic costs that discussed earlier also contributed to this expensive scenario (Hyams, Mccann and Ferguson, 2018; Tzourmakliotou, 2021). Meanwhile, modular construction requires additional transport vehicles, lifting plants and labours because the components or modules need to deliver to the construction site for assembly. As a result, this leads to the expensive cost of modular construction although it saves more costs than conventional construction (Wilson, 2019a).

2.5.10 Lack of Social Knowledge

Compared to traditional construction, there is a lack of social knowledge about modular construction and the public is negatively perceiving off-site construction (Kamali and Hewage, 2016). Davies (2018) further emphasised that the public perception of modular construction is a temporary solution. This is because the prefabricated house served as an emergency solution during the post-war period to fulfil the urgent needs of housing where the labour, material and money supplies were on a short-term basis (Hyams, Mccann and Ferguson, 2018). Besides, most off-site accommodations are used on the construction site, with low-quality material and less functional features (Veiskarami, 2020). This perception is still aroused in the public mind which reduces the demand and supply of modular construction in the market. As a result, people prefer buildings with conventional construction and refuse to purchase buildings built with modular construction.

2.6 Strategies to Enhance the Implementation of Modular Construction

Although the opportunities and challenges of modular construction have been discussed, the motivation to apply modular construction may not exist due to presence of various challenges. Therefore, the strategies to enhance the adoption of modular construction also need to assess. This is to encourage the construction practitioners to employ modular construction and the government to take necessary steps in making it happens. Some strategies had been identified to enhance the implementation of modular construction as shown in Table 2.5.

Table 2.5: Strategies to Enhance the Implementation of Modular Construction

Ref	Strategies	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
S1	Government incentives and subsidies	√	√	√	√		√		√	√		√	√		√	√		√	√	13
S2	Training and education	√	√	√		√	√		√		√		√	√	√	√	√		√	13
S3	Encourage close collaboration	√	√	√				√	√	√	√		√	√		√	√		√	12
S4	Establish effective logistic and supply chain management	√	√				√	√	√	√	√			√			√			9
S5	Policies and regulation		√	√	√		√	√	√			√	√		√					9
S6	Revision of building codes and standards		√				√	√	√			√	√		√					7
S7	Research and development	√	√			√		√	√						√			√		7
S8	Government leadership and initiative	√	√	√			√		√	√							√			7
S9	Publicity and promotion		√	√	√		√			√			√				√			7
S10	Technology improvement		√				√		√	√							√			5

Author: **1**-Algumaei and Sarpin (2022); **2**-Khan, et al. (2022); **3**-Marinelli, et al. (2022); **4**-Yuan, et al. (2022); **5**-Kwang, et al. (2021); **6**-Wuni and Shen (2020a); **7-**Wuni and Shen (2020b); **8**-El-Abidi, et al. (2019); **9**-Ismail, et al. (2019); **10**-Liu, et al. (2019); **11**-Wuni and Shen (2019); **12**-Hwang, Shan and Lye (2018); **13**-Hwang, Shan and Looi (2018); **14**-Rahimian, et al. (2017); **15**-Mahazir and Ng (2017); **16**-Kamar, Azman and Nawi (2014); **17**-Lou and Kamar, (2012); **18**-Mohamad, Zawawi and Nekooie (2009)

2.6.1 Government Incentive and Subsidy

Modular construction posed various financial challenges to construction practitioners. For example, the need for high capital costs, expensive transportation costs and the requirement for high-quality materials (Bertram, et al., 2019). These financial constraints had rubbished the interest of construction practitioners in implementing modular construction. It becomes more significant to the small and medium construction organisations due to the lesser capital available and financial capabilities (Hwang, Shan and Lye, 2018). Therefore, the role of the government is critical to support the development of modular construction. The government should offer the construction stakeholders with incentives and subsidies to motivate them to adopt modular construction (Algumaei and Sarpin, 2022; Khan, et al., 2022; Wuni and Shen, 2020a; El-Abidi, et al., 2019). Wu, et al. (2021) classified the incentives into two groups which are economic incentives and non-economic incentives. The incentives that fall into the economic domains are financial subsidy, credit incentives, loan incentives, tax relief, land approval policy, and gross floor area concessions. In contrast, non-economic incentives include the approval process, reputation and transportation benefits.

In Singapore, the Building and Construction Authority (BCA) established the Off-site Construction Special Scheme (OCSS) to encourage the development of modular construction projects (Building and Construction Authority, 2022c). Besides, tax exemption is also one of the motivation schemes for the industry. In Malaysia, the Industrialised Building System tax incentive allows the construction players to offset the yearly statutory income by up to 70% (Construction Industry Development Board, 2020c). With the incentive or subsidy available, the construction player will be encouraged to apply this new technology because they can enjoy the benefit provided by the government and reduce the financial burden. This can increase the practitioners' satisfaction when implementing modular construction (El-Abidi, et al., 2019). The researchers further revealed that the limited number of contractors, manufacturers and suppliers in modular construction had resulted in monopolistic market conditions and led to a high-price contract. Therefore, the government's incentive and subsidy allow more construction organisations to participate in modular construction and enhance the competitiveness of tendering (El-Abidi, et al., 2019).

Besides, the government shall provide home purchase subsidies and property tax incentives to the developers and buyers (Yuan, et al., 2022). For instance, optimisation of land acquisition procedure and instalments of land transaction fees can be offered to the developer. On the other hand, the government can increase the mortgage loan amount and decrease the ratio of down payment for the buyer to buy the modular building. This can encourage developers and buyers to choose the building constructed with modular construction (Yuan, et al., 2022). However, the public lacks confidence in the modular building due to its low implementation. With the availability of the incentives, the buyer will be convinced to purchase the house constructed with modular construction and increase the demand for modular construction. Therefore, both the demand and supply of modular construction can increase simultaneously (Khan, et al., 2022).

2.6.2 Training and Education

The modular construction required skilled personnel to deliver the project. However, there is a lack of such skilled players in the industry (Ferdous, et al., 2019; Hwang, Shan and Looi, 2018). The designers, suppliers and manufacturers lack of experience in designing, producing and delivering modular project. By transferring on-site activities to off-site, the labours also need to upgrade their skill to adapt to the new working environment. However, previous construction and engineering graduates did not have the opportunities to learn about modular construction (Wuni and Shen, 2020a). Therefore, there are lesser trained personnel that specialise in modular construction available in the industry.

To deal with this problem, adequate training and education should be provided to the construction players including architects, manufacturers, contractors, consultants, labours and all involved to increase their knowledge and capability to handle the modular construction project (Khan, et al., 2022). It is necessary for the professionals to transfer the skills and knowledge of modular construction to the project team through a series of training. This allows the project team to increase their familiarity with the technologies and have more confidence to adopt modular construction method (Hwang, Shan and Looi, 2018). In Singapore, several vocational education institutions have launched the training and workshops. For instance, the BCA Academy that affiliated with the BCA, which is the construction industry authority of Singapore, offers training courses related to PPVC, such as the 1-day PPVC lifting course for crane operators and 2-day supervision of PPVC project course for project managers (BCA Academy, 2020). Kwang, et al. (2021) suggested that CIDB should launch more training and consultancy services regarding modular construction to upskill the construction players.

Besides, the university should provide the students with the necessary engineering and construction knowledge related to modular construction. For instance, the related course can be introduced by the universities with scholarships and seminars can be organised to enhance the engagement of students (Marinelli, et al., 2022). This was mentioned by Wuni and Shen (2020a) that many universities have incorporated the engineering, operation and management of modular construction into the Construction Engineering Management Programme. Furthermore, the industry-university partnership can be established to provide internships, scholarships and training to the university students (El-Abidi, et al., 2019). For example, seminar related to modular construction can be held by universities or professional bodies with the collaboration of CIDB to share the professional knowledge. Hwang, Shan and Lye (2018) also stated that the government should fund more education programmes for modular construction to improve the built environment. With this, the students and construction players can gain the necessary knowledge and skills for modular construction, which in turn allow the implementation of modular construction to develop smoothly in the country.

2.6.3 Encourage Close Collaboration

Modular construction required extensive collaboration between the project stakeholder throughout the project processes (Xu, Zayed and Niu, 2020). Strong working relationship and collaboration between the multidisciplinary team is paramount to the success of the modular construction project. Therefore, the collaboration between various parties should be encouraged (Liu, et al., 2019; Mahazir and Ng, 2017). In the planning and design stage, the project team members need to work together to produce detailed designs because modular construction design is inflexible during the manufacturing stage. As a result, a high level of design should be provided before the manufacturing process to avoid time and cost overrun, as any changes to the design at the later stage are expensive and time-wasting (Wilson, 2019a).

Unlike the traditional procurement that is applied in traditional construction, the manufacturers and contractors should involve in the planning stage of the process. This is because the manufacturers and contractors are qualified for the buildability and tolerance of the components or modules (Wuni and Shen, 2020b). The structural design such as the interface and connection between the components must be communicated well between the designers, engineers and manufacturers. Wuni and Shen (2020b) highlighted that RFID and BIM-enabled platforms allow effective information exchange and progress monitoring between the parties. All members should receive identical information to prevent the potential for dispute.

It should be highlighted that BIM is an effective process to optimise the communication and information flow between the parties. Autodesk (2022) defined BIM as “a process of creating and managing information for a built asset throughout its lifecycle—from planning and design to construction and operations”. Unlike 2D CAD, 3D BIM can offer both visualisation and collaboration benefits. The communication and information flow between the multidisciplinary teams are enhanced by the ability to work on the same model as the members can be updated when the design changes occur. The BIM database allows the stakeholders to access the latest information about the project and communication can be made on time when the problem happens.

According to Dalui, et al. (2021), the adoption of BIM software such as Revit and Navisworks allows the project stakeholders to have a virtual visualisation of the proposed building with other additional functions such as clash detection. If the architect and engineer work on different model, clash may not be able to discover until the site installation take place. Yet, possible design discrepancies can be detected before the model is put into the manufacturing and construction progress (Chahrour, et al., 2021). Hence, BIM can enhance both the communication and collaboration to improve the information flow between the parties.

2.6.4 Establish Effective Logistic and Supply Chain Management

Effective supply chain management is another vital strategy to improve the adoption of modular construction (El-Abidi, et al., 2019; Ismail, et al., 2019). The components or modules are manufactured in an off-site environment before being assembled on the site. Hence, the project team must ensure that the project delivery is seamless to prevent any delay, especially on the logistics. The raw material supply, production process, transportation of modules, etc., need to be appropriately coordinated. Therefore, an effective logistic system is important to ensure that the supply of modular components is compatible with the site demand to ensure the project can deliver smoothly. Veiskarami (2020) revealed that it is important to synchronise the transportation, factory supply and site demand. This is because a delay in the logistics will affect not only the project schedule but also the storage and demand of both off-site and on-site environments.

To guarantee the desired logistic performance in components or modules supply, a material flow plan from the factory to the designated location, and the mechanism to simplify and manage the process is required (Wilson, 2019a). Besides, the improvement of the coordination between various parties is also crucial in optimising intermodal transportation. Niu, Yang and Pan (2019) also revealed that the staging area that close to the construction site can help resolve the storage issue and avoid the delay in module delivery. In addition, Wang, et al. (2019) divided supply chain management into four thrusts of production, inventory management, transport management, and overall performance. Thrust 1 consisted of production scheduling and resources allocation; Thrust 2 covered layout optimisation, inventory level, and identifying, tracking and locating prefabricated components; Thrust 3 proposed the JIT delivery, transportation tracking, and transportation operations management; while Trust 4 focused on the information management as well as the risks and disturbances management.

It should be highlighted that JIT has been mentioned to be an effective system to manage the supply chain in modular construction (Veiskarami, 2020; Wuni and Shen, 2020a; El-Abidi, et al., 2019; Liu, et al., 2019; Hwang, Shan and Looi, 2018). Cambridge English Dictionary (2022) defines JIT as "a manufacturing system in which parts and materials are delivered when they are needed, rather than before." According to Hussein and Zayed (2021, p.3), JIT is "a lean construction approach, which aims to deliver required materials on-time, at the right location, and with the required quality and quantity." This system is significant in modular construction as the building components or modules should supply to the site when needed to prevent additional storage costs and waste of time. Wilson (2019a) also mentioned that the insufficient or excessive supply of components and modules can be eliminated by employing JIT. It allows the schedule and budget of the project to go smoothly as planned to minimise the interruption in logistic and supply chain areas.

Furthermore, the digital twin can be incorporated into modular construction to aid efficiency in supply chain (Lee and Lee, 2021). This allows real-time monitoring to take place in modular construction. The researcher revealed that integrating digital twin with BIM and GIS enables an effective logistic simulation. In addition, the IoT devices can be attached to the module to detect the real-time location and condition of the assets. With this, the real-time information is updated to the BIM-based digital twin model to monitor the progress of the work. This allows the 'what if' scenarios to be generated to identify the potential risk along the logistic system and look for an optimal delivery route based on GIS. Hence, the logistic delay problem can be prevented to ensure the components or module transportations are going smoothly to meet the schedule and site demand.

2.6.5 Policies and Regulations

The development and implementation of appropriate policies and regulations are one of the strategies in encouraging the adoption of modular construction (Khan, et al., 2022; Marinelli, et al., 2022). The role of government in providing policies, regulations, guidelines, incentives and schemes is considered as an enormous boost and encouragement for the adoption of modular construction. In Malaysia, modular construction is one of the key technologies under the Construction 4.0 Strategic Plan. Khan, et al. (2022) found that the government's policies are closely related to socially driven impacts and will affect the demand growth. Therefore, the policymakers must clearly understand the social aspects in formulating the policies and regulations.

The CIDB has published the Manual for IBS Content Scoring System (IBS Score) which is a construction industry standard. The objective of this manual is "to provide a well-structured assessment system in calculating the IBS Score of a building" (Construction Industry Development Board, 2018, p.1). The IBS score looks into four attributes which are the IBS components usage, MS 1064 standardised material usage, structural layout repetitive, and the utilisation of productivity enhancement solutions such as the BIM, modular gridlines and volumetric module. To obtain a higher IBS score, the construction project should have high productivity to enable a shorter project schedule and reduce the dependency on labour incentive activities by reducing the site labour. Besides, the project should reduce the wastage and material on site to result a cleaner and neater site. A better output quality, safer site and lower construction cost are also the key points contributing to a high IBS score. Through the implementation of modular construction, the project can obtain a high IBS score which can enhance the reputation of the involved construction organisation and members. Hence, the IBS policies such as the IBS scoring system can guide the construction practitioner towards achieving higher-level modular construction such as the 3D module.

Besides, the incentive-based policies discussed in Section 2.6.1 is also the policies that can enhance the adoption of modular construction. Incentive policies can actively introduce and promote the modular construction. Furthermore, it allows the developer reduced the incremental investment costs for developing and designing modular construction (Yuan, et al., 2022). The researcher also revealed that the government could promote the pre-sale policies in which the developer is enabled to enjoy the return on capital and turnover to reduce the incremental development cost. Moreover, economic incentives such as credit policy support to the homebuyers can be considered by the policymakers to encourage the homebuyers to purchase the modular building. As a result, the demand and supply of modular building will increase, and more construction practitioners will be attract to implement modular construction.

2.6.6 Revision of Building Codes and Standards

The construction product, either a component, element or building, should meet the standard requirements. This is to ensure the construction deliverables are performed safely and optimally to enhance the function and value. Therefore, building codes and standards are the important criteria in the industry to guide the construction player in delivering the project and creating the desirable construction product. With this, adequate codes and standards should be established as guidance in meeting the standard requirement for the modern method of construction such as modular construction (Khan, et al., 2022).

Wuni and Shen (2019) claimed that the government should review and revise the building code to encourage the adoption of modular construction. In Malaysia, Uniform Building By-Laws (UBBL) that specify the design and specification requirement of the building's structure such as the materials, foundation and superstructure is generally followed to ensure the safety of a building (Wong, 2021). However, MBAB revealed in an interview with The Edge Markets that UBBL needs to be amended to make the modular construction more economical (Idris, 2017). While the IBS panels and components have the standard size, every local council possesses different UBBL with their own measurement standards. The interviewee suggests the authorities to establish a standard to be followed by the construction industry. In Singapore, BCA enhanced the framework of the Code of Practice of Buildability in 2019 to increase the adoption of PPVC in Singapore (Building and Construction Authority, 2022a). Malaysia authorities should conduct the same to revise the building codes that suit the modular construction.

Besides, standards need to be set to enhance the modular implementation. For instance, the IBS Impact Certification has been established and ISO 21723:2019 for modular coordination has been published

(International Organization for Standardization, 2019; SIRIM QAS International Sdn. Bhd., 2022). With the available standard provided, the construction players can be guided to implement modular construction. As an illustration, Home Builder Petra Modular (M) Sdn. Bhd. becomes Malaysia's first modular manufacturer to obtain the IBS Impact Certificate. The company had been invited to attend the Vision 2045 at Edinburgh to share their sustainability practice to address climate change (The Star, 2022b). Obviously, available standards and achievement of standards allow the organisation to enjoy a growing status and reputation with modular construction. Therefore, appropriate codes and standards that fit modular construction should be established to increase the application of modular construction in the industry.

2.6.7 Research and Development

Although various research about modular construction is available, the local research and implementation rate of modular construction are still low in the country. Hwang, Shan and Looi (2018) claimed that there is insufficient research in the field of modular construction and hence more research is needed to discover various aspects of modular construction. Therefore, the government should put more funds into the research area. With this, more research and development inputs are available for the relevant research centre to conduct research on modular construction (El-Abidi, et al., 2019). As an illustration, the Korean government has invested $30 million in the research and development of modular construction that aims to support the commercial and residential projects with advanced modular engineering methods (Wuni and Shen, 2019).

In foreign countries, multiple research centres and laboratories operate as modular construction research and development centres. For instance, the University of Alberta in Canada had set up the Modular Construction Research Group to discover and develop the process of industrialisation and modernisation (University of Alberta, 2022). Hence, research and development centres are required to disclose the innovative areas of modular construction to raise the industry awareness. Moreover, Lou and Kamar (2012) highlighted that more research should be done on change management, benchmarking and identify the critical success factors to help construction players adopt modular construction methods. If the academicians or research institutions can deliver an effective project scenario that highlight the cost and return on investment, it would be beneficial to the construction players by providing them guidance and confidence to implement modular construction (Khan, et al., 2022).

Furthermore, Khan, et al. (2022) mentioned that the strategies and framework to promote modular construction should be developed by the researcher in assisting the culture shift of the construction industry. This can reduce the resistance to change as reliable findings can help the industry to understand that the role of key players in the traditional construction will not be affected by the shift to modular construction. Meanwhile, the researcher should establish the feasibility assessment framework for modular construction as highlighted by Wuni and Shen (2020a). More research about this sustainable construction method should be developed to promote the effectiveness of modular construction.

2.6.8 Government Initiatives and Leaderships

The government's leadership and initiative are important drivers toward the implementation of modular construction (Khan, et al., 2022; Marinelli, et al., 2022; Wuni and Shen, 2020a). Wuni and Shen (2020a) revealed that the government should take the initiative to demonstrate the feasibility of implementing the modular construction. For instance, the industry will be encouraged to practice modular construction through the establishment of private-public partnerships and alliances (Kamar, Azman and Nawi, 2014).

According to Sadran (2022), the private-public partnership is the partnership between government agencies and the private sector in delivering goods or services to the public. Although the private-public partnership is often associated with Malaysian infrastructure development, it has also been extended to the Malaysian housing sector. For example, the 1 Malaysia Housing Programme (PR1MA) was one of the government's private-public partnership initiative projects in which the private sector is expected to execute the project. At the same time, the public sector provides the land and other incentives (Razi, Ali and Ramli, 2020). Through the private-public partnership, the loan and incentive processes are simplified as the financial institutions have more confidence to provide fund due to government intervention. Therefore, it is a financing vehicle for the modular construction project (Khan, et al., 2022). Meanwhile, the technology transfer, local personal training and national capital markets can continue to develop (Mishra, 2022). Under this condition, the construction players will be motivated to collaborate with the government to carry out the development project through the modular construction method.

In addition, the government is playing a role in generating the demand for modular construction projects (Marinelli, et al., 2022). It is needed for the government to act like a leader in taking the initiative to implement modular construction. For instance, the Building and Construction Authority requires that all public housing projects in Singapore implement the modular construction method (Bertram, et al., 2019). Besides, Sweden's government uses the modular construction method to deliver 250,000 housing projects to handle the growing housing crisis (Wuni and Shen, 2019). However, Khan, et al. (2022) highlighted that the client, developer, contractor, manufacturer and other construction players lack intent toward modular construction. Therefore, the government should call for more public or private-public projects to implement the modular construction method. This is because the government interventions can facilitate the demand and supply of modular housings. Meanwhile, the incentive, promotion and policies should be developed together to encourage the construction players to participate in modular construction.

2.6.9 Publicity and Promotion

To encourage the implementation of modular construction, promotion is one of the tactic to make it happened (Marinelli, et al., 2022; Ismail, et al., 2019; Kamar, Azman and Nawi, 2014). Khan, et al. (2022) indicated the most critical driver for the adoption of modular construction is the social force. Government programs that promote the social capital scheme and social cohesion make it easier for people to realise the rich benefits of modular construction. For instance, advertising and awareness programs through media could be made to the public to raise their attention toward modular construction and its value. This promotion can be done through CIDB (Kamar, Azman and Nawi, 2014). As an illustration, CIDB has set up the IBS Info Gallery since 2008 that allows the visitor to visualise various models and showroom of IBS (Construction Industry Development Board, 2022c). In view to this, CIDB and the education organisation can collaborate to organise a student visitation to promote and enhance their understanding of IBS and modular construction.

Moreover, incentives need to be promoted to raise the awareness of industry stakeholders and the public toward modular construction (Yuan, et al., 2022). For example, the land transaction instalment can be made to the developer and a lower lending rate can be provided to the buyers. This could promote modular construction as the industry players and the public will be attracted to develop and purchase the modular building. Apart from this, the IBS Promotion Fund 2.0 (IBS 2.0) has been promoted to the Grade 7 contractors, manufacturers or installers who involved in the IBS project or possess the IBS certification with CIDB (SME Bank, 2022). The objective of this program is to promote the adoption and encourage the development of IBS in the industry, thereby increasing the adoption of modular construction.

Furthermore, the publicity and awareness campaign would also be an effective promotion (Ismail, et al., 2019). Today, every industry and business require a new mindset and changes in order to stay competitive. Therefore, the government and non-government bodies should organise awareness campaign to raise the awareness among the construction participants and public about the benefits of modular construction. Relevant training and education are required to provide by the construction organisation in collaboration with CIDB to ensure the industry personnel is aware and possessed the knowledge of the modern technologies, method and sustainable construction that emerged in the industry such as the modular construction (Hwang, Shan and Lye, 2018). Likewise, publicity can motivate the public toward sustainable living through modular construction (Khan, et al., 2022). This is because modular construction is sustainable, durable and of high quality. Therefore, the demand and supply of modular construction can increase when more people are aware of its advantages.

2.6.10 Technology Improvement

The modular construction will adopt various technologies into the project process. For instance, BIM, CAD and CAM will be used for the design and communication between the parties (Wilson, 2019a); automation and the robotic system will be facilitated in the manufacturing process (Bertram, et al., 2019); and other enabling technologies that will benefit the modular construction process. However, there is a lack of such technologies and the fund to invest in technology development (Veiskarami, 2020). Moreover, many small-scale manufacturers or contractors are not able to afford the alignment of BIM. Therefore, the stakeholder and government should enhance the use of technologies through investment and funding. The team members should also be able to adapt to the technologies in delivering the project. Hence, training is to be provided to the team members to ensure their competency in utilising the technologies.

The industry should invest into advanced technologies such as 3D fixturing and laser cutting other than those mentioned above (Wuni and Shen, 2020a). With the employment of technologies, the manufacturing process in modular construction is faster. Therefore, the most mentioned opportunities of modular construction, which is the improvement in project schedule and productivity can be achieved (Wilson, 2019a; Bertram, et al., 2019; Hyams, Mccann and Ferguson, 2018). As discussed in Section 2.4, precise machines allow for higher quality products and can reduce the potential of rework by eliminating the error. Hwang, Shan and Looi (2018) also mentioned that incorporating 3D visualisation and BIM into modular construction can effectively address the information-related barrier which allows the project team to plan the design properly before the actual work starts. Therefore, it is needed for industry to strengthen and invest in the technologies applied to modular construction.

2.7 Summary of Chapter

Chapter 2 reviews the researchers' ideas from various previous studies. The definition of modular construction across different countries have been provided, with the modular construction systems have been identified. In the following, this chapter discusses the opportunities of modular construction to justify the potential merits and advantages. The opportunities are divided into three groups of economic aspect, social aspect and environmental aspect. Meanwhile, the challenges of modular construction have also been explored to call the attention of construction practitioners about the potential barriers. Lastly, this chapter also assesses the strategies to enhance the implementation of modular construction.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

Research is "a search of knowledge" and "a scientific and systematic search for pertinent information on a specific topic" (Kothari, 2004, p.1). Chapter 3 discusses the research methodology applied to this study. This chapter focuses on the quantitative research method, research design and sampling design. In the following, the data collection and analysis methods are also provided.

3.2 Research Methodology

Research methodology is the way to systematically achieve the research objectives by answering the research problems (Kumar, 2011). The methodology is the term regarding the ways the researcher deals with questions and seeks answers. In other words, it refers to how the research is conducted. The choice of methodology will be influenced by people's assumptions, purposes and interests (Taylor, Bogdan and DeVault, 2016). Qualitative, quantitative and mixed methods are the types of research methodology that can be applied in the research (Creswell, 2014).

Taylor, Bogdan and DeVault (2016, p.7) defined the qualitative method as "the broadest sense to research that produces descriptive data—people's own written or spoken words and observable behaviour." According to Kabir (2016), most qualitative data is non-numeric, usually descriptive or nominal. Kothari (2004) highlighted that the subjective assessment of opinions, behaviour and attitudes is concerned with the qualitative method. This means that the research depends on the researchers' impressions and insights. For example, interviews, oral histories and participants' observations are some approaches to the qualitative method (Kumar, 2011).

Besides, Kothari (2004, p.5) mentions the quantitative research method as "involves the generation of data in quantitative form which can be subjected to rigorous quantitative analysis in a formal and rigid fashion." The quantitative data can be computed mathematical and numerically (Kabir, 2016). Kumar (2011) revealed that the study designs in the quantitative method are more than that in the qualitative method. The quantitative technique is well structured and specified. Moreover, the validity and reliability of the procedures have been tested and can be clearly defined and identified. For example, a survey such as a questionnaire is one of the ways to conduct the research under the quantitative method.

On the other hand, the mixed method is where qualitative and quantitative methods are integrated into a study (Creswell, 2014). The questionnaires were first used to collect data on the research questions. After statistically analysing the data collected, a smaller population sample is called for an interview to obtain further findings through their personal experiences and opinions (Leavy, 2017). Through mixed method, the qualitative and quantitative data are gathered, analysed and interpreted to provide a more accurate understanding of the study problems than the qualitative or quantitative data alone (Creswell, 2014).

This study adopted the quantitative research method, and the rationale for choosing this method is discussed in Section 3.2.1. The construction stakeholders within the Klang Valley area served as the data provider on their preferences for modular construction in Malaysia.

3.2.1 Quantitative Research

This study applied the quantitative research method to confront the research questions and achieve the research objectives. A questionnaire was adopted to collect the primary data from the targeted respondents. This method was selected because it is easier to obtain a large sample size than the qualitative method. Since the samples are considered representatives of the population, the results are deemed to be a general and adequate integrated view of the entire population (Queirós, Faria and Almeida, 2017). Therefore, generalisation can be achieved if the questionnaire is well designed. Besides, using statistical data can save time and resources for analysing the data by employing computer software (Daniel, 2016). The questionnaire was distributed to the respondent through email and social platforms like LinkedIn and WhatsApp. Moreover, the closed-ended questions were designed into the questionnaire where the respondents were required to answer within the suggested timeframe. After gathering the data from the respondents, Statistical Package for the Social Sciences (SPSS) will used to process the data.

3.3 Research Design

According to Kothari (2004, p.31), “the research design is the conceptual structure within which research is conducted; it constitutes the blueprint for the collection, measurement and analysis of data.” It is the flow of research that ensures the study runs smoothly. Kumar (2011) suggested two main functions for the research design. First, it identifies and develops the study procedure and the logistics required to conduct the study; second, to ensure the processes adequately answer the research questions validly, accurately and objectively. Figure 3.1 shows the research process for this study.

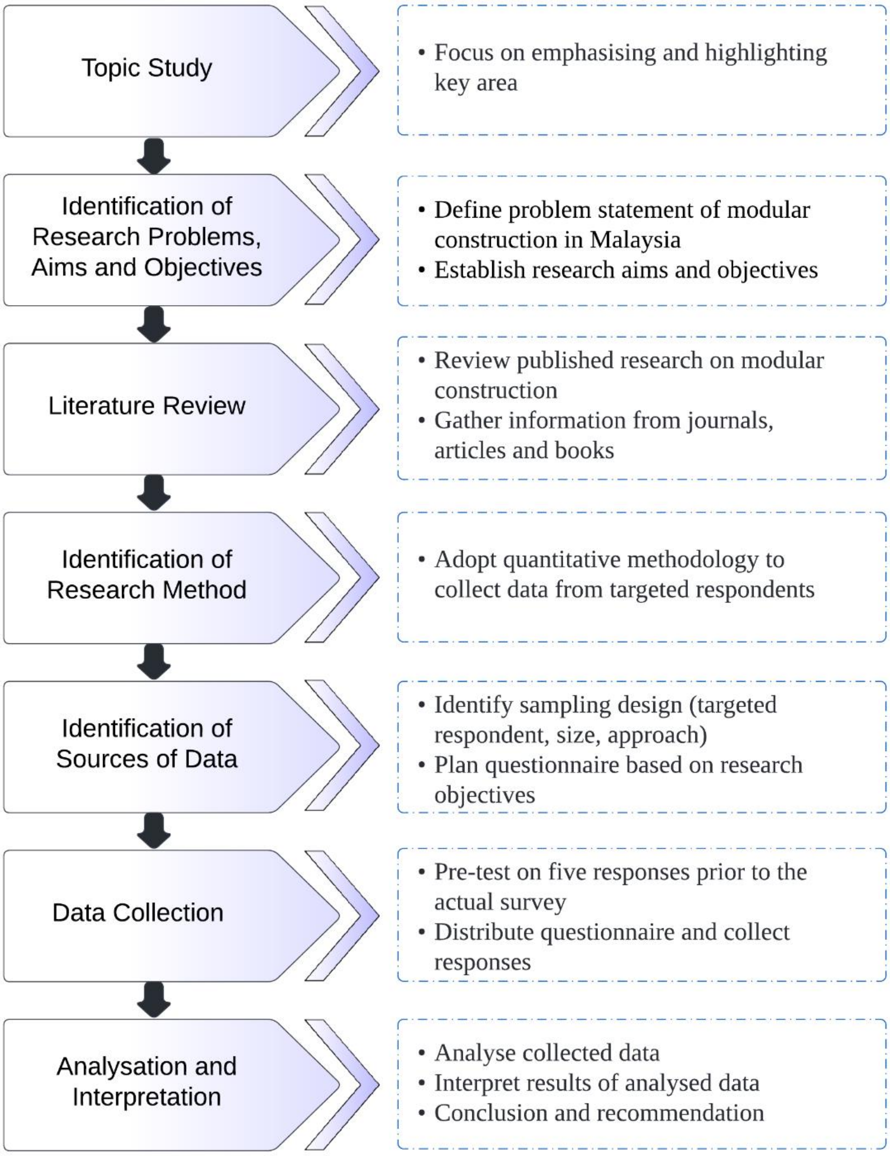

Figure 3.1: Research Flow

The first step is where the topic of the study was investigated to get a broad idea of modular construction. This allows the researcher to propose a realistic boundary for the study and focus on discovering the critical areas within the topic. It also assists the researcher in verifying the topic is interesting and feasible to study. In Step 2, the issues in the construction industry that pushed the topic to be researched were identified. A problem statement that clearly describes the current construction issues to show the need for research on this topic was provided, with the research gap identified. After the problem statement had been produced, the research questions, aims and objectives were developed.

During Step 3, the literature review was conducted to gather, tabulate and synthesise the ideas of previous researchers. The definitions of modular construction were provided across some of the developed nations, and the modular system types were discussed. Then, the opportunities and the challenges of modular construction, followed by the strategies to enhance the implementation of modular construction, were studied in detail by combining and comparing the context of various previous studies. Journal articles, conference papers, reports, handbooks, newspapers and magazines are the primary sources of literature review. Consequently, the research method was developed in Step 4. The quantitative research method was selected to answer the research questions adequately and accurately.

Step 5 is to determine the sources of data for this study. Before the commencement of data collection through the survey, the sampling design which includes the targeted respondent, sampling size as well as sampling method was developed. This process is crucial to ensure that the populations are correctly targeted and that the study findings are reliable. In this study, the raw data was to be derived from the targeted respondent and collected with the questionnaire. It consisted of four sections: demographic background, opportunities, challenges and strategies of modular construction. Multiple choice questions were furnished in Section A, while Sections B, C and D were designed with Likert scale questions. Moving on to Step 6, the data collection process had taken place. The pre-test was conducted on five responses before the actual survey commenced. Consequently, the questionnaire was distributed via email, WhatsApp and LinkedIn to the targeted respondents, the client, consultant and contractor personnel within the Klang Valley area.

After sufficient data had been collected from the targeted respondent, the study moved into Step 7 where the data analysis process occurred. In this study, the data analysis methods used included Cronbach’s Alpha Reliability test, Mean Ranking, Kruskal-Wallis test, Spearman’s Correlation test and Factor Analysis. The findings from the analysis were then interpreted and compared with the previous studies. Lastly, Step 7 concluded the study with the recommendation had been provided for future research.

3.4 Sampling Design

Before collect the data, the sample from a population was acquired through the development of a sampling design. Sampling is “the selection of some part of an aggregate or totality on the basis of which a judgement or inference about the aggregate or totality is made” (Kothari, 2004, p.152). It is also referred to as a process that examines a portion of a population to obtain information about that entire population. The targeted respondent, sampling size and sampling method will be identified during the sampling design.

3.4.1 Targeted Respondent

One critical criterion to consider when designing the sampling is the targeted respondent. The sample size is a defined boundary of a large population. The targeted respondent is not necessarily limited to one group, but it is possible to have more than one group. This allows the study to gather diversified information and perspectives in achieving the study objectives.

In this study, there are three groups of respondents which are the client, consultant and contractor within the Klang Valley area. The respondents are from a construction background or those related to modular construction or IBS who possess modular construction knowledge. These three groups of respondents were targeted to obtain different preferences on the opportunities, challenges and strategies for modular construction. Besides, Klang Valley was chosen because it involves the area of Kuala Lumpur and the adjoining towns of Selangor, where a large portion of the construction project is carried out. According to Construction Industry Development Board (2022a), Selangor and Kuala Lumpur are the top three states for the number of projects awarded in 2021, with more than 2500 projects for the former and more than 1000 projects for the latter. Therefore, the client, consultant and contractor from this area had been targeted as the respondent in the survey with the perception that the respondents have sufficient experience and knowledge of the industry.

3.4.2 Sampling Size

Before the commencement of the data collection process, the sample size would be identified. This allows the researcher to plan the number of questionnaires to distribute to the targeted respondent to collect sufficient data sets. This is paramount important as sample size will guide which data analysis method to be used to secure valid, reliable and consistent analysis results.

In this study, the sample size is determined based on Roscoe (1975), Raosoft (2004) and Yap, Low and Wang (2017). A sample size of 377 was calculated with Raosoft calculator (Raosoft, 2004). The rule of thumb proposed by (Roscoe, 1975) for determining the sample size revealed that the sample size between 30 and 500 is appropriate but a minimum of 100 is required for factor analysis (Yap, Low and Wang, 2017). This is because every explanatory variable should have at least five sample sizes (Yap, Chow and Shavarebi, 2019). In this study, the 20 opportunities of modular construction will undergo explanatory factor analysis. With this, at least 100 data sets should be collected. Therefore, a sample size of 377 is adequate for this study.

3.4.3 Sampling Method

Probability and non-probability sampling are two classifications of sampling methods (Kothari, 2004). According to Kumar (2011), random sampling is the alternate name for probability sampling. It indicates that every element in the population is provided with equal and independent opportunities for selecting as the sample. Equality means that there is an equal probability for the element to be chosen and not affected by other factors like personal interference. Besides, independence means that the selection of one element does not depend on the selection of another element in the sampling (Kumar, 2011).

In contrast, non-probability sampling has the opposite indication from probability sampling and is named non-random sampling. It is used when the number of elements cannot be individually identified or is unknown in the population. Therefore, the element is selected based on other factors or considerations (Kumar, 2011).

The non-probability sampling was adopted to select the sample that was appropriate for this study. The convenience sampling and snowball sampling had been employed as the sampling techniques. Yap, et al. (2022) highlighted that the convenience and snowball techniques were commonly adopted in the studies within the construction management area. According to

McCombes (2022), convenience sampling is used when the researcher has readily accessible individuals for gathering the initial data. On the other hand, snowball sampling achieves the sample selection through the network system in which information is collected from the selected people (Kumar, 2011).

3.5 Data Collection Method

Data collection happens to be a critical undertaking in systematically collecting and measuring information on variables to answer the research questions, examine the hypotheses and appraise the result (Kabir, 2016). According to Kumar (2011), primary and secondary data are the two major approaches for data collection. The primary source is said when the information is collected using the first approach to provide first-hand data. The data is collected afresh and happens to be the original data (Kothari, 2004). This means that the raw data collected is not evaluated and need to interpret by the researcher. There are several approaches for collecting the primary data, such as the survey, experiment and interview. On the other hand, the secondary source is said when the information is collected using the second approach to provide second-hand data (Kumar, 2011). Those data collected by others and underwent the statistical process are known as secondary data (Kothari, 2004). For example, it includes data from books, journals, newspapers, magazines and internet sources.

This study employed the primary data. Kabir (2016) revealed that primary data is more reliable, truthful and objective. The primary data will be derived from the questionnaire survey with the targeted respondents. The respondents were requested to respond to closed-ended questions in the questionnaire, and the data collected served as primary data. This is because the responses from the questionnaire are the freshly collected raw data and have not been analysed. After the primary data was collected, the data analysis stage would take place to process the data.

3.5.1 Questionnaire

This study employed a questionnaire survey for data collection. A well-developed questionnaire with proper wording and sequence is vital to secure the quality of the survey result. The questionnaire consisted of four sections with closed-ended questions. Before these, a brief introduction about the study such as the title of the study, aims and objectives were provided to allow the respondents to have some understanding of this study.

Section A aimed to collect the demographic background of the respondent. For example, the respondents were requested to provide their gender, education qualification, professional role, year of experience, etc. Section B focused on the opportunities for modular construction in Malaysia. The respondents were required to rank the 20 opportunities. In Section C, there were 10 challenges of modular construction in Malaysia that need to rate by the respondents. For Section D, it comprises of 10 strategies to enhance the implementation of modular construction in Malaysia which the respondents were asked to rank. All the questions in Sections B, C and D were extracted from Chapter 2 (Literature Review).

The questions in Section A were designed into multiple-choice questions with predetermined answers. On the other hand, Sections B, C and D consisted of five-point Likert scale questions in which the answer was in the range of 1 to 5. The range reflected the degree of awareness; agreement; and effectiveness in ascending order, where 1= "not at all aware; strongly disagree; ineffective", 2= "slightly aware; disagree; slightly effective", 3= "moderately aware; neutral; moderately effective", 4= "very aware; agree; very effective", 5= "extremely aware; strongly agree; extremely effective." In these three sections, the respondents needed to rank the opportunities, challenges and strategies to enhance the implementation of modular construction in Malaysia based on their preferences. Table 3.1 shows the five-point Likert scale employed in the questionnaire.

Table 3.1: Five-Point Likert Scale

Weighting	Section B	Section C	Section D
1	Not at All Aware	Strongly Disagree	Ineffective
2	Slightly Aware	Disagree	Slightly Effective
3	Moderately Aware	Neutral	Moderately Effective
4	Very Aware	Agree	Very Effective
5	Extremely Aware	Strongly Agree	Extremely Effective

3.5.2 Pre-Test

According to Reynolds, Diamantopoulos and Schlegelmilch (1993), the pre-test is a process during the development of the questionnaire. It aims to ensure that the questions are well understood by the respondent in determining the effectiveness of the questionnaire (Kumar, 2011). This study aimed at five sets of questionnaire responses for the pre-test before the full-scale questionnaire survey started. The questionnaire was sent to the five construction practitioners like the architect, quantity surveyor and engineer, and these responses were excluded from the actual study. If there are problems in the questionnaire, amendments and improvements could be made according to the feedback from the pre-test. This is important to ensure that the questionnaire is well developed before the official distribution to effectively collect reliable data for the study.

3.6 Data Analysis Method

Mishra, et al. (2019) revealed that a data set is a collection for an individual case or subject. Often, presenting these data individually does not make sense as this would not lead to any significant conclusions. After distributed the questionnaire and collected the data, the data obtained would undergo a series of analyses. The data analysis is carried out to appropriately interpret the data collected and ensure accurate results are produced in the study. This includes the preparation, summarisation, rearrangement and tabulation of data to facilitate data interpretation. In this study, the data analysis techniques that adopted were as follows:

1. Cronbach’s Alpha Reliability test
2. Mean Ranking
3. Kruskal-Wallis test
4. Spearman’s Correlation test
5. Factor Analysis

SPSS was used to analyse the data collected. It is a statistical software package developed by IBM Corporation and widely adopted by academics and researchers worldwide. The descriptive analysis, reliability test and correlation test are among the various parametric and non-parametric tests supported by SPSS (Ong and Puteh, 2017). Therefore, it is adequate as a data analysis tool in the study.

3.6.1 Cronbach's Alpha Reliability Test

Cronbach's alpha, α, was developed in 1951 by Lee Cronbach. It is a reliability test to assess the internal consistency of a set of tested items (Goforth, 2015). Reliability is defined as "the extent to which [measurements] are repeatable and that any random influence which tends to make measurements different from occasion to occasion is a source of measurement error" (Nunnally, 1967 cited in Cortina, 1993, p.98). Besides, the alpha value is displayed as a figure within the range of 0 to 1 (Tavakol and Dennick, 2011). This test is commonly used in determining the reliability of the scale for the Likert scale-based questionnaire.

Table 3.2 illustrates the rule of thumb for Cronbach's alpha based on Glen (2022). It revealed that the alpha value higher than or equal to 0.7 ($\alpha \geq 0.7$) reflects the data collected is reliable and acceptable. In contrast, an alpha value smaller than 0.7 ($\alpha < 0.7$) is unreliable and unacceptable. Theoretically, a higher alpha value indicates a greater level of internal consistency among the tested items. This test was applied to identify the internal consistency of the opportunities, challenges and strategies group in this study.

Table 3.2: Rule of Thumb for Cronbach's Alpha

Cronbach's Alpha	Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.5 > \alpha$	Unacceptable

3.6.2 Measures of Central Tendency

The central value of a data set is identified through the measures of central tendency. Mean is the average value, the medium is the middle position value, and the mode is the most frequently happened value within a data set (Mishra, et al., 2019). Meanwhile, the mean is the most commonly used among these three measures. This is because the median only employs some available data and is unsuitable for further mathematical calculations. Likewise, the mode is unsuitable for analysis due to its non-algebraic expression and high fluctuation in a small sample size (Manikandan, 2011a).

On the other hand, the mean is a satisfactory representative of the data because all available data is employed. Besides, it is resistant to fluctuation as the data derived from the same population tends to have similar means (Manikandan, 2011b). Hence, the mean was used in this study due to its adequacy. According to Manikandan (2011b), mean finds the average score of a particular variable as ranked by the respondent. Moreover, a standard deviation (σ) measures the degree of dispersion of the data from the mean. A low standard deviation implies that the data are grouped around the mean, whereas a large standard deviation shows that the data are more dispersed (Hargrave, 2022). In this research, the opportunities, challenges and strategies to enhance the implementation of modular construction were ranked according to the calculated mean to assess the study objectives.

3.6.3 Kruskal-Wallis Test

The Kruskal-Wallis test is a non-parametric test that also known as H-test. It aims to detect whether there are significant differences between the independent variables (Zhang and Zhang, 2009). In other words, it determines whether statistical differences exist between different groups of respondents. Meanwhile, another non-parametric test that performs a similar function is the Mann-Whitney U test. The difference between H-test and U-test is that U-test is used when examining two variables, while H-test can accommodate more than two variables (Zhang and Zhang, 2009).

This study adopted the Kruskal-Wallis test to determine whether a significant difference existed between three independent groups of client, consultant and contractor on each variables. Both null hypothesis (H_0) and alternative hypothesis (H_1) will be tested in Kruskal-Wallis test. H_0 demonstrates the groups have no significant differences, while H_1 demonstrates the groups have significant differences. If the value is equal to or smaller than 0.05 ($\leqslant$ 0.05), H_1 will be accepted, while H_0 will be rejected. In contrast, if the value is larger than 0.05 (> 0.05), H_0 will be accepted by rejecting H_1.

H_0: There is no significant difference between the groups.
H_1: There is a significant difference between the groups.

3.6.4 Spearman's Correlation Test

Gunduz and Ahsan (2018) revealed that Spearman's Correlation test does not require normal distribution and homogeneous data, which is a significant advantage for employing this technique over other approaches. It is applied for determining the strength of association between paired data as a non-parametric test. The result will show the strength of relationship, either positive or negative (Pallant, 2016).

The resulting value will be in the range of -1 to +1. A stronger positive relationship is developed when the correlation coefficient is closer to a positive one while a stronger negative relationship is developed when the correlation coefficient is closer to negative one. Meanwhile, it indicates no relationship existed between the variables when the correlation value equals 0. In this study, the statistical correlations between the challenges of modular construction and the strategies to enhance the implementation of modular construction was assessed through this test. The strength of the correlation as suggested by Pallant (2016) is highlighted in Table 3.3.

Table 3.3: Correlation Strength between Variables

Correlation Strength	Interpretation
0.100 to 0.290 (0.000 to -0.290)	Weak Correlation
0.300 to 0.490 (-0.300 to -0.490)	Moderate Correlation
0.500 to 1.000 (-0.500 to -1.000)	Strong Correlation

3.6.5 Factor Analysis

According to Pallant (2016), factor analysis is a technique of data reduction whereby a smaller set of factors summarises a large set of factors. To allow an appropriate interpretation, factor analysis reduced the variables to a more manageable standard (Yap, Low and Wang, 2017). The intercorrelation of variables that the naked eye could not observe can be identified with factor analysis. The exploratory and confirmatory factor analysis are the two main approaches to factor analysis. Usually, the exploratory factor analysis collects the interrelationship information among the variables, while the confirmatory factor analysis tests the designated hypotheses about the underlying structure of the variables (Pallant, 2016). This study employed exploratory factor analysis to analyse the 20 opportunities of modular construction to uncover the underlying factor.

Besides, Pallant (2016) highlighted that the strength of the relationship between the variables is a critical consideration when evaluating the appropriateness of data for factor analysis. Therefore, the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity will be conducted before the factor analysis. These tests are critical to ensure that the variables are suitable for the factor analysis to proceed in consequence. A KMO value that greater than 0.50 is satisfactory for the factor analysis (Yap, Low and Wang, 2017). However, 0.60 was recommended by Pallant (2016) to be the minimum value in order to achieve a good factor analysis. On the other hand, Bartlett's test should have a significant value lower than 0.05 to be accepted by the factor analysis. Therefore, the KMO value closes to 1.0 and Bartlett's test value closes to 0.0 indicate that the data is adequate and appropriate for the factor analysis (Hoque and Awang, 2016).

3.7 Summary of Chapter

This chapter identifies and discusses the research methodology of this study. The quantitative research method was adopted, and a questionnaire survey was conducted. Besides, the targeted respondents were the construction stakeholders, the client, the consultant and the contractor within the Klang Valley area. Before the commencement of the actual survey, a pre-test was conducted on five sets of samples. Consequently, the questionnaire was distributed to the respondent through email, WhatsApp and LinkedIn. Lastly, the data analysis methods implemented to analyse the collected data were also identified in this chapter. This included Cronbach's Alpha Reliability test, Mean Ranking, Kruskal-Wallis test, Spearman's Correlation test and Factor Analysis.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

With the commencement and closure of the questionnaire, Chapter 4 discusses the outcomes of the survey. The data collected was organised and processed through a series of data analysis methods discussed in Chapter 3 using SPSS. In the following, the analysed results were discussed with visual representations, such as tables and figure, to achieve the study objectives.

4.2 Pre-test

This study had undergone a pre-test with 1 developer, 1 consultant and 3 contractors from 30th January 2023 to 5th February 2023. All five questionnaires had been returned, bringing to a 100% response rate. Since this pre-test aimed to enhance the questionnaire design to check grammatical errors based on the respondents' feedback, the data collected for the pre-test was excluded from the data analysis. From the pre-test, the respondents suggested providing some alternative terms for modular construction, such as prefabrication and off-site construction, to facilitate understanding by respondents in Questions 7 and 8. The questionnaire was reviewed in conjunction with the feedback before the actual distribution of the questionnaire.

4.3 Response Rate

This study adopted the e-survey method to distribute the questionnaire to the targeted respondents in Klang Valley. The email and social platforms like LinkedIn and WhatsApp were used to disseminate the questionnaire. As a result, 380 questionnaires were distributed to the construction professionals, with 80 questionnaires to the developers, 125 questionnaires to the consultants and 175 questionnaires to the contractors. The questionnaire survey commenced on 6th February 2023 and closed on 5th March 2023. Over the one-month period, 120 valid responses were recorded and incorporated into this study. With this, the questionnaire attained a response rate of 31.6% that is satisfactory with the standard response rate in the construction industry, 30%, as mentioned by Yap, et al. (2022).

4.4 Demographic Background of Respondents

The respondent's background which including the position, working experience, academic qualification, type of project involved and value of project undertaken are illustrated in Table 4.1. This survey was mainly contributed by the contractor (49.2%), followed by the consultant (32.5%) and the developer (18.3%) within the Klang Valley area. Among the respondents, 14.2% are junior, with 30.8% in the executive position and the remaining 55% in the managerial position. Besides, most respondents are having 5 to 15 years of working experience in the construction industry, as 30.0% of the respondents fell into the range of 11-15 years, while the range of 5-10 years occupied 29.2%.

It was also attractive to observe that more than 90% of respondents had received higher education, including a diploma (21.7%), bachelor's degree (57.5%), or a postgraduate degree (12.5%). This can reflect that the Malaysian construction industry is now sustained by highly educated employees with better knowledge and soft skills. Meanwhile, almost half of the respondents (50.8%) were frequently involved in the residential project, and 65% had dealt with projects valued at over RM 10 million.

In this survey, all the respondent (100%) knows about modular construction technology, but only 60% of the respondent has had experience with this modern construction method. Therefore, it is necessary for modular construction technology to be encouraged and incorporated into more construction projects to enhance the development of the construction industry. To conclude, the survey recorded the perception of construction personnel, including the developer, consultant and contractor, towards modular construction from various viewpoints.

Table 4.1: Demographic Background of Respondent

Parameter	Categories	Respondents Group			Total	Frequency (%)
		Client/ Developer	Consultant	Contractor		
Position	Director/Top Management	3	2	4	9	7.5
	Senior Manager	5	9	8	22	18.3
	Manager	7	11	17	35	29.2
	Executive	7	10	20	37	30.8
	Junior	-	7	10	17	14.2
Working Experience	Over 20 years	3	1	5	9	7.5
	16-20 years	-	8	9	17	14.2
	11-15 years	11	8	17	36	30.0
	5-10 years	7	13	15	35	29.2
	Less than 5 years	1	9	13	23	19.2
Academic Qualification	Postgraduate Degree	5	5	5	15	12.5
	Bachelor’s degree	11	25	33	69	57.5
	Diploma	6	7	13	26	21.7
	High School	-	2	8	10	8.3
Type of Project	Residential	12	14	35	61	50.8
	Commercial	5	8	7	20	16.7
	Industrial	2	5	5	12	10.0
	Infrastructure	3	12	12	27	22.5
Value of Project (RM)	Over 10 million	17	19	42	78	65.0
	5-10 million	4	14	11	29	24.2
	Less than 5 million	1	6	6	13	10.8

4.5 Cronbach's Alpha Reliability Test

The reliability of the data was analysed with Cronbach's Alpha, α. Since the alpha value represents the internal consistency of the variables, a high alpha value proves that the data is highly consistent among the respondents. Table 4.2 shows the internal consistency of three variable groups. The alpha value for all groups is above 0.80, with 0.944 for the opportunities of modular construction, 0.855 for the challenges of modular construction, and 0.921 for the strategies to enhance the implementation of modular construction. Therefore, the resulting alpha values that fall within the acceptable level of 0.80 (Glen, 2022) prove that this study is reliable.

Table 4.2: Cronbach's Alpha for Reliability Test

Variables	Number of Items	Cronbach's Alpha, α
Opportunities of Modular Construction	20	0.944
Challenges of Modular Construction	10	0.855
Strategies to enhance the Implementation of Modular Construction	10	0.921

4.6 Opportunities of Modular Construction

4.6.1 Mean Ranking for Opportunities of Modular Construction

Table 4.3 shows the mean ranking of the opportunities of modular construction with its significance based on the respondents' perceptions. According to the outcome, the top five opportunities of modular construction are as follows:

O1 = "Improve project schedule and productivity"
(Mean = 4.567, SD = 0.576)
O2 = "Better quality" (Mean = 4.525, SD = 0.579)
O3 = "Cost-efficient and effective" (Mean = 4.442, SD = 0.547)
O17 = "Sustainable" (Mean = 4.425, SD = 0.603)
O11 = "Better occupational safety and health"
(Mean = 4.417, SD = 0.588)

O1 = "Improve project schedule and productivity" is ranked as the highest opportunity for modular construction in Malaysia. This finding is supported by the outcome of several previous studies where Paliwal, et al. (2021), Kisi, et al. (2019) and Goodier and Gibb (2007) found that this opportunity sit at the top place in Las Vegas, Nepal and UK. One of the common problems found in the construction project is the schedule issue. According to Ullah, et al. (2017), poor labour productivity and unfavourable weather are some factors that lead to construction delays. To handle these issues, the construction industry must look for alternative solutions to enhance the project schedule and productivity. Therefore, modular construction where the building elements are produced under a controlled environment with advanced technologies becomes an effective approach to replace conventional construction. This is because modular construction allows the site and manufacturing activities to execute simultaneously rather than the step-by-step procedures as in conventional construction (Subramanya, Kermanshachi and Rouhanizadeh, 2020; Veiskarami, 2020). Besides, the elements production process that happened in the factory will not be affected by the external weather condition (Hořínková, 2021; Paliwal, et al., 2021). Bertram, et al. (2019) revealed that the off-site factory that incorporates automatic and modern machines could boost productivity regarding 24/7 working hours. Therefore, modular construction can significantly improve the project schedule and productivity compared to conventional construction.

Product quality is another essential criterion to be looked into in every construction project. In this study, O2 = “Better quality” was ranked at second place among 20 opportunities for modular construction. This finding is supported by the US researchers Paliwal, et al. (2021), where quality improvement was ranked at third significant opportunity out of 13 variables. Musa, et al. (2018) mentioned that modular construction involves a strict program of quality assessment and quality control due to its manufacturing nature. Besides, the materials are being delivered to and stored in the factory warehouse. Therefore, the risk of deterioration of construction materials due to moisture can be prevented since the factory environment has a more complicated standard of procedure to protect the material. While the manufacturing facilities involve adopting precise machines to fabricate the component, it enables a higher level of product consistency and accuracy of elements' interfaces (Wilson, 2019a). With this, Lawson, Ogden and Bergin

(2012) agreed that modular construction could offer a better thermal and air-tightness performance than conventional construction due to tighter joint tolerance between the building elements.

Apart from these, O3 = "Cost-efficient and effective" is rated third. In the construction industry, money is a major input for conducting the project. People are targeting higher quality products but at a lower cost. Therefore, the cost-efficient and effective advantages offered by modular construction make it powerful to replace conventional construction (Nazir, et al., 2021). As discussed, modular construction enhances the project schedule and productivity. A quicker process means significant savings in time and costs, which can cut off operational expenses. According to McKinsey, 20% of cost savings can be achieved with modular construction (Bertram, et al., 2019). Since there are lesser site activities, the site overhead and construction management costs can be reduced. Additionally, modular construction enables economies of scale when the materials are ordered in bulk to the manufacturing facilities for multiple projects. While precise machines are implemented in producing the building elements, it can assure quality while eliminating material wastage to reduce the possibility of rework (Veiskarami, 2020). Therefore, it is rational that the respondents have a higher perception of the cost benefits of modular construction.

In this globalising era, sustainable development is the primary concern of all countries and industries. In the construction industry, people targeted sustainable construction to minimise the negative environmental impacts derived from the industry (Gatley, 2021). Recent years, the conducts of the construction industry were blamed by the media and the public. In London, 34% of particle emissions are derived from the construction industry, which is higher than that 27% from road transport (Farlow, 2020). In Malaysia, the Penang South Islands project was heavily criticized by many due to the environmental risks that arose from the artificial island project (The Edge Markets, 2022). To promote sustainable construction, renewable and recycled resources should be applied to the project while reducing the emission of GHG to the environment. It was found that modular construction is more sustainable in terms of production, use and demolition process (Prajapati, Pitroda and Raichura, 2022; Paliwal, et al., 2021; Nazir, et al., 2021; Hyams, Mccann and

Ferguson, 2018). As modular building offers better air tightness and thermal performance, it helps to reduce energy consumption during the occupancy phase (Wilson, 2019a). Also, lesser site operation means less noise and air pollution. While the modular element can be recycled and reused, it reduces raw material needs and forms a circular economic movement (Khan, et al., 2022).

Nevertheless, it is observed that O11 = "Better occupational safety and health" rated as the fifth place of opportunities for modular construction in Malaysia. It is unsurprised that "dirty" and "dangerous" are the rigid public impression towards the construction industry. According to Hořínková (2021), construction workers frequently experience falling from heights at the workplace, leading to fatal and non-fatal injuries. Therefore, occupational safety and health need to strengthen to protect the welfare of the construction players. In a modular construction project, most site activities are transferred to off-site. Alternatively, it provides a safer working environment for the construction players while reducing the noisy site working conditions (Wilson, 2019a). Moreover, the process in manufacturing facilities will follow the standard of procedure, which in turn will provide additional safeguards to the player. Ahn, et al. (2020) conducted an evidence-based study through the case study of two projects, and interview with the site supervisors to compare the safety risks of worker in conventional and modular construction. From the case study, the researchers found that modular construction can reduce the safety risks compared to the conventional construction as the modular construction case possessed 25.8 total risk score while conventional construction case obtained 41.5 total risk score. From the interviews, the interviewees mentioned that the reduction of working at heights, falling objects, exposure to weather conditions, crowded site conditions and contact with live electricity contributed to the reduction of safety risks in modular construction projects. Therefore, modular construction can provide a better occupational safety and health to the construction players compared to conventional construction.

4.6.2 Kruskal-Wallis Test for Opportunities of Modular Construction

Kruskal-Wallis test was applied to identify whether heterogeneous perceptions existed between different respondent groups towards the opportunities of modular construction in Malaysia. Table 4.3 demonstrates the asymptotic significance of the opportunities of modular construction. The outcomes revealed the alternative hypothesis is failed to reject on O9 = “Reduce life cycle cost” and O15 = “Decrease transportation and traffic movement” with a significance level that lower than 0.05. Therefore, the respondents have different perceptions for these two variables.

There is a significant difference between the respondent's opinions on O9 = "Reduce life cycle cost", with a mean value of 4.136 for the developer, 4.128 for the consultant and 3.712 for the contractor. The contractor ranked this opportunity 15th compared to the developer and consultant who ranked it 8th and 9th, contributing to a p-value of 0.026. In every construction project, life cycle costing must be taken into consideration instead of focusing on the construction cost alone. According to Zakaria, Ali and Zolkafli (2020), LCC is used to estimate the total cost of ownership. Therefore, the developer, who is the owner of the building has higher consideration towards the optimisation of LCC in the construction project. Like the consultants, life cycle costing is an essential part of planning and estimating budget costs to offer long-term benefits in terms of maintenance and operation. For example, Lim, Zhang and Oo (2018) found that most quantity surveyors are furnished with the fundamental knowledge of LCC and appreciate its benefit. On the other hand, the contractor's role in the construction project is more limited to the construction phase rather than the long-term cost. Therefore, both the developer and consultant have a higher level of awareness towards the life cycle costing opportunities offered by modular construction as it enables better decision-making.

Besides, the mean score for O15 = "Decrease transportation and traffic movement" was 3.864, 3.769 and 3.458 for the developer, consultant and contractor respectively, with a p-value of 0.045. The developer (16th) and consultant (18th) possess a higher level of awareness than the contractor (20th) on this variable. This is because the developer and consultant are less involved in the transportation management of a building project compared to other parties such as contractor, supplier and manufacturer. According to Ferdous, et al. (2019), modular construction can decrease the transportation movement since the building elements are produced in a controlled environment. This can reduce the brick and block deliveries as in conventional construction. However, it is not surprising that the developer, consultant and contractor have different perceptions of it due to the practical engagement of the contractor in the manufacturing and construction stage. Based on the finding, the contractor perceived O15 = "Decrease transportation and traffic movement" as the least aware opportunity compared to other opportunities. Although the prefabricated structures produced in a controlled environment can minimise the delivery of material to the construction site, the transportation of prefabricated structures requires a robust system (Lawson, Ogden and Goodier, 2014). Ibrahim, Sorazan and Muhammad (2022) found that modular construction demands a high number of larger trucks to transport, and heavy cranes to lift the elements. Therefore, the contractor who mainly takes control over the manufacturing and construction process has a lower level of agreement with the transportation opportunity for modular construction compared to the developer and consultant.

Table 4.3: Mean Ranking and Asymptotic Significance of Opportunities of Modular Construction in Malaysia

No	Opportunities	Overall (N=120)			Developer (N=22)			Consultant (N=39)			Contractor (N=59)			Chi-Square	Asymptotic Significance
		Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank		
O1	Improve project schedule and productivity	4.567	0.576	1	4.546	0.510	1	4.718	0.456	1	4.475	0.653	1	3.708	0.157
O2	Better quality	4.525	0.579	2	4.500	0.598	2	4.641	0.537	2	4.458	0.597	2	2.486	0.289
O3	Cost-efficient and effective	4.442	0.547	3	4.409	0.590	4	4.539	0.505	3	4.390	0.558	4	1.592	0.451
O17	Sustainable	4.425	0.603	4	4.318	0.646	5	4.462	0.600	5	4.441	0.595	3	0.797	0.671
O11	Better occupational safety and health	4.417	0.588	5	4.318	0.477	5	4.513	0.506	4	4.390	0.670	4	1.922	0.383
O18	Waste reduction	4.392	0.584	6	4.455	0.510	3	4.462	0.555	5	4.322	0.628	6	1.233	0.540
O5	Minimise material wastage	4.233	0.683	7	4.273	0.631	7	4.333	0.701	7	4.153	0.690	7	1.826	0.401
O19	Reduce pollution	4.075	0.724	8	4.091	0.610	9	4.180	0.790	8	4.000	0.719	9	1.545	0.462
O4	Lesser weather disruption	4.042	0.691	9	4.046	0.722	11	4.026	0.743	13	4.051	0.655	8	0.033	0.984
O8	Reduce rework	4.017	0.756	10	4.091	0.750	9	4.103	0.754	10	3.932	0.763	10	1.449	0.485

Note: *. The mean difference is significant at the 0.05 level of significance.

Table 4.3: (Continued)

No	Opportunities	Overall (N=120)			Developer (N=22)			Consultant (N=39)			Contractor (N=59)			Chi-Square	Asymptotic Significance
		Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank		
O20	Reduce embodied energy and energy efficient	4.000	0.733	11	4.000	0.617	12	4.103	0.788	10	3.932	0.740	10	1.267	0.531
O12	Noise reduction on site	3.933	0.764	12	3.909	0.610	15	4.103	0.821	10	3.831	0.769	12	2.778	0.249
O9	Reduce life cycle cost	3.925	0.811	13	4.136	0.774	8	4.128	0.767	9	3.712	0.811	15	7.281	0.026*
O13	Lesser site disruption	3.875	0.681	14	3.955	0.486	13	3.923	0.739	15	3.814	0.706	13	0.933	0.627
O6	Reduce site labour	3.858	0.714	15	3.955	0.653	13	3.974	0.668	14	3.746	0.756	14	2.982	0.225
O14	Reduce disturbance to surrounding community	3.742	0.794	16	3.818	0.588	18	3.795	0.801	17	3.678	0.860	16	0.843	0.656
O10	High potential for market share	3.700	0.784	17	3.864	0.560	16	3.846	0.670	16	3.542	0.897	18	4.066	0.131
O16	Job creation	3.633	0.777	18	3.773	0.528	19	3.641	0.811	19	3.576	0.835	17	1.319	0.517
O15	Decrease transportation and traffic movement	3.633	0.829	18	3.864	0.640	16	3.769	0.842	18	3.458	0.857	20	6.210	0.045*
O7	Flexible and removable	3.567	0.886	20	3.727	0.631	20	3.615	0.935	20	3.475	0.935	19	1.844	0.398

Note: *. The mean difference is significant at the 0.05 level of significance.

4.7 Challenges of Modular Construction

4.7.1 Mean Ranking for Challenges of Modular Construction

Table 4.4 shows the mean ranking of the challenges of modular construction with its significance based on the respondents' perceptions. According to the outcome, the top five challenges of modular construction are as follows:

C1 = "Transportation constraint" (Mean = 4.467, SD = 0.607)
C2 = "Lack of skilled personnel" (Mean = 4.458, SD = 0.593)
C6 = "Time-consuming planning and design"
(Mean = 4.292, SD = 0.571)
C3 = "High initial cost" (Mean = 4.283, SD = 0.624)
C10 = "Lack of social knowledge" (Mean = 4.267, SD = 0.561)

Among the ten challenges of modular construction in Malaysia, C1 = "Transportation constraint" was rated as the top challenge. Due to the prefabrication process, the building elements are manufactured in the factory before being transported to the site for installation. Therefore, problems arise as to the design of the prefabricated component in terms of size, weight and loading capacity (Hwang, Shan and Looi, 2018). The project team has to follow the local road regulation, which gives rise to the design considerations (Veiskarami, 2020). For example, an escort from the authority may be required to transport large-size modules on the road. Besides, the transportation process will produce vibration. Hence, the building elements should be designed with the capability to withstand external force. If the structures are weak, damage could occur before the structures are put in place. As a result, it may lead to wastage and supply issues which in turn cause the project to delay and cost overrun (Ferdous, et al., 2019). It becomes more significant due to the long travelling distance between the factory and the construction site which derive from the lacking of local manufacturer as highlighted by Veiskarami (2020). As an illustration, Singapore imports the modules overseas due to its limited industrial capacity and land resources. The movement of heavy vehicle that the government strictly controls make the transportation of prefabricated element more worst (Xu, Zayed and Niu, 2020). This finding is consistent with the researches done by Nabi and El-adaway

(2021), Kazem-Zadeh and Issa (2020) and Hwang, Shan and Looi (2018), where transportation constraint is the most significant challenge towards modular construction in US, Canada and Singapore.

The construction industry is a labour-intensive industry. Labour shortage is a common problem the industry faces, especially the skilled and knowledgeable players. While modular construction is an advanced construction method, it creates a knowledge gap for the conventional construction worker due to the absence of involvement in the modular construction project. As a result, C2 = "Lack of skilled personnel" was found to be the second challenge facing modular construction in Malaysia. This finding was supported by Paliwal, et al. (2021) and Nabi and El-adaway (2021) where the shortage of experienced labour is a significant challenge in US. According to Nazir, et al. (2021), most construction players are familiar with the conventional construction method. As a result, the construction players only have little or even no experienced with modular construction. Besides, Navaratnam, et al. (2019) revealed that the project planning for modular construction is more complicated as various factors must be considered. For instance, different components have to be incorporated into the module, which involves the lifting, transforming, placing and assembling processes. With this, experienced designers, manufacturers and engineers are needed, but the industry has a limited pool of such skilled personnel.

C6 = "Time-consuming planning and design" was rated third place. Kazem-Zadeh and Issa (2020), Hwang, Shan and Looi (2018) and Goodier and Gibb (2007) also found that one of the top three challenges facing modular construction in Canada, Singapore and UK is the requirement of excessive planning and design. Effective planning and design are another critical success factors in the construction project. In modular construction, the building components are produced before erection and stacked with other elements to form the building. Therefore, careful planning and design must consider all the relevant issues, such as the interface, transportation, connection, etc. (Navaratnam, et al., 2019). As discussed, an early design freeze in modular construction is to eliminate potential design changes in the future (Nabi and El-adaway, 2020). This is because late design changes can lead to cost and schedule overrun (Nabi and El-adaway, 2021). Hence, modular construction requires the early involvement of various parties, such as architects, engineers and manufacturers, to contribute additional effort to the planning and design of a project (Hwang, Shan and Looi, 2018).

Nevertheless, this study found that C3 = "High initial cost" was at the fourth place of the challenges. This is sustained by the finding of Hwang, Shan and Looi (2018) where Singaporeans ranked the high initial cost of modular construction as the fifth significant challenge. According to Hořínková (2021), modular construction requires high startup capital, although the manufacturing and assembling of prefabricated elements contributed to a lower construction cost. This is because the setting up of the production plant to replace conventional technology and site labour is necessary. It is supported by McKinsey where factory investment can occupy 5% to 15% of the overall project cost (Bertram, et al., 2019). Besides, the design change is necessary for transforming conventional construction into modular construction. As modular construction is a more advanced construction method, the first design attempt to test the buildability of the element can be expensive (Veiskarami, 2020). However, it should also be noted that investment in manufacturing facilities allows a return on investment in the future (Ferdous, et al., 2019).

The fifth challenge of modular construction in Malaysia is C10 = "Lack of social knowledge". Compared to conventional construction, the modular construction can be considered a new concept to the public. Moreover, the public has a negative impression towards the construction industry and modular construction is viewed as a temporary solution such as site accommodation (Veiskarami, 2020). Ferdous, et al. (2019) revealed that financial institutions are unwilling to provide financial assistance to modular construction projects due to their unfamiliarity with this construction method. As a result, the clients reject to adopt modular construction technology in their projects as contributed by the low implementation rate.

4.7.2 Kruskal-Wallis Test for Challenges of Modular Construction

Kruskal-Wallis test was applied to identify whether heterogeneous perceptions existed between different groups of respondents towards the challenges of modular construction in Malaysia. Table 4.4 demonstrates the asymptotic significance of the modular construction challenges. The outcomes showed that all variables have a significance value that greater than 0.05. With this, the null hypothesis is failed to reject. Therefore, there are no significant differences across the perception of developer, consultant and contractor on the challenges of modular construction in Malaysia.

Table 4.4: Mean Ranking and Asymptotic Significance of Challenges of Modular Construction in Malaysia

No	Challenges	Overall (N=120)			Developer (N=22)			Consultant (N=39)			Contractor (N=59)			Chi-Square	Asymptotic Significance
		Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank		
C1	Transportation constraint	4.467	0.607	1	4.500	0.598	2	4.590	0.498	2	4.373	0.667	1	2.362	0.307
C2	Lack of skilled personnel	4.458	0.593	2	4.546	0.510	1	4.615	0.493	1	4.322	0.655	2	5.392	0.067
C6	Time-consuming planning and design	4.292	0.571	3	4.364	0.492	3	4.359	0.537	5	4.220	0.618	3	1.369	0.504
C3	High initial cost	4.283	0.624	4	4.273	0.631	4	4.385	0.544	4	4.220	0.671	3	1.235	0.539
C10	Lack of social knowledge	4.267	0.561	5	4.182	0.395	6	4.436	0.502	3	4.186	0.629	5	4.947	0.084
C4	Need for excessive coordination and collaboration	4.083	0.602	6	4.227	0.528	5	4.154	0.540	6	3.983	0.656	6	3.193	0.203
C8	Lack of guidance and government support	3.967	0.788	7	4.046	0.722	7	4.077	0.774	7	3.864	0.819	7	2.089	0.352
C9	Expensive	3.925	0.735	8	3.955	0.575	8	4.051	0.724	8	3.831	0.791	8	2.279	0.320
C7	Client resistance	3.883	0.676	9	3.864	0.560	9	4.051	0.560	8	3.780	0.767	9	4.265	0.119
C5	Low flexibility in design	3.733	0.764	10	3.818	0.588	10	3.769	0.742	10	3.678	0.840	10	0.633	0.729

Note: *. The mean difference is significant at the 0.05 level of significance.

4.8 Strategies to Enhance the Implementation of Modular Construction

4.8.1 Mean Ranking for Strategies to Enhance the Implementation of Modular Construction

The mean ranking of the strategies to enhance the implementation of modular construction with its significance based on the perception of the respondents are shown in Table 4.5. According to the outcome, the topmost effective strategies towards the implementation of modular construction are as follows:

S1 = “Government incentives and subsidies” (Mean = 4.642, SD = 0.577)
S2 = “Training and education” (Mean = 4.600, SD = 0.509)
S4 = “Research and Development” (Mean = 4.425, SD = 0.529)

S1 = "Government incentives and subsidies" was found to be the most effective strategy to enhance the implementation of modular construction in Malaysia. The ranking is compatible with the finding of Hwang, Shan and Lye (2018) and Mohamad, Zawawi and Nekooie (2009) where government subsidies to offset premium was appraised as the best solution to overcome the barrier towards sustainable construction in Singapore. Modular construction that requires a high capital cost to start the project has raised the reluctance of construction players to be involved in modular construction projects. Besides, the limited number of modular suppliers in the industry has led to a monopolistic market with high-price contracts (El-Abidi, et al., 2019). Therefore, modular construction technology has become an expensive alternative to a construction project, causing most construction players to stick with the conventional method. Hence, reducing the financial burden of the construction player through incentives and subsidies is essential to encourage the construction player to adapt to modular construction. For example, the IBS tax incentive allows the construction company to offset 70% of its yearly income (Construction Industry Development Board, 2020c). With this, the construction players will be motivated to undertake the modular construction project due to the government's incentives and subsidies, which can enhance their satisfaction towards the implementation of modular construction (El-Abidi, et al., 2019).

Moreover, S2 = “Training and education” ranked as the second most effective strategy towards modular construction. The knowledge and skills regarding modular construction are critical for every construction player to adapt to modular technology. To move from conventional to modular construction, the construction players have to be trained well with the capability to conduct the modular construction project (Khan, et al., 2022). Meanwhile, the finding of this study shows that a lack of skilled personnel is one of the significant barriers towards modular construction in Malaysia. This critical issue will generate the gap between modular literacy and illiteracy. Hence, it is crucial to provide adequate training and education to the construction players, as well as the construction and engineering students to prepare them with sufficient modular construction knowledge (Kwang, et al., 2021). For example, Kwang, et al. (2021) suggested that CIDB should organise more outreach on training and consulting services, together with adopting the course structure in the college. Besides, it is unarguable that education is necessary as modular construction requires thoughtful planning to execute the project smoothly. Hwang, Shan and Looi (2018) also found that training was the one of the top three effective strategies to mitigate the constraints towards modular construction in Singapore.

Furthermore, S4 = “Research and development” ranked as the third most effective strategy to facilitate the application of modular construction in Malaysia. Since modular construction is an advanced construction technique, the implementation framework is not yet mature. For example, the lack of automation to streamline the workflow and insufficient capabilities of manufacturing processes are the critical issues during the manufacturing stage. Khan, et al. (2022) revealed that innovation in technology is required to break through and upgrade the boundaries of manufacturing production. Therefore, market reports and academic research are required to disclose the critical and innovation aspect modular construction. Besides, the government should grant more research activities to increase the research and development inputs in the construction industry, specifically in modular construction (El-Abidi, et al., 2019).

4.8.2 Kruskal-Wallis Test for Strategies to Enhance the Implementation of Modular Construction

Kruskal-Wallis test was also applied to identify whether heterogeneous perceptions existed between different groups of respondents towards the strategies to enhance the implementation of modular construction in Malaysia. Table 4.5 demonstrates the asymptotic significance on the strategies. The outcomes revealed that the p-value of S3 = "Encourage close collaboration" is 0.011 which is lower than 0.05. Therefore, it failed to reject the alternative hypothesis. The mean score for S3 = "Encourage close collaboration" was 4.136, 4.590 and 4.322 for the developer, consultant and contractor respectively.

In every construction project, communication and cooperation are the critical success factors for ensuring work efficiency. It became more significant in the modular construction project as the structure's design has to be finalised before the manufacturing and construction processes occur due to the low flexibility of change in these stages (Wilson, 2019a). Based on the finding, the consultant and contractor perceive "encourage close collaboration" as a more effective strategy (3rd and 4th place) than the developer (8th place). This is because consultants and contractors always work closely to keep track of the project. On the other hand, the developer has less direct involvement in the day-to-day execution of the project while acting as the financer to fund the project. This could contribute to different opinions on the importance of close collaboration. According to Ishaq, et al. (2019), the difference in interest is one factor that leads to poor communication between the developer and contractor. This is because the developer tends to minimise the expenses while the contractor tends to maximise the profit. Korvinus (2017) revealed that clients prefer a control-based approach at the pre-construction stage. However, the contractor in the modular construction project will engage in the project at the early stage. Therefore, the client perceives "encourage close collaboration" as a less effective strategy believing that the client's role is to finance the project with ultimate control.

Table 4.5: Mean Ranking and Asymptotic Significance of Strategies to Enhance the Implementation of Modular Construction in Malaysia

No	Strategies	Overall (N=120)			Developer (N=22)			Consultant (N=39)			Contractor (N=59)			Chi-Square	Asymptotic Significance
		Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank		
S1	Government incentives and subsidies	4.642	0.577	1	4.546	0.596	1	4.769	0.427	1	4.593	0.646	1	2.599	0.273
S2	Training and education	4.600	0.509	2	4.455	0.510	2	4.744	0.442	2	4.559	0.534	2	5.379	0.068
S7	Research and development	4.425	0.529	3	4.364	0.492	3	4.436	0.552	5	4.441	0.534	3	0.483	0.786
S3	Encourage close collaboration	4.375	0.609	4	4.136	0.468	8	4.590	0.498	3	4.322	0.681	4	9.074	0.011*
S4	Establish effective logistic and supply chain management	4.350	0.589	5	4.227	0.429	5	4.539	0.505	4	4.271	0.665	5	5.855	0.054
S8	Government leadership and initiative	4.242	0.661	6	4.364	0.581	3	4.231	0.742	7	4.203	0.637	6	0.878	0.645
S10	Technology improvement	4.217	0.624	7	4.091	0.526	9	4.359	0.537	6	4.170	0.699	8	3.071	0.215
S6	Revision of building codes and standards	4.208	0.620	8	4.227	0.528	5	4.205	0.695	8	4.203	0.610	6	0.015	0.992
S5	Policies and regulation	4.158	0.635	9	4.182	0.501	7	4.128	0.656	9	4.170	0.673	8	0.173	0.917
S9	Publicity and promotion	4.033	0.673	10	4.046	0.486	10	4.077	0.703	10	4.000	0.719	10	0.306	0.858

Note: *. The mean difference is significant at the 0.05 level of significance.

4.9 Spearman's Correlation Test

Table 4.6 displays the statistical association between the challenges of modular construction and the strategies to enhance the implementation of modular construction in Malaysia as reflected by Spearman's Correlation test. The analysis indicated that every challenge of modular construction was associated with a minimum of six strategies. The C6 = "Time-consuming planning and design" had the weakest relationship, with only six correlations with the strategies, followed by C1 = "Transportation constraint" with seven correlations with the strategies. Based on the finding, S1 = "Government incentives and subsidies", S2 = "Training and education", S4 = "Establish effective logistic and supply chain management" and S7 = "Research and development" shared the standing as the most effective strategies to enhance the implementation of modular construction as these four variables achieved a perfect association (10 correlations) with all challenges.

Firstly, S1 = "Government incentives and subsidies" is one of the most effective strategies to enhance the implementation of modular construction (10 correlations). The mean ranking methodology also shows that "government incentives and subsidies" is at the first place of the strategies towards modular construction as perceived by the respondents. In contrast to conventional construction, modular construction requires a high initial cost to establish the project (Mydin, Sani and Taib, 2014). Besides, high transportation cost is also the main barrier to modular construction as delivering large components from the factory to the site will increase the logistic expenses (Hořínková, 2021). Yuan, et al. (2022) mentioned that the government should provide diversified incentives and subsidies to fully mobilise the enthusiasm of the construction player to develop modular construction. For example, tax exemption and loan concession are some of the incentives to persuade the developer to adopt modular construction. Meanwhile, Hwang, Shan and Looi (2018) highlighted that small-size contractor firms often face financial difficulties due to their limited financial capability and chances to obtain subsidies. It would be influential if the government could incentivise small contractor firms as the construction stakeholder will be motivated to utilise modular construction. In China, Dou, et al. (2019) found that incentives and subsidies are the most critical strategies for diffusing innovation in modular construction. Therefore, government incentives and subsidies are effective strategies to improve the adoption of modular construction as these help the construction players receive the financial assistance and reduce the burden of incorporating modular construction.

Secondly, S2 = “Training and education” was another most effective strategy towards modular construction (10 correlations). This is compatible with the mean ranking of this study where “training and education” was perceived as the second most effective strategy by the respondents. According to Wuni and Shen (2020a), previous construction and engineering graduates did not have the opportunities to gain knowledge of modular construction. The finding of this study also showed that “lack of skilled personnel” is the major challenge as perceived by the respondent. Due to the advancement of modular construction, the construction players might be unable to crop with the modular construction process. Therefore, it is vital to upgrade the construction players with modular construction skills and knowledge by offering the training courses (Hwang, Shan and Looi, 2018). With this, the construction players can better appreciate the modular technologies and have ample confidence to engage in the modular construction project. In addition, the universities and colleges shall include the knowledge of modular construction in their education program. This is because the student will learn about modular construction technologies and have a basic understanding of modular construction before entering the workplace. El-Abidi, et al. (2019) revealed that seminar, scholarship and internship programs can be provided to the student through the industry-university partnership. With this, the new generation is ready to contribute to the future implementation of modular construction.

Thirdly, it is observed that S4 = “Establish effective logistic and supply chain management” is also one of the most effective strategies in enhancing the application of modular construction (10 correlations). Unlike on-site construction, the building elements in modular construction are prefabricated under a controlled environment before transport to the construction site. Therefore, it is crucial to synchronise the supply and demand of prefabricated elements with effective logistics and supply chain management (Veiskarami, 2020). There is no doubt that JIT has been frequently mentioned by the previous study as an effective system for handling the modular construction project (Veiskarami, 2020; Wuni and Shen, 2020a; El-Abidi, et al., 2019; Liu, et al., 2019; Hwang, Shan and Looi, 2018). This is because JIT can prevent the excessive supply that will increase the storage cost and eliminate insufficient supply that will affect the schedule and budget of the project (Wilson, 2019a). Therefore, effective logistic and supply chain management can assist in achieving the goals of modular construction in terms of time, cost and quality.

Fourth, S7 = "Research and development" is also significantly correlated to the challenges of modular construction (10 correlations). This is compatible with the mean ranking where "research and development" was ranked at the third place among the strategies. To enhance the implementation of modular construction, the industry has to experience a cultural shift to admit to the modern construction method. Therefore, it is needed for the researcher to facilitate the cultural shift by developing frameworks and strategies (Wuni and Shen, 2020a). El-Abidi, et al. (2019) stated that government can fund research and development to explore the development of design, new materials, innovative methods and advanced scientific information on modular construction. In Malaysia, modular construction is one of the key research scope under the Construction Research Institute of Malaysia (CREAM) to assist the development of the built environment (Construction Research Institute of Malaysia, 2023). Also, the market research and academic studies that demonstrate the key performance indicators of modular construction will simulate the adoption of modular construction (Khan, et al., 2022).

There are a total of 91 significant associations between the challenges of modular construction and the strategies to enhance its implementation. The finding revealed that S1/C2, S2/C2, S6/C8, S8/C8, S9/C8 and S9/C9 are having a strong correlation with the significance level higher than 0.600.

S1 = "Government incentives and subsidies" and S2 = "Training and education" are strongly correlated to C2 = "Lack of skilled personnel" at the significance level of 0.607 and 0.616. Modular construction requires skilled player to handle and conduct the project. Unfortunately, the lack of skilled personnel posts a major challenge to the implementation of modular construction. To address this issue, the analysis disclosed that government incentives, subsidies, training and education are the main remedial actions to train the skilled personnel. According to Khan, et al., (2022), training and learning programs should be encouraged to upskill the players. Technologies like gaming-based learning can effectively train and assess the players, enhancing their knowledge and skills. For instance, Ezzeddine and Soto (2021) developed a game engine platform to integrate the process in modular construction project. It enables the connection among diverse teams in modular construction projects. Besides, the government should fund more training and workshop programs to the construction players to address the shortage of skilled personnel. Ismail, et al. (2019) suggest that the government should establish the training centre to introduce modular construction training program. This allow the players to gain more knowledge about modular construction and therefore enhance their capability to involve in modular construction project (Wuni and Shen, 2019).

Besides, S6 = "Revision of building codes and standards" and S8 = "Government leadership and initiative" are strongly correlated to C8 = "Lack of guidance and government support" at the significance level of 0.616 and 0.668. As modular construction is an advanced construction technology, government guidance and support are vital to direct the construction player to adapt to it. Therefore, adequate building codes, standards, leadership and initiative are needed to transform the practice of conventional construction to modular construction. This discovery is corroborated by Dou, et al. (2019) that looking into the technology diffusion of modular construction in China. Through the questionnaire survey with the construction company that practically involved in the modular construction project, the government is found to have significant positive impact on the diffusion of modular construction technology innovation in

China. Besides, the building codes and standards have to be revised to fix the modular construction due to different processes and requirement with the conventional construction (Wuni and Shen, 2019). This could provide the construction stakeholder with adequate guidance to implement modular construction. Since modular construction requires contractor early involvement in the initial stage of the project, Marinelli, et al. (2022) mentioned that appropriate government initiatives are needed to set aside the traditional and fragmented procurement method and replace it with integrated options such as early contractor involvement (ECI). The researcher also highlights that the government takes power in generating the demand for modular construction projects. For example, all public housing projects are required to achieve at least 70 IBS scores. In view of this, the government may take the initiative to intervene in the private project to enhance the implementation of modular construction. For instance, financial schemes and tax exemptions can be provided to the private sector to encourage modular construction. According to Khan, et al. (2022), public-private partnership is also a practical initiative that can provide by the government to work together with the private sector in developing modular construction in Malaysia.

Moreover, S9 = “Publicity and promotion” is strongly correlated with C8 = “Lack of guidance and government support” and C9 = “Expensive” at the significant level of 0.602 and 0.630. Publicity and promotion can help to raise awareness about the benefits and potential of modular construction among the construction stakeholders and the public. By showcasing successful modular construction projects and highlighting its advantages, such as reduced construction time and cost savings, the governments can provide guidance, regulations, and support for the industry (Yuan, et al., 2022). Besides, it also can raise the demand and supply and help overcome the perception that modular construction is expensive along with the appropriate incentive policies (Ismail, et al., 2019). This can attract more investors, developers, and clients to adopt modular construction methods, driving economies of scale and further reducing costs.

Table 4.6: Correlation between the Challenges and Strategies for Modular Construction

Strategies / Challenges	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	No. of Significant Correlation
C1	0.545**	0.452**	0.259**	0.342**	0.288**	0.285**	0.187*	-	-	-	7
C2	0.607**	0.616**	0.481**	0.526**	0.328**	0.354**	0.490**	0.346**	0.371**	0.344**	10
C3	0.421**	0.343**	0.303**	0.331**	0.231*	0.279**	0.233*	0.216*	0.183*	-	9
C4	0.434**	0.346**	0.334**	0.259**	0.473**	0.526**	0.306**	0.590**	0.523**	0.472**	10
C5	0.201*	0.186*	0.245**	0.307**	0.378**	0.364**	0.227*	0.443**	0.574**	0.543**	10
C6	0.405**	0.470**	0.431**	0.458**	-	-	0.441**	-	0.184*	-	6
C7	0.247**	0.326**	0.493**	0.367**	0.242**	0.198*	0.300**	0.306**	0.369**	0.352**	10
C8	0.355**	0.224*	-	0.206*	0.582**	0.616**	0.208*	0.668**	0.602**	0.568**	9
C9	0.312**	0.249**	0.209*	0.256**	0.540**	0.559**	0.223*	0.591**	0.630**	0.593**	10
C10	0.448**	0.451**	0.396**	0.424**	0.405**	0.416**	0.468**	0.373**	0.512**	0.568**	10
No. of Significant Correlation	10	10	9	10	9	9	10	8	9	7	91

Note: **. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Note to Table 4.6:

C1 - Transportation constraint; C2 - Lack of skilled personnel; C3- High initial cost; C4 - Need for excessive coordination and collaboration; C5 - Low flexibility in design; C6 - Time-consuming planning and design; C7 - Client resistance; C8 - Lack of guidance and government support; C9 – Expensive; C10 - Lack of social knowledge.

S1 - Government incentives and subsidies; S2 - Training and education; S3 - Encourage close collaboration; S4 - Establish effective logistic and supply chain management; S5 - Policies and regulation; S6 - Revision of building codes and standards; S7 - Research and development; S8 - Government leadership and initiative; S9 - Publicity and promotion; S10 - Technology improvement.

4.10 Factor Analysis

Factor analysis brings together a large number of variables and looks for a way to "reduce" or use smaller factors or components to summarise the data (Pallant, 2016). With this, it allows a more proper interpretation by reducing a large number of relevant variables to a more manageable level (Yap, Low and Wang, 2017). Regarding this study in the context of modular construction in Malaysia, factor analysis has been used to reclassify the twenty opportunities of modular construction into limited categorical variables that fit the shared variance. It is a prerequisite to investigate the adequacy of the data collected before proceeding to factor analysis. To commence the analysis process, KMO and Bartlett's tests were initially implemented.

The KMO value and Bartlett’s significant value are shown in Table 4.7. According to Yap, Low and Wang (2017), KMO value can be in 0 to 1 and should be greater than 0.50 for the result to be considered satisfied. Any value less than 0.50 indicates that factor analysis cannot produce unique and reliable results. In this study, the analysis of twenty opportunities showed that the KMO value was 0.879. This value is outstanding as it is higher than the satisfactory value of 0.50 and the recommended value of 0.60 (Pallant, 2016). Besides, the significant value for Bartlett's test was 0.001, which the variables are sufficiently correlated, and the correlation matrix is not identity. Since the requirement for KMO and Bartlett's tests had been fulfilled, it allows for factor analysis as the data is appropriate.

Table 4.7: Results of KMO and Bartlett's Tests

Parameter		Value
Kaiser-Meyer-Olkin measure of sampling adequacy		0.879
Bartlett's test of sphericity	Approximate chi-square	2070.040
	Degree of freedom	190
	Significance	<0.001

This analysis employed eigenvalue and variance percentage methods to disclose the number of latent factors for twenty opportunities of modular construction in Malaysia. Table 4.8 shows the four components with eigenvalues greater than 1.0. The scree plot diagram revealed that four factors had been extracted after analysing the twenty opportunities. In addition, it can observe that the four underlying root factors captured accounted for 73.783% of the opportunities of modular construction in Malaysia, thus satisfying the 60% total variance requirement to justify the data to construct effectiveness. Moreover, the variables shall deem to be practically significant when the value of the loading is greater than 0.5 (Yap, Chow and Shavarebi, 2019). Based on Table 4.9, all twenty factors possess a loading value that higher than 0.5. Besides, the alpha values that lie between 0.761 and 0.960 indicate that each extracted factor is internally consistent (Yap, Leong and Skitmore, 2020). The four underlying factors extracted are as follows:

i. Corporate Social Responsibility;
ii. Efficient Project Control;
iii. Climate and Resources Consumption;
iv. Competitiveness.

Table 4.8: Total Variance Explained

	Initial Eigenvalues		
	Total	Percentage of Variance (%)	Cumulative (%)
O1	9.950	49.750	49.750
O2	2.638	13.192	62.942
O3	1.117	5.584	68.526
O4	1.051	5.256	73.783

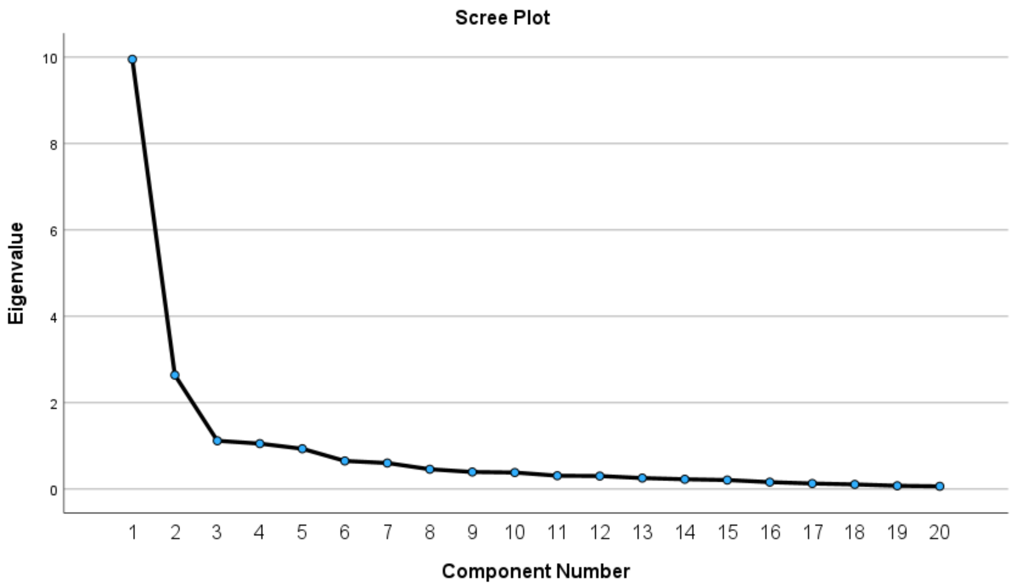

Figure 4.1: Screen Plot for 20 Opportunities of Modular Construction

Table 4.9: Factor Analysis Loading Results for Opportunities of Modular Construction

Opportunities of Modular Construction	Factor Loading	Variance explained (%)	Cronbach Alpha	Average Mean
Factor 1: Corporate Social Responsibility		38.139	0.960	3.830
Reduce disturbance to surrounding community	0.878			
Flexible and removable	0.865			
Decrease transportation and traffic movement	0.847			
Job creation	0.834			
High potential for market share	0.833			
Reduce life cycle cost	0.794			
Lesser site disruption	0.779			
Reduce site labour	0.763			
Noise reduction on site	0.755			
Reduce embodied energy and energy efficient	0.667			
Reduce pollution	0.613			
Reduce rework	0.604			
Factor 2: Efficient Project Control		15.272	0.781	4.450
Improve project schedule and productivity	0.759			
Better occupational safety and health	0.758			
Sustainable	0.745			
Waste reduction	0.633			
Factor 3: Climate and Resources Consumption		12.556	0.818	4.318
Lesser weather disruption	0.750			
Minimise material wastage	0.729			
Factor 4: Competitiveness		7.816	0.761	4.484
Cost-efficient and effective	0.827			
Better quality	0.648			

4.10.1 Extraction of Underlying Factors

Factor 1: Corporate Social Responsibility

Factor 1 accounted for the highest total variance of around 38.139% among other underlying factors for the opportunities of modular construction. This factor consists of the highest number of opportunities with 12 variables, which are "reduce disturbance to surrounding community", "flexible and removable", "decrease transportation and traffic movement", "job creation", "high potential for market share", "reduce life cycle cost", "lesser site disruption", "reduce site labour", "noise reduction on site", "reduce embodied energy and energy efficient", "reduce pollution" and "reduce rework". This category is mainly related to corporate social responsibility that is focusing the triple bottom line of economic, social and environmental sustainability. It is vital to create a harmonious relationship between the construction industry with the social and natural environment (Li, et al., 2021).

As a material-intensive and labour-intensive industry, the construction industry is inherently socially responsible (Zhang, Oo and Lim, 2019). However, the construction industry has a bad reputation and is not socially conscious. It consumes a lot of resources and energy during different stages such as manufacturing and transportation, negatively affecting the environment (Vigneshkumar, Ginda and Salve, 2022). Therefore, the industry is under pressure to promote corporate social responsibility. Being a sustainable construction technology, modular construction can enhance the corporate social responsibility of the construction firm. This is because modular construction involves producing building elements in a controlled environment, which significantly reduces waste, noise, and pollution. Hence, this technique helps minimise construction's environmental impact on the surrounding area (Wu, et al., 2021). The disruption to the surrounding community can be reduced, as well as the amount of energy and resource consumption. Besides, people are one of the main focuses of corporate social responsibility. Apart from reducing community disruption, modular construction allows for flexible and customisable design options. As a result, the specific needs of a community can be met while reducing the environmental impact of the building (Hořínková, 2021). Furthermore, modular construction can create jobs and offer a better working environment to the worker since there are lesser site activities needed. With this, the construction industry and construction firms can proactively fulfil corporate social responsibility by implementing modular construction.

Factor 2: Efficient Project Control

Factor 2 accounts for 15.272% of the total variance explained. It mainly derives from the project activities which consists of "improve project schedule and productivity", "better occupational safety and health", "sustainable" and "reduce waste". By its unique nature, the construction projects are highly complex with numerous interrelated and interdependent activities (Ashaari, Razak and Siow, 2018). Each activity must be strictly controlled as construction projects involve lengthy development periods, are labour-intensive and can affect the environment. As conventional construction follows the sequence of work, from piling to roof construction, a delay in an early stage will affect the later work schedule. As a result, delay often happens in the construction industry and leads to conflict (Ullah, et al., 2018). However, modular construction can offer efficient project control when it involves intensive manufacturing activities to replace labour. The factory activities can carry out simultaneously with the site activities to enhance the project schedule (Nabi and El-adaway, 2020).

Besides, since the progress of a construction project is dependent on the productivity of the construction workers, it is imperative to ensure that sufficient qualified workers are employed in the project. Hence, occupational safety and health must be improved to protect and attract workers. As the process of modular construction mainly happens in the controlled environment, it provides a higher level of safeguard to the worker at the workplace. The worker can work in a more comfortable environment, with minimal exposure to adverse weather conditions and dangerous site environments (Boafo, Kim and Kim, 2016). Furthermore, the process of modular construction can reduce GHG emissions as compared to conventional construction. The amount of waste produced over the building’s lifetime is significantly reduced as modular buildings are often designed to be energy-efficient and require less maintenance than conventional buildings (Khan, et al., 2022).

Factor 3: Climate and Resources Consumption

Factor 3 makes up 12.556% of the variance explained with 2 items. "Lesser weather disruption" and "minimise material wastage" fall within this category. In the construction industry, climatic elements such as monsoon season must be considered in a construction project. According to Refaie, et al. (2021), the weather condition will affect labour productivity, which in turn affects the project schedule. Yet, modular construction combats this question as it is independent of the weather condition. This is because most site tasks had been transformed to off-site, thus stabilising the manufacturing process (Murali and Sambath, 2020). On the other hand, modular construction allows better control of resource consumption. This is due to the manufacturing facilities that equipped with precision machines can optimise the resource use to produce the building elements and reduce material wastage (Tzourmakliotou, 2021).

Factor 4: Competitiveness

Factor 4 contributes to 7.816% of the total variance explained. The opportunities in this category included "cost-efficient and effective" and "better quality". Competition is a dominant business strategy in many industries as well as the construction industry (Sutrisna, Ramnauth and Zaman, 2022). To stay competitive, construction firms should be able to offer distinct products or services to differentiate themselves from their competitors. In the business market, most customers seek a balance between cost and quality. According to Khan, Saquib and Hussain (2021), construction projects require higher quality at lower cost, thus putting pressure on contractors to deliver projects at the best value for money. The researcher found a significant relationship between the budget and the quality of the project. It is challenging to expect high-quality service at the lowest bid. This is because the client tends to spend less on getting the better-quality product, while the builder tends to make more profit with less spending. Yet, through the implementation of modular construction, a better-quality product can be achieved in a cost-efficient manner.

This construction approach can provide competitiveness in terms of cost and quality in several ways. Modular construction can save costs as the project can complete faster, which equals lower construction costs (Kamali and Hewage, 2016) and faster building occupancy (Hořínková, 2021). Besides, low labour requirements can reduce labour costs and achieve cost-efficiency and effectiveness. Moreover, modular construction is conducted under a controlled environment, where quality control measures are easier to implement and monitor (Musa, et al., 2018). This can result in higher quality products that meet or exceed industry standards and provide competitive advantages. Also, modular construction allows for greater design flexibility since modules can be customised to meet specific design requirements. This can lead to better-quality buildings that meet the client's specific needs. Overall, modular construction can provide competitiveness in cost and quality by reducing labour costs and material waste, improving quality control, speeding up construction time, and offering design flexibility.

4.11 Summary of Chapter

To conclude, Chapter 4 discussed the findings drawn from the 120 responses of the construction professionals, which included the developer, consultant and contractor in the Klang Valley area. This study achieved a response rate of 31.6%. The data analysis methods adopted in this study were Cronbach's Alpha Reliability test, Mean Ranking, Shapiro-Wilk test, Kruskal-Wallis test, Spearman's Correlation test and Factor Analysis. The data collected was proved reliable with the alpha values higher than 0.8. Besides, O1 = "Improve project schedule and productivity", O2 = "Better quality", O3 = "Cost-efficient and effective", O17 = "Sustainable" and O11 = "Better occupational safety and health" were identified as the most aware opportunities of modular construction in Malaysia. On the other hand, the significant challenges faced by modular construction in Malaysia were mainly C1 = "Transportation constraint", C2 = "Lack of skilled personnel", C6 = "Time-consuming planning and design", C3 = "High initial cost" and C10 = "Lack of social knowledge". In addition, this study disclosed that the top three strategies that can enhance the implementation of modular construction in Malaysia as perceived by the respondents were S1 = "Government incentives and subsidies", S2 = "Training and education" and S4 = "Research and development". Furthermore, the results of the Kruskal-Wallis test showed significant differences between the perception of developers, consultants and contractors on the opportunities of modular construction and strategies to enhance the implementation of modular construction. Nevertheless, Spearman's Correlation test demonstrated that S1 = "Government incentives and subsidies", S2 = "Training and education", S4 = "Establish effective logistic and supply chain management" and S7 = "Research and development" have a total correlation with all the challenges of modular construction. Lastly, four underlying factors were successfully identified through the Factor Analysis from 20 opportunities of modular construction, namely "corporate social responsibility", "efficient project control", "climate and resources consumption" and "competitiveness".

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

Chapter 5 summarises the study findings in relation to the achievement of aims and objectives. The research implication and limitations are provided as well. Lastly, some recommendations for future studies have been proposed to facilitate the development of modular construction in Malaysia.

5.2 Conclusions

The construction industry is blamed as the dirty, dangerous and difficult sector as affected by various factors such as weather, working environment, pandemic and multiple project-based constraints such as time, cost and quality. These issues shall be seriously addressed and sought remedies to confront on time. With this, modular construction is seen as a key driver in navigating the growth of the construction industry with robust connectivity with other economic sectors.

This study was carried out to assess construction stakeholders' perceptions on modular construction in Malaysia. It is also an effort to raise awareness of modular construction among construction stakeholders and society for the betterment of the country and the industry. The objectives of this study as outlined in Chapter 1 were (1) to evaluate the opportunities of modular construction in Malaysia, (2) to examine the challenges of modular construction in Malaysia, and (3) to appraise the strategies to enhance the implementation of modular construction in Malaysia. Although a wealth of research has explored the opportunities and challenges of modular construction, research on strategies to address these issues remains to be limited, especially in the context of Malaysia. Given this literature gap, this study assesses the statistical relationship between the challenges and strategies to enhance the implementation of modular construction.

A comprehensive literature review was conducted with the previous study regarding modular construction. In view of this, 20 opportunities, 10 challenges and 10 strategies to enhance the application of modular construction were successfully identified. Consequently, a questionnaire survey targeted the construction disciplines of developers, consultants and contractors within Klang Valley was commenced to collect the data from different perspectives. A total of 120 responses were collected and processed with SPSS. Before further data analysis, Cronbach's Alpha Reliability test was used to verify the reliability of the data to ensure its qualification. In brief, the research questions and objectives have been answered and fulfilled as summarised below.

Objective 1: To evaluate the opportunities of modular construction in Malaysia.

The first research question was how modular construction can benefit the Malaysian construction industry. To combat this question, Objective 1 tends to evaluate the opportunities of modular construction in Malaysia. In this study, 20 opportunities for modular construction were first identified with a comprehensive literature review. Then, the respondents were requested to rank the modular construction opportunities that can benefit the industry based on their awareness level. Among the twenty opportunities of modular construction, the five most aware opportunities in Malaysia as rated by the respondents were stated below:

1. Improve project schedule and productivity;
2. Better quality;
3. Cost-efficient and effective;
4. Sustainable;
5. Better occupational safety and health.

Besides, the outcome disclosed that "reduce life cycle cost" and "decrease transportation and traffic movement" was perceived differently by the respondent, where the contractor ranked these variables lower than the developer and consultant. In addition, these 20 opportunities were analysed using Factor

Analysis, and consequently, four underlying factors that accumulated 73.783% of the total variance explained were uncovered as follows:

Factor 1: Corporate social responsibility;
Factor 2: Efficient project control;
Factor 3: Climate and resources consumption;
Factor 4: Competitiveness.

This allows the researcher to have a deeper insight towards the opportunities of modular construction in Malaysia and raise the awareness of the construction stakeholder.

Objective 2: To examine the challenges of modular construction in Malaysia.

To answer the second research question regarding why modular construction is challenging to implement in Malaysia, Objective 2 is inclined towards examining the challenges of modular construction in Malaysia. From the literature review, 10 challenges of modular construction have been pointed out. In the questionnaire survey, the respondents had to rate the challenges based on their agreement level. Interestingly, the Kruskal-Wallis test disclosed that different groups of respondents did not have heterogeneous opinions on the challenges. Meanwhile, the following five variables were perceived as the major barriers to modular construction in Malaysia:

1. Transportation constraint;
2. Lack of skilled personnel;
3. Time-consuming planning and design;
4. High initial cost;
5. Lack of social knowledge.

Objective 3: To appraise the strategies to enhance the implementation of modular construction in Malaysia.

The third research question in this study is how to improve the implementation of modular construction in Malaysia. Hence, Objective 3 aims to appraise the strategies to enhance the implementation of modular construction in Malaysia. 10 strategies that were determined from the literature review were ranked by the respondent. Overall, the topmost effective strategies were as follows:

1. Government incentives and subsidies;
2. Training and education;
3. Research and development.

Also, the Kruskal-Wallis test disclosed that the respondents had different perception on “encourage close collaboration”, where the consultant and contractor ranked it higher than the developer. Apart from these, Spearman’s Correlation test discovered that “government incentives and subsidies”, “training and education”, “establish effective logistic and supply chain management” and “research and development” can effectively overcome the challenges of modular construction as these variables owned the highest number of correlations with the challenges. Lastly, the finding showed a strong correlation between “government incentives and subsidies with lack of skilled personnel”, “training and education with lack of skilled personnel”, “revision of building codes and standards with lack of guidance and government support”, “government leadership and initiative with lack of guidance and government support”, “publicity and promotion with lack of guidance and government support” and “publicity and promotion with expensive”. This allows the government and policymaker to look into the strategies that can effectively address a particular challenge.

5.3 Research Implication

The outcomes of this study are expected to serve as a barometer of modular construction practice in Malaysia, thus better predicting the opportunities and challenges of modular construction along with the strategies to enhance the implementation of modular construction in Malaysia. The research implications are discussed based on the view of the construction industry, statutory bodies, and academic circles.

From the perspective of the Malaysian construction industry, this study can raise the awareness of the construction stakeholder towards the competitive opportunities of modular construction compared to conventional construction. Meanwhile, it highlighted the challenges the construction stakeholders might face when adopting modular construction. Therefore, effective strategies to combat the challenges have been proposed to motivate the construction stakeholder to incorporate modular construction technology into their project. Based on the findings, modular construction is productive and sustainable. It can reduce the environmental impacts cause by the construction industry such as reducing the waste. Therefore, this study allows the stakeholders to consider the related risks and develop an effective strategic plan for adopting and developing modular construction. It can enlighten and persuade the construction stakeholders to implement modular construction and lead the industry towards a more sustainable development.

Besides, the government plays the role of an intervener in the adoption of modular construction. This study could provide statutory bodies with insights to develop appropriate laws and regulations to facilitate modular construction. Also, it enables the regulatory bodies to enact relevant codes and standards to guide the stakeholders in the modular construction process. Hence, the government can take appropriate measures by identifying the stakeholders' challenges to better help the professionals adapt to modular construction projects. In doing so, it can contribute to the future advancement of the industry and country.

Alternatively, this study enables the academic community to review the needs for related surveys, training, and curricula. Regular construction personnel should have sufficient knowledge of modular construction, so training and seminars should be provided by knowledgeable professionals. In addition, modular-related courses must be incorporated into the course structure to provide students and trainers with basic information on modular construction. Thus, it helps academia to supply educated and trained human resources to the industry through the development of research and education. While this study disclosed the four underlying factors of the opportunities in terms of corporate social responsibility, efficient project control, climate and resources consumption, and competitiveness, it allows the academia to have a deeper insight towards these unique points. Alternatively, the academia can apply this finding to explore different area of modular construction, such as the corporate social responsibilities offered by modular construction in improving the market status of the organisation. This in turn could encourage the construction company to implement modular construction to gain reputation by practising sustainable construction.

5.4 Limitation of Study

Although this study contributes valuable insights into the construction industry, it also has some limitations. One of the limitations of this study is the data collection method. This study employed the quantitative approach by collecting the data through a questionnaire survey. The survey comprised only close-ended questions, restricting respondents from contributing their knowledge based on pre-determined options. The access to a broader and in-depth information are being restricted. As a result, the respondents may not be able to raise up other potential opportunities, challenges and strategies regarding modular construction that were excluded from the questionnaire survey.

Besides, another limitation of this study is the restricted scope, which focuses only on the client, consultant and contractor within the Klang Valley area. This restricted scope excluded other construction professionals that closely involved in the modular construction project, such as the manufacturer and supplier, to enlighten the research findings. Hence, the research findings may not reflect the perspectives of all key stakeholders in the industry. Also, the scope is limited to the Klang Valley area, which may limit the applicability of the study beyond the Klang Valley area and West Malaysia.

In addition, it is worth noting that some respondents did not have relevant experience in modular construction projects. While all respondents are aware of modular construction, those without practical experience may not have sufficient knowledge about modular construction, leading to misunderstandings about the opportunities, challenges and strategies to enhance the implementation of modular construction in Malaysia. Therefore, it may affect the accuracy of variable ranking.

Moreover, as the development of modular construction technology in Malaysia is slower than other countries, there is limited local research on this topic. Consequently, much of the information on this subject is obtained from other developed countries and regions, such as Singapore and Hong Kong. However, it is important to note that the pace and level of technological advancement in these regions differ from that of Malaysia which is still considered a developing country. As such, the situation in the Malaysian construction industry may differ significantly from that of these other regions.

5.5 Recommendation for Future Study

To response the above-mentioned limitations, several suggestions are made for future research. Firstly, a mix method can be adopted to collect the data by combining the quantitative and qualitative approaches. The questionnaire survey can first be conducted to collect the variables' ranking, followed up with the interviews to verify and validate the results with the professionals. The in-depth perceptions of different construction players can be obtained through the open-ended questions. This also creates an opportunity for the researcher to explore the variables not covered in the questionnaire survey during the interviews. Hence, the validity and reliability of the study finding are enhanced due to their trustworthiness.

Secondly, the study scope can be expanded beyond the Klang Valley area to include construction stakeholders from across Malaysia. This will allow the study to capture a broader perspective and gain insight into how modular construction is perceived and implemented in different parts of the country. This is because the development status may differ across different parts of Malaysia. Hence, targeting the construction stakeholder across Malaysia can achieve the finding generalisation which contributes to the overall advancement of the Malaysian construction industry. Therefore, construction stakeholders other than the developer, consultant and contractor, such as the manufacturer, supplier, and governmental agents are recommended to act as a source of data in future study. This enables the researcher to attain the perspective of various construction stakeholders from various viewpoint due to their different background.

Thirdly, since modular construction is a modern construction technology, only some construction practitioners may have relevant experience or knowledge. Therefore, future studies can focus on respondents with relevant experiences and knowledge towards modular construction. This allows the respondents to contribute their perceptions based on their first-hand experiences. As a result, a more detailed and nuanced understanding of the subject matter can be captured to increase the reliability and accuracy of the data by providing valuable insights into the construction industry.

Fourth, since modular construction is still under development in Malaysia, it is recommended to conduct more study regarding this modern construction technology. It would be interesting to explore different areas of modular construction. For instant, this study had explored the underlying factors of the opportunities for modular construction. Hence, further extended investigation can be done on the challenges and strategies towards modular construction. Future researchers could develop a framework to help construction companies achieve the goals and mission of projects or companies by examining the critical success factors for implementing modular construction. Furthermore, it is suggested that future study can evaluate the key risks and their impact on modular construction projects to demonstrate causality. This can provide deeper insights into the application of modular construction techniques and prepare construction stakeholders for the adoption of modular construction.

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APPENDICES

APPENDIX A: Questionnaire

APPRAISING THE OPPORTUNITIES AND CHALLENGES OF MODULAR CONSTRUCTION IN MALAYSIA

Dear Sir/Madam,

Sincere greetings and best regards to you.

My name is Kho Hui Yi and I am a final year undergraduate student pursuing a Bachelor of Science (Honours) Quantity Surveying in Universiti Tunku Abdul Rahman (UTAR). Currently, I am conducting a research for my Final Year Project with the title **"Appraising the Opportunities and Challenges of Modular Construction in Malaysia"**.

It will be much appreciated if you could spend time participating in this survey to contribute your valuable information which is highly imperative to the research and the development of our Malaysian construction industry. This questionnaire consists of four sections and is designed to be completed within 15 minutes. All the information collected through this survey are strictly assured to be kept private and confidential and solely for academic purpose. Should you require any clarification, please do not hesitate to contact me at huiyikho0930@gmail.com or 017-5165292.

Your precious time and effort in participating in the survey are deeply appreciated. Thank you.

Yours faithfully,
Kho Hui Yi

*Required

Section A: Respondent's Background Information

This section will collect several information of your working experience.

INSTRUCTION: Please read EACH question and select your answer.

1. Which of the following best classifies your organisation? *

- ☐ Client/ Developer
- ☐ Consultant
- ☐ Contractor

2. What is your position in your organisation? *

- ☐ Director/Top Management
- ☐ Senior Manager
- ☐ Manager
- ☐ Executive
- ☐ Junior

3. How many years of working experience do you have in the construction industry? *

- ☐ Over 20 years
- ☐ 16-20 years
- ☐ 11-15 years
- ☐ 5-10 years
- ☐ Less than 5 years

4. What type of projects you frequently involved with in your career? *

- ☐ Residential
- ☐ Commercial
- ☐ Industrial
- ☐ Infrastructure

5. What is the value of the projects your company often undertakes? *

- ☐ Over RM 10 million
- ☐ RM 5 million - RM 10 million
- ☐ Less than RM 5 million

6. What is your highest academic qualification? *

- ☐ Postgraduate Degree
- ☐ Bachelor's Degree
- ☐ Diploma
- ☐ High School

7. Do you know about modular construction? (a.k.a. “prefabrication”, "IBS", “off-site construction”, “off-site manufacture (OSM)”, “off-site prefabrication”, “modern method of construction”, “volumetric construction”, “volumetric prefabrication”, “standardisation and pre-assembly”, “modular integrated construction (MiC)”, “prefabricated prefinished volumetric construction (PPVC)”, etc) *

- ☐ Yes
- ☐ No

8. Have you been involved in any project that adopted modular construction technology? (a.k.a “prefabrication”, "IBS", “off-site construction”, “off-site manufacture (OSM)”, “off-site prefabrication”, “modern method of construction”, “volumetric construction”, “volumetric prefabrication”, “standardisation and pre-assembly”, “modular integrated construction (MiC)”, “prefabricated prefinished volumetric construction (PPVC)”, etc) *

- ☐ Yes
- ☐ No

Section B: Opportunities of Modular Construction in Malaysia

This section requires respondent's perception towards the opportunities of modular construction in Malaysia.

INSTRUCTION: Based on the question below, please choose the most appropriate response which ranges from not at all aware to extremely aware to indicate the importance rating of attributes with a scale from 1 to 5 as below.

9. What is your perception of the opportunities for modular construction in Malaysia? *

Mark only one oval per row.

Opportunities	Not At All Aware (1)	Slightly Aware (2)	Moderately Aware (3)	Very Aware (4)	Extremely Aware (5)
Improve project schedule and productivity					
Better quality					
Cost-efficient and effective					
Lesser weather disruption					
Minimise material wastage					
Reduce site labour					
Flexible and removable					
Reduce rework					
Reduce life cycle cost					
High potential for market share					
Better occupational safety and health					
Noise reduction on site					
Lesser site disruption					
Reduce disturbance to surrounding community					
Decrease transportation and vehicular traffic					
Job creation					
Sustainable					
Reduce waste					
Reduce pollution					
Reduce embodied energy and energy efficient					

Section C: Challenges of Modular Construction in Malaysia

This section requires respondent's perception towards the challenges of modular construction in Malaysia.

INSTRUCTION: Based on the question below, please choose the most appropriate response which ranges from strongly disagree to strongly agree to indicate the importance rating of attributes with a scale from 1 to 5 as below.

10. What is your perception of the challenges of modular construction in Malaysia?
*

Mark only one oval per row.

Challenges	**Strongly Disagree (1)**	**Disagree (2)**	**Neutral (3)**	**Agree (4)**	**Strongly Agree (5)**
Transportation constraint					
Lack of skilled personnel					
High initial cost					
Need for excessive coordination and collaboration					
Low flexibility in design					
Time-consuming planning and design					
Client resistance					
Lack of guidance and government support					
Expensive					
Lack of social knowledge					

Section D: Strategies to Enhance the Implementation of Modular Construction in Malaysia

This section requires respondent's perception towards the strategies to enhance the implementation of modular construction in Malaysia.

INSTRUCTION: Based on the question below, please choose the most appropriate response which ranges from ineffective to extremely effective to indicate the importance rating of attributes with a scale from 1 to 5 as below.

11. What is your perception of the strategies to enhance the implementation of modular construction in Malaysia? *

Mark only one oval per row.

Strategies	**Ineffective (1)**	**Slightly Effective (2)**	**Moderately Effective (3)**	**Very Effective (4)**	**Extremely Effective (5)**
Government incentives and subsidies					
Training and education					
Encourage close collaboration					
Establish effective logistic and supply chain management					
Policies and regulation					
Revision of building codes and standards					
Research and development					
Government leadership and initiative					
Publicity and promotion					
Technology improvement					

End of Questionnaire Survey.

Thank you for your participation.