REPORT ON RESIDENTIAL HOUSING COST: A COMPARISON BETWEEN INDUSTRIALISED BUILDING SYSTEM (IBS) AND CONVENTIONAL SYSTEM

CIDB MALAYSIA

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World Trade Centre,
No. 45, Jalan Tun Ismail,
50480 Kuala Lumpur,
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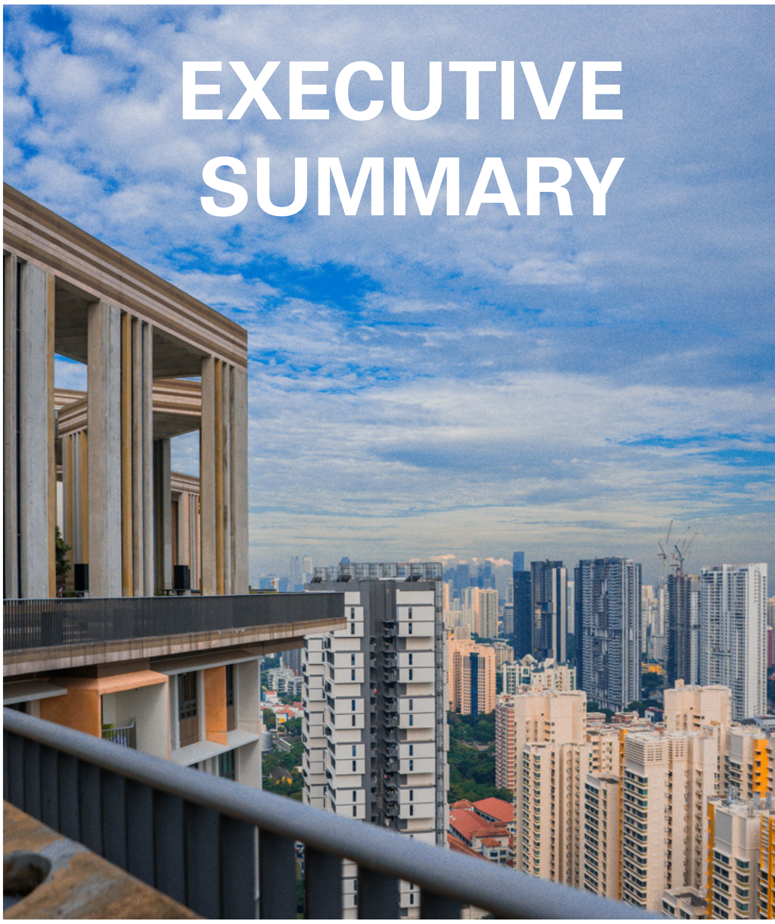
EXECUTIVE SUMMARY



The construction industry in Malaysia has shifted from employing the conventional construction methods to embracing a more effective construction method, known as Industrialised Building System (IBS). The IBS is a construction method that assembles separate structural components on the site. Hence, beams and columns in suitable size are critical for the IBS method. The type of connection between the structural elements has a crucial role in ensuring that the building is functional, economic, and safe. Both the structural member and the connection should enable smooth transfer of load without causing any severe damage. The adoption of IBS in the Malaysian construction industry is, nevertheless, untapped, particularly in light of housing development, due to cost impact. As such, this case study looked into cost comparison, equipment cost, overhead cost, and profit for both IBS and conventional projects involving residential projects. Data were gathered by distributing survey questionnaires to relevant stakeholders. The comparison of costs between IBS system and conventional method was calculated based on several housing development projects, namely Avanti Project, Seroja Project, Darul Hana Project, and Pangsapuri Aurora Project. The cost incurred differed based on the components used for the construction. It was found that the cost using IBS method for structural part was higher than that using conventional method. Most of the IBS methods applied more concrete and reinforcement, while the conventional method was only designed in frame that led to minimal use of concrete and reinforcement. This infers that the IBS method generated lower cost than the conventional method for architectural aspect, except for Seroja blockwork system. The conventional method used brick wall and plaster finish, whereas the IBS, which already consisted of wall panel for structural and finish with a layer of skim coat, significantly slashed the cost for architectural. Overall, the cost incurred using IBS method was lower than that using conventional method, except for blockwork system in Seroja which is vice versa. The survey outcomes revealed varying costs for the three housing projects; single-storey house, double-storey house, and apartment. In fact, 87.6% of the stakeholders agreed that the IBS is more cost-effective than the conventional method. This is supported with the highest ranking Mean score that reflected more saving on the cost factors with IBS. In conclusion, the total cost of a building may be reduced by using the IBS method. Some benefits of implementing the IBS are reduction in construction time, cost saving, better building quality, minimal waste, fewer requirement of workers at site, and less air pollution at the construction site. This study sheds light onto stakeholders to encourage developers and contractors in making the best decision that benefits all parties.

CHAPTER 1

INTRODUCTION: CONSTRUCTION SECTOR IN REVIEW

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The aim of this case study is to assess, propose, and develop a cost sheet comprising of cost comparison, equipment cost, overhead cost, and profit for Industrialised Building System (IBS) and conventional projects involving residential projects.

1.1 The Construction Industry in General

The construction industry has a significant role in boosting the overall economy of any given country. The manifestation of this crucial role, however, greatly varies from one country to another. This is particularly true in developing countries as it is likely that the extraction of raw materials and the on-site construction activities are integral, for they seek to erect significant infrastructure in the form of roads, railways, and buildings. As for developed countries, the onus is on professional services and sale of end products. Broadly speaking, the construction industry is a crucial part for the process of creating and sustaining the built environment. The construction industry is placed solely in the secondary sector, as it accounts for the transformation from manufactured materials into a final product.

In reality, the construction industry spans across the primary, the secondary, and the tertiary sectors, mainly because the process involves the transformation of raw materials into manufactured materials, and later, into a final product, along with professional services and sale of products at the end of the line. The weighting of each part of the chain tend to vary from one country to another, skewed based on their level of development and with more focus placed on both primary and secondary sector firms in developing countries, while more emphasis on tertiary sector firms across developed countries (e.g., UK). Weighing upon the importance of the construction industry, the General Industrial Classification of Economic Activities has been established within the European Community (NACE). Another factor that highlights the significance of the construction sector for the economy is due to its function in sustainable development through proper execution of a sound infrastructure - the very basis for sustainable development. Coupled with cutting-edge technologies into new build and similar technologies applied to maintenance and alteration of existing builds, the construction industry has a key role to ascertain that a country can sustain a given level of development. Sustainability is increasingly becoming a priority worldwide. As stipulated in the "Sustainable Development and the Future of Construction" (CIB, 1998), the drive for sustainability identifies economic, social, and cultural aspects as components of the sustainable construction framework. While special attention is given to the ecological impacts on the environment, more countries are joining the environmental pacts with fossil fuels and exhaustible materials for building are in scarcity. Hence, sustainable development is an integral fraction in the construction industry. Building projects that incorporate energy saving schemes (e.g., advanced insulation), natural energy-creating technologies (e.g., solar panels) or novel materials in the physical build contribute to sustaining the environment, thus attaining the overall objective of sustainable development.

Table 1.1. National GDP and Construction Sector GDP trend

	National GDP (%)	Construction Sector GDP (%)
2016	4.5%	7.5%
2017	5.7%	6.7%
2018	4.7%	4.2%
2019	4.6%	4.5%

Source: Bank Negara Malaysia (2018) and Department of Statistic Malaysia (2020)
*GDP refers to Gross Domestic Product

Table 1.1 shows that the construction sector slumped down to 4.2% in 2018, which reflects a downtrend since 2017. The growth rate of this sector was marginally below the National GDP growth rate of 4.7% in 2018, unlike those observed for 2016, 2017, and 2019, whereby the growth of the construction sector remained higher than the National GDP rates in the respective years. The driving force for the national GDP and the economy, as a whole, exhibited almost matching growth rates between the sector and the National GDP in 2019.

1.2 The Malaysian Construction Industry in General

The construction sector has often been touted as one of the few important and productive sectors that play a significant role in Malaysia's economic growth. As a developing country, this sector not only spurs the country's economic growth, but also contributes to the quality of life and the living standard of Malaysians (Khan et al., 2014). In 2006, the expenditure for the funding of building construction and infrastructure upgrading, such as schools, hospitals, and government living quarters, by the Federal Government was RM35.8 billion, in comparison to RM 40.6 billion in 2007 (Construction Industry Development Board [CIDB], 2008). Clearly, the construction process went through a transitional change to a more systematic and mechanised system, along with the adoption of prefabrication technology and employment of skilled workers, thus signifying a trend that spiralled towards business sustenance amidst global competition (Haron et al., 2005; Chan, 2011; Rahim & Qureshi, 2018). The four major parts of the construction method typically applied within the construction industry are:

(i) Conventional method
(ii) Full fabrication method
(iii) Cast in-situ method (formwork system)
(iv) Composite construction method

Table 1.2 lists the volume of projects for 2017 and 2018 by states. Selangor seemed to lead in the volume of projects for both years. Nonetheless, all the states displayed reduction in the volume of projects year-on-year (YoY) against 2017 performance, except Wilayah Persekutuan Kuala Lumpur that exhibited increment in the volume of projects from 922 in 2017 to 979 projects in 2018. The highest volume of projects in 2018 was led by Selangor (1455), followed by Wilayah Persekutuan Kuala Lumpur (979), Johor (883), Sarawak (412), and Perak (384).

Table 1.2. Number of Projects for 2017 and 2018 by States

State	2017	2018
Johor	1436	883
Selangor	2050	1455
Wilayah Persekutuan	922	979
Sabah	460	273
Sarawak	522	412
Negeri Sembilan	384	298
Perak	551	384
Pulau Pinang	571	402
Pahang	452	285
Terengganu	259	138
Melaka	340	204
Kedah	262	181
Kelantan	124	91
Perlis	41	23

Source: CIDB Malaysia (2019)

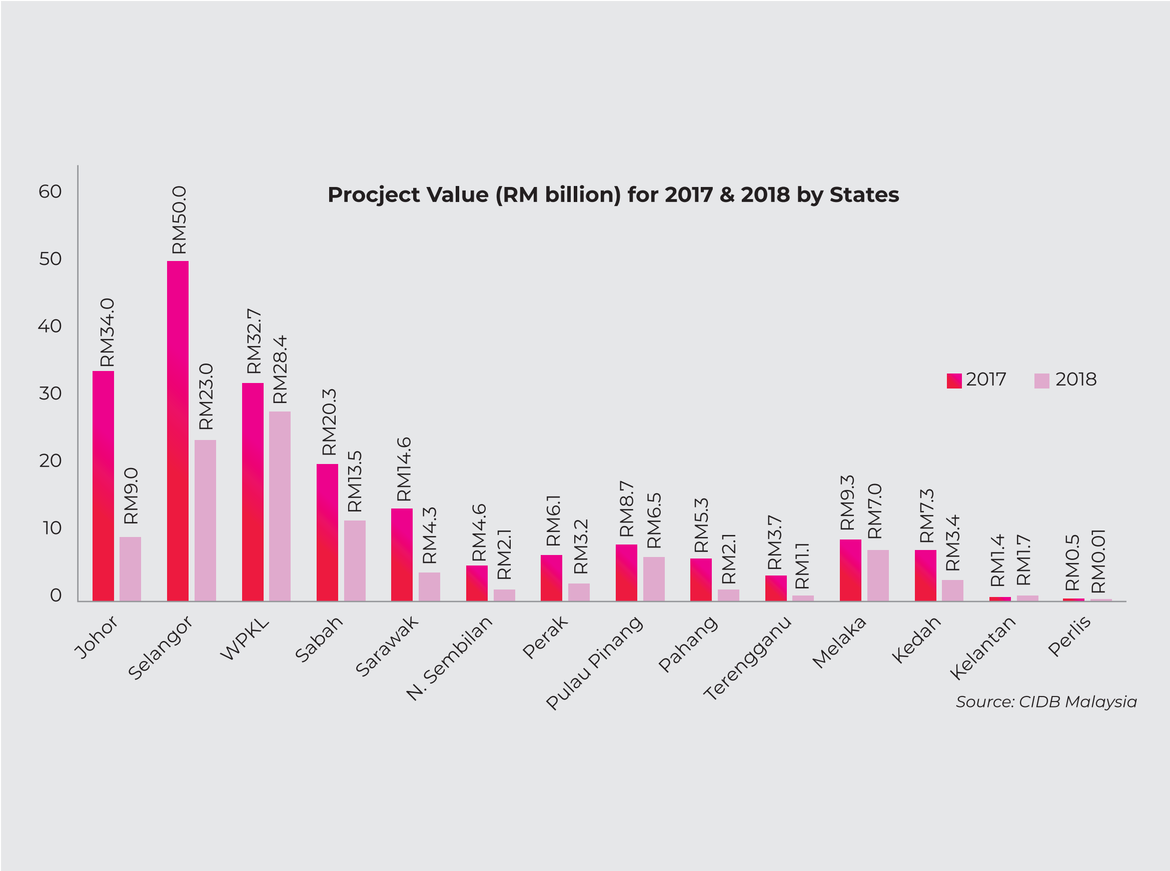

Figure 1.1. Project Values (RM billion) for 2017 and 2018 by States

Source: CIDB Malaysia (2019)

Referring to Figure 1.1, a drop was noted in the value of projects for Selangor, Johor, and Sarawak in 2018 against their achievements recorded in 2017. Wilayah Persekutuan Kuala Lumpur surpassed all the other states to command the highest rank in value of projects at RM 28.4 for 2018.

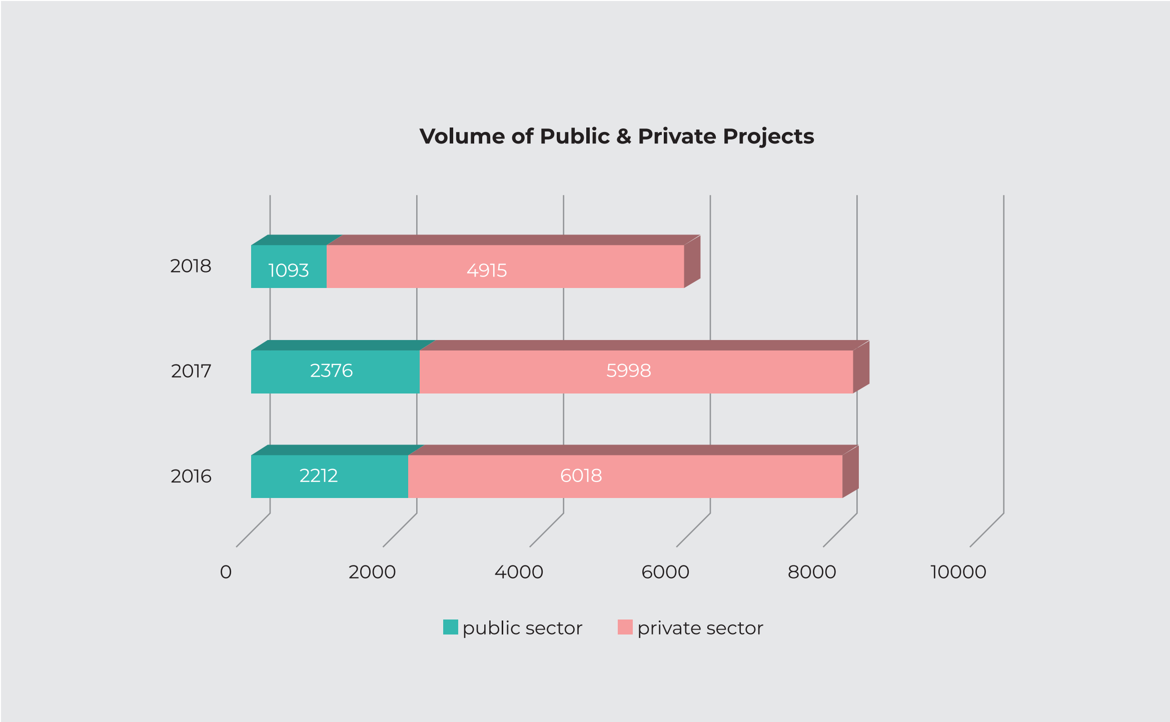

Figure 1.2. Volume of Public and Private Projects

Figure 1.2 presents the projects undertaken in both public and private sectors. The public and private projects continued to collectively drive the construction market with similar proportion of share in 2018, although lower project volume was noted in past years. The private sector served as a stimulus driver of the construction industry with 4,915 projects in 2018.

Table 1.3. Projects in Public and Private Sectors

Sector	Year 2018	Percentage
Public	RM32 billion	30%
Private	RM75 billion	70%
Total	**RM107 billion**	**100%**

In 2018, the public sector had a vital stimulus role, primarily by undertaking both national infrastructural and public amenities development projects, which contributed to 30% or 1,093 projects with a total value of RM32 billion, when compared to the private sector that recorded 70% or 4915 projects with a total value of RM75 billion. Both sectors collectively contributed RM107 billion into the economy in the form of 6,008 projects for 2018 (see Table 1.3).

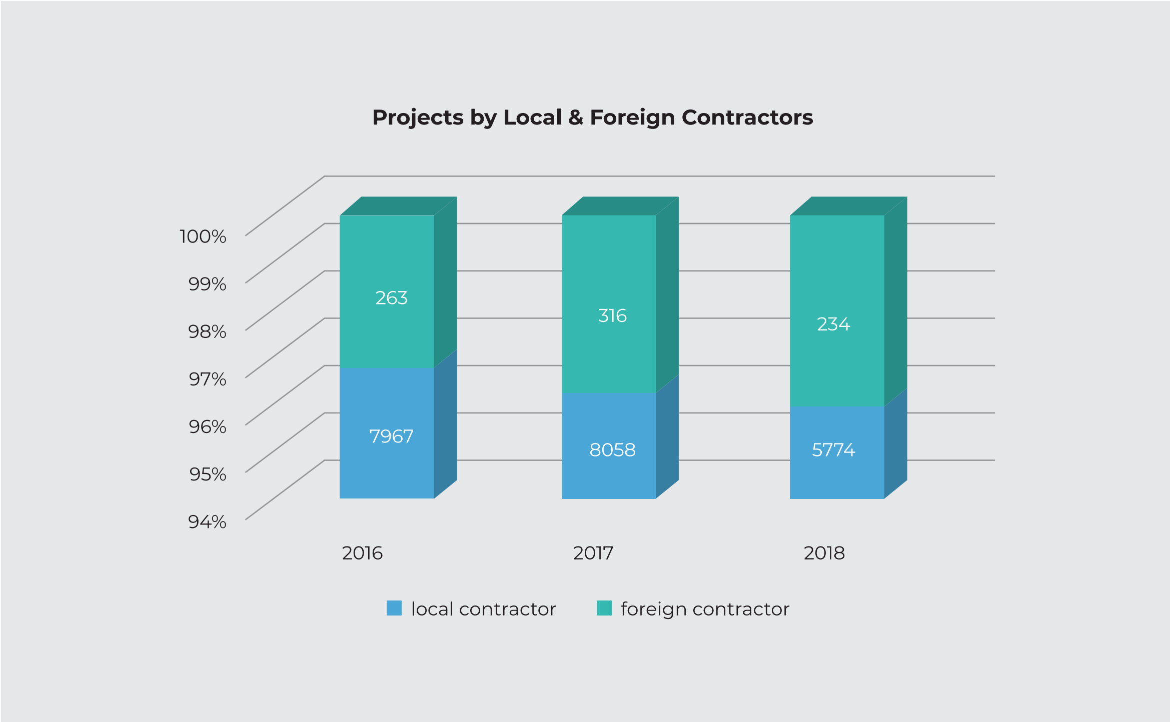

Figure 1.3. Volume of Projects by Local and Foreign Contractors

The highest number of local contractors was 8058 in 2017, followed by 7967 and 5774 in 2016 and 2018, respectively. Local contractors represented the majority share of the project volume in 2018, but with a significantly lower volume than that in 2016 and 2017. Meanwhile, foreign contractors had sustained their participation in the construction industry by securing 234 projects in 2018, 316 projects in 2017, and 263 projects in 2016.

Being an integral sector for the country's economic advancement, the construction sector exemplifies high productivity levels through efficient adoption of new technologies and modern practices, along with high-skilled and highly paid workforce. Part of the industrialisation process is the prefabricated construction, which was introduced in the 21st century as a plausible solution to enhance construction performance and its image (Mohamad Kamar et al., 2009) that has long been characterised as labour-intensive and surrounded by significant risks linked with market, site, weather conditions, and low productivity relative to other sectors. Upon proper delivery, prefabrication construction gives importance to client choice and involvement, especially in housing projects that embed a range of features and systems that can be realised by the manufacturers. The government's vision for Malaysia to turn into a developed country by 2020 has encouraged the use of innovative technologies across multiple sectors. With the implementation of various government projects under the Entry Point Projects (EPPs) via Economic Transformation Programme (ETP), a platform has been established to highly implement mechanised and enhanced automation in the construction sector. One of the few construction technologies preferred by the Malaysian government is the IBS.

1.3 Industrialised Building System (IBS)

The IBS does not have a commonly approved definition. Some definitions given by authors who had studied this topic area, as depicted in the literature, emphasised on prefabrication, off-site manufacturing (OSM), and mass production of building components (Abd Rahman & Omar, 2006; Warszawski, 1999; Trikha, 1999). This method enables cost saving and quality enhancement by reducing labour intensity and construction standardisation. Additionally, IBS offers minimal wastage, less materials, clean and economic environment, controlled quality, and a cost-efficient construction. The IBS is known as off-site construction, OSM, and prefabrication in other various countries. The mostly used components are prefabricated. Some worldwide successful IBS implementation refer to Sekisui Home (Japan), Living Solution (UK), Open House (Sweden), and Wenswonen (the Netherlands) (Oostra & Jonsson, 2007).

Meanwhile, in Malaysia, the CIDB had classified the IBS system into six categories, as listed in the following (CIDB; IBS Roadmap, 2010; IBS portal, 2020):

I. Precast Concrete Framing, Panel and Box Systems
II. Steel Formwork Systems
III. Prefabricated Timber Framing Systems
IV. Steel Framing Systems
V. Blockwork Systems
VI. Innovative System

Malaysia's CIDB has established a range of strategic plans since 1998 to upgrade the construction industry into world class, sustainable, and technologically competitive, so as to further contribute to Malaysia's economy. One of the many strategies outlined is to promote the use of IBS in the local construction industry, regardless of huge or small projects. The adoption of IBS into the construction industry has introduced a new paradigm, apart from elevating the quality of the construction industry to be acknowledged at the global level and further rise in competition amongst the industry players. The earlier usage of IBS was mainly to minimise dependency on foreign workers, to achieve high quality build, and to attain faster completion time by executing a more systematic approach and methodology in construction.

The Malaysia's construction industry has been moving from the conventional techniques to a more systematic and mechanical method, also known as the IBS. Each state in Malaysia has been assessing the development of the IBS, as well as its potential to overcome the shortage of housing accommodation faced in this country. The Malaysian government, through the CIDB, has been persistently encouraging the construction industry to implement the IBS method since 2003. It is also part of an incorporated endeavour to improve the aptitude, the potential, the efficacy, and the competitiveness of the industry, besides diminishing dependency on foreign workforce. This reflects an attempt taken by the Malaysian construction industry to encourage positive inroads in matters related to construction-site safety, so as to generate a working environment that is cleaner, more convenient, and more organised.

The Malaysian construction industry has been growing rapidly, particularly in the housing sector with a GDP of 11.6% in 2014, when compared to 10.9% in 2013 (MITI, 2014). However, the industry has been plagued with a number of issues pertaining to quality and abandoned projects. The impact of foreign labour has exerted an adverse impact mainly on the flow of the Malaysian ringgit and rising social ills in the country (Azman, 2014).

1.4 IBS Projects in Malaysia

The potential of implementing IBS for the construction of residential housing in Malaysia was well reflected in a study conducted by CIDB in 2018. The findings revealed that the total number of contractors involved in building construction for year 2016 was 3004. From that figure, 31.7% of the contractors were IBS contractors (see Figure 1.4). Meanwhile, Figure 1.5 shows the percentage of project status in both the public and private sectors. In total, 65.4% of the projects were undertaken by the public sector, while the remaining 34.6% were linked with the private project.

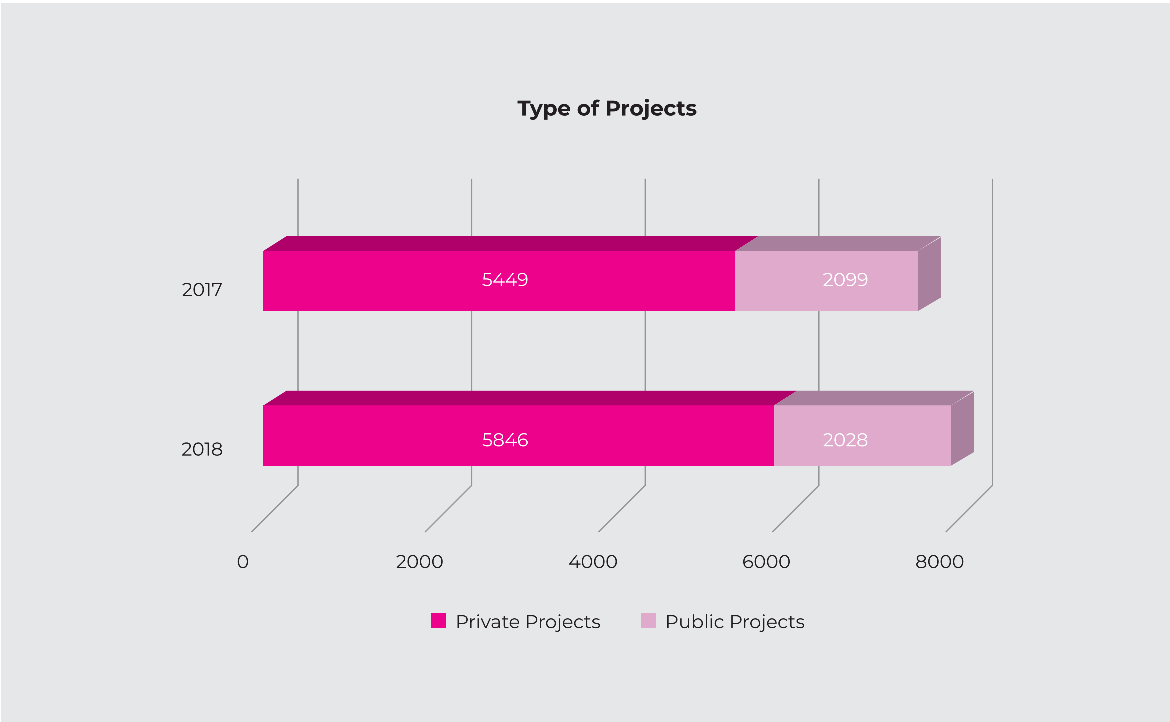

Figure 1.4. Number of Contractors for Private and Public Projects in 2016 and 2017

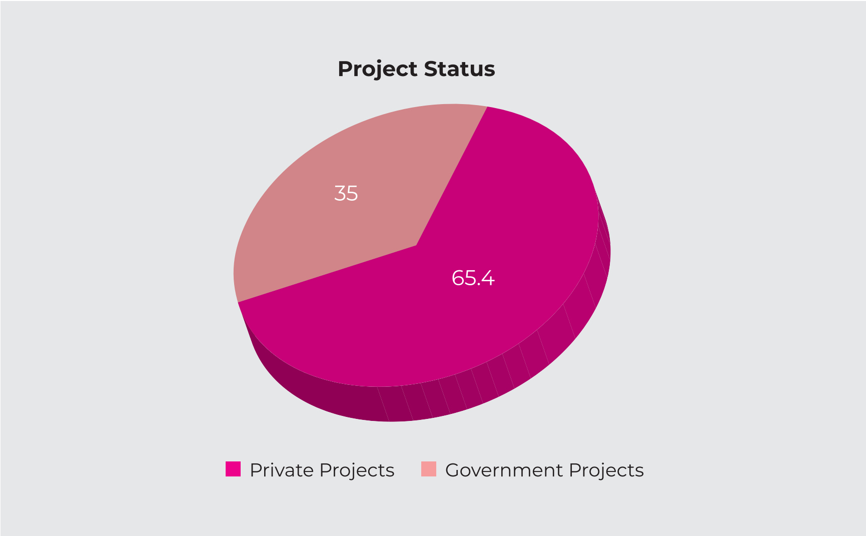

Figure 1.5. IBS uptake in Private and Government projects

Source: CIDB (2018)

Figure 1.6 illustrates the percentages of IBS and non-IBS contractors in both government and private projects. Clearly, only 31.7% of the contractors executed IBS, whereas 68.3% of the contractors disregarded IBS. From the percentage of 31.7%, 21.0% of the projects were undertaken by the private sector, while the remaining 10.7% referred to government projects.

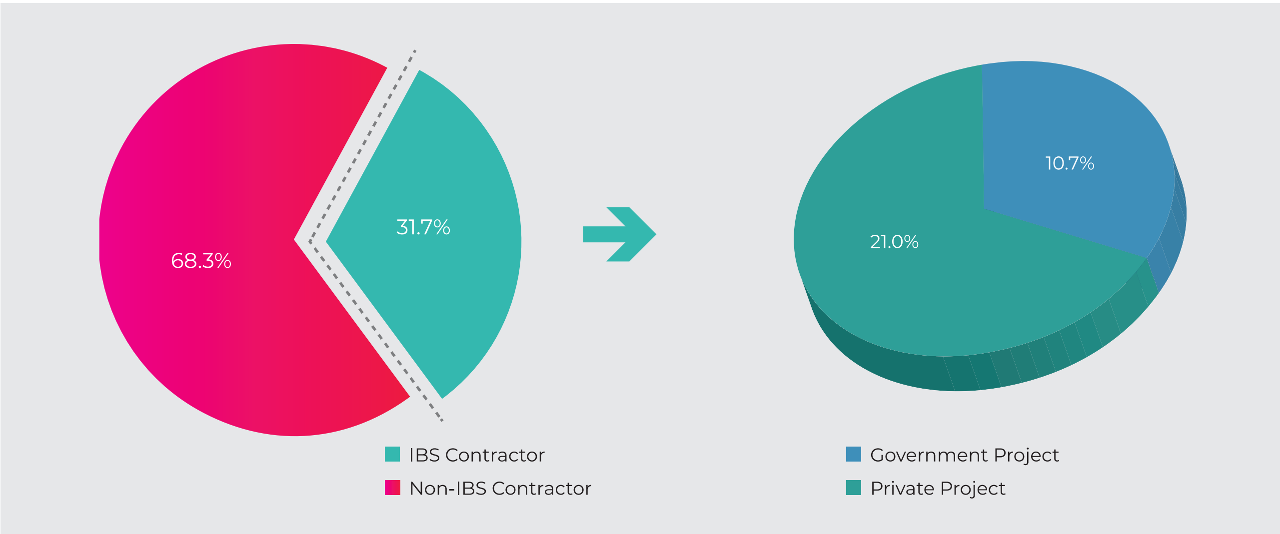

Figure 1.6. IBS and non-IBS Contractors Based on Government and Private Projects

Source: CIDB (2018)

Figure 1.7 illustrates the percentages of IBS and non-IBS contractors based on IBS classification. The steel framing system mostly implemented the IBS at 27.0%, followed by precast system at 3.4%, while 0.5% for reusable formwork system, and 0.4% for blockwork and timber framing system. in total, 31.7% were IBS contractors, whereas 68.3% were non-IBS contractors.

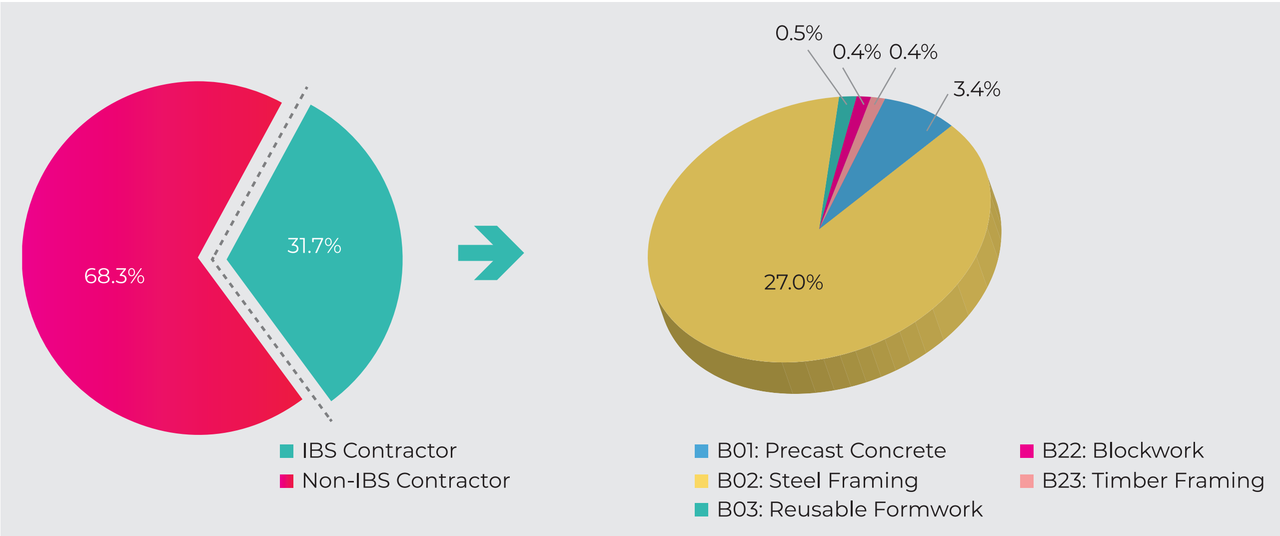

Figure 1.7. IBS and non-IBS Contractors Based on the Types of IBS

Source: CIDB (2018)

1.5 IBS vs. Conventional Construction

In Malaysia, the construction industry has been shifting from conventional methods to a more standardised and mechanised approach known as the Industrialised Building System (IBS). At present, all states in Malaysia are experimenting with the execution of IBS to address the uprising issue of housing shortage. The IBS appears to offer a potential solution in achieving the overall performance within the construction sector in terms of increased labour quality, reduction in costs, adequate protection, reduced waste, and increased productivity. The IBS refers to a construction technique, whereby all its components are manufactured in a controlled environment and later transported, installed, and assembled at the site with minimal additional structures. Not only does the IBS speed up the construction of housing projects, it also improves both the quality and the sustainability of the projects. Despite the wide popularity of the IBS and it acceptance by most construction companies due to its theoretical benefits in terms of speed, safety, and quality; the conventional wet construction method is still widely regarded as a safe choice in Malaysia, despite its higher costs and lower completion rates. The conventional construction method is one of the oldest methods applied in the construction industry that excludes factory-made building materials or finished parts. The conventional technique executes construction work at the site. This includes installation of prefabricated building components at the construction site following the initial installation of a wood or plywood formwork, reinforcement steel, and metal.
The conventional construction method uses wooden moulds to this end. It becomes costlier

due to the rising costs of labour, raw materials, transport, and extended construction period. Instances of conventional construction, which is also known as cast in-situ, are foundations, frame structures, floors, walls, and roofs. The present buyers who prefer houses built of brick-and-mortar appear to be a new challenge. One misconception on the pre-cast panels is that the buyers assume the building has lower quality, mainly because it is commonly used to build low-cost houses in Malaysia. Due to the ongoing dilemma, the present developers are not prepared to take risk by undertaking pre-cast constructions. Lack of contractor experience and technical knowledge pertaining to IBS has escalated the costs, primarily stemming from their inefficiency in cost management. This has given rise to apprehensive feeling towards the effectiveness of the IBS approach. Since local contractors do not have sufficient technology or relevant experience in managing quality, productivity, and safety issues; they are unable to compete with their counterparts in other countries that have widely adopted and implemented IBS.

More often, people have misconceptions when it comes to IBS. Many opinions tend to take on the low end, widely manufactured homes, and impossibly expensive custom homes. In reality, ÌBS buildings are the more common and accessible alternative to multitude arrays of budget levels. In fact, there are many reasons for one to choose IBS over conventional construction methods.

In these recent years, the implementation of IBS has improved significantly, thus enabling them to compete with the conventional construction methods. Sometimes, the quality of IBS is better than that of conventional techniques. In IBS, the components are built in a factory setting on an assembly line, which reflects that the manufacturing process of each and every piece is under intense quality control. Meanwhile, components for the conventional method are built from scratch at the site where it will sit. Hence, builders may fail to protect the lumber used for the construction from elements. Such negligence may give rise to multiple issues.

Although IBS may be executed by the same manufacturer with least possible downtime, fewer costs can be linked with the construction process. The cost of IBS may be lower than the cost incurred using conventional method, apart from the possibly of more affordable if the location of the manufacturing is not far from the construction site. Besides, IBS construction can be disassembled easily and relocated smoothly to other sites. It significantly reduces the ultimate demand for raw materials, expended energy, and overall time expense, unlike the conventional method. The IBS allows for flexibility in the design of the structure, so as to ensure limitless opportunities. Apart from its ability to be used in varied spaces, the neutral aesthetics of prefabricated construction units can be incorporated with almost every variety of building.

1.6 IBS vs. Conventional Construction in Housing Development

In line with present housing demands in the global market, the construction industry has begun adopting mass production assembly and standardisation of product development. These strategies have prompted the Malaysian construction industry to re-evaluate the achievements of other countries in executing the prefabricated technology, such as the UK, Australia, Singapore, and Hong Kong. The prefabrication technology in Malaysia is called IBS, alternatively known as modern methods of construction (MMC) or OSM. Othuman Mydin et al., (2014) reported that IBS is similar to MMC in the UK, while OSM is used both in the Australian and the UK construction industry, and prefabrication in Hong Kong and Singapore.

In Malaysia, the IBS has been implemented since the 1960s when the Ministry of Housing and Local Government made visits to several European municipalities with the objective of assessing their housing development plans. After a successful tour in 1964, the Malaysian government had launched a project that tested the efficiency of IBS. The test was meant to gauge its potential as a system, which might be deployed as an alternative to the conventional system that already had a strong foothold in Malaysia. The key objectives included the acceleration and the increase of affordable housing of substantial quality in Malaysia. The IBS proved to be a success. Not only was it efficient in accelerating the construction of housing projects, it also improved the quality and the affordability of the projects with deployment of IBS. Based on different reference materials accepted by the authorities within the construction fraternity, a number of ways have been outlined to define IBS. Despite the IBS being well-known and accepted by most construction firms worldwide due to its theoretical advantage in terms of speed, safety, and quality; the conventional wet construction method is still widely used in Malaysia as a safe option, despite higher costs and slower production rates.

In ensuring that Malaysians can afford to own a house, various strategies and steps have been undertaken by the federal and state governments. Preparation Affordable housing is a key step introduced by the government to manage the growing cost of living. Some other initiatives were also translated into the preparation of the National Housing Policy 2013-2017 (Jabatan Perumahan Negara, 2019) with clear objectives of providing adequate and quality housing complete with facilities and conducive environment, enhancing the access and the ability amongst Malaysians to own or rent housing, as well as assuring the sustainability of the housing sector in the future.

The priority of future housing deals is to ascertain that the people can afford and live in quality housing. In order to determine the provision of quality housing for the people, the government had introduced Quality Housing Standards (QHS) to assess the quality of the existing and future housing. The existing housing standards (CIS 1, 2, 3, and 4) (CIDB, 2019) were reviewed and various aspects related to local culture, demographics, climate, and materials were considered in the QHS. The process of gaining feedback from the public and stakeholders was also embedded so that the PPB may weigh in the needs and aspirations of the people. As for new housing, the minimum standard setting includes a greater focus on quality control of the home units to be built. For existing housing, specific standards have been developed to ensure upgrading and maintenance of the housing system and quality.

Standard Affordable housing refers to a standard guideline that involves all construction and affordable housing development in Malaysia, so as to ensure that provision of quality and sustainable housing standards can be fully referenced in the Housing Standard National CIS 26:2019 (CIDB, 2019), as issued by the CIDB. The features of a basic affordable house are based on some criteria found in IBS.

The government have begun encouraging the relevant party to execute the construction of affordable housing by stages using the IBS System Quality. Affordable housing is necessary to meet the QLASSIC rating to guarantee the quality of the building.

Saving construction costs for each affordable house unit has been accounted for through construction activities and implementation on a bigger scale, which is bound to produce more low-cost development due to the production of enhanced building components (CIDB, 2019).

Singapore has successfully minimised its overall construction costs by executing IBS, which is already widespread in every public housing project. The use of IBS in 80% of the buildings could save costs up to 45%, when compared to conventional methods. This IBS method of construction has more sophisticated systems, besides enhancing the level of efficiency, reducing construction period, minimising project costs, and avoiding delay on project completion. Additionally, tax incentives and exemptions on IBS machinery and equipment may be implemented.

1.7 Types of Building System

1.7.1 Reusable Formwork System

The formwork consists of prefabricated modules with a metal frame (usually steel or aluminum) and is covered by material with the desired surface structure (steel, aluminum, timber, etc.) on the application (concrete) side. The two main benefits of using formwork systems, when compared to conventional wood formwork, are speed of construction (modular framework pin, clip or screw together quickly) and lower lifecycle costs (with exception of major force, the frame is almost indestructible and the covering is made of wood that may need to be replaced after a few hundreds of uses. But when the covering is made of steel or aluminum, the form can achieve up to 2000 uses depending on care and applications). Metal formwork systems are better protected against rot and fire than conventional timber formwork.

Plastic formwork. This formwork can be reused. The interlocking and modular systems, which are used for the construction of concrete structures, come in varieties but relatively simple. The panels are sturdy and lightweight. They are suitable for projects with similar structures and low in cost, especially for mass housing schemes. In order to obtain an additional protective layer against destructive weather, galvanised roofs eliminate the risk of corrosion and rust. Such modular enclosure forms may have load-bearing roofs that maximise space by stacking on top of each other. They can be mounted on an existing roof or built without floor and lifted using a crane to existing enclosures.

Permanent Insulated Formwork. This formwork is assembled on site, usually out of insulating concrete forms (ICF). The formwork stays in place after the concrete has cured, hence may provide advantages in terms of speed, strength, superior thermal and acoustic insulation, space to run utilities within the EPS layer, and integrated furring strip for cladding finishes.

Stay-In-Place structural formwork system. This formwork is assembled on site, usually out of prefabricated fibre-reinforced plastic forms. It is in the shape of hollow tubes and usually used for columns and piers. The formwork stays in place after the concrete has cured and acts as axial and shear reinforcement, apart from confining the concrete and preventing against adverse environmental effects, such as corrosion and freeze-thaw cycles.

Flexible formwork. On the contrary to rigid moulds described above, flexible formwork refers to a system that applies lightweight and high strength sheets of fabric to take advantage of the fluidity of concrete and create highly optimised, architecturally interesting building forms. By using the flexible formwork, it is possible to cast optimised structures that use significantly less concrete than an equivalent strength prismatic section, thus the potential for significant embodied energy savings in new concrete structures.

1.7.2 Steel Framework

Steel Framing System refers to a fast-structural system designed for panel construction and continuous walls, individually standing low-rise buildings, and high separation walls. This system is beneficial for cold-rolled sections, such as extreme flexibility, ease of execution, rapid build, and low final frame weight. It is an ideal bearing system for low-rise buildings, where building speed is a concern. Precisely designed light components facilitate handling at the construction site, besides reducing waste from building materials. Individual components are supplied and assembled on site. Based on the production documents, the components can be custom-made or supplied in standard lengths and cut on site.

1.7.3 Prefabricated Timber Framing Systems

Prefabricated timber framing system forms a skeletal structure to support the weight and the number of loads carrying member. Its essential function is to transfer heavy loads over large spans. The prefabricated timber framing may be applied to form a structure of heavy timber jointed with various joints, regularly and initially with lap jointing, and the later pegged mortise and tenon joints. Timber frame-based structures use industrial facilities to generate wall panels, floor, and rooftop boards. The frameworks are arranged by method for either open panel, protected or closed panel.

1.7.4 Blockwork

Blockwork system is an evolution of the use of conventional brick. Blockwork system is the construction of concrete or concrete blocks larger than standard clay or concrete bricks. The block system is lighter and easier to work with as it has hollow cores that increase insulation capacity. The block system is composed of ‘lightweight block’ and ‘concrete masonry block’. CMU blocks are used to build load-bearing wall pile and wall components, whereas light blocks are used to build walls. The two types of light blocks are Autoclaved Aerated Concrete (AAC) and Cellulose Lightweight Concrete (CLC).

Block concrete brick units are rectangular and made of concrete with hollow cores. It is manufactured in automated manufacturing process that consists of mixing materials, laying the material in mould, and later, transferring the unit to the curing operation. Block categories are similar to brick-based methods, but their sizes are adapted from “Guide to Modular Coordination in Buildings” (MS1064: part 8 coordinating sizes and preferred sizes for masonry bricks and blocks).

1.7.5 Precast Concrete

Precast concrete denotes a form of concrete that is prepared, cast, and cured off-site, usually in a controlled factory environment by using reusable moulds. Precast concrete elements can be joined to other elements to produce a complete structure. It is commonly used for structural components, such as wall panels, beams, columns, floors, staircases, pipes, and tunnels.

Structural steel frames are an alternative to prefabricated structural components, but precast concrete can be more economical and practical. At present, many buildings have included a mixture of both construction techniques, sometimes incorporating structural steelwork, in-situ concrete, and precast concrete elements.

1.7.6 Innovative system

Innovative system refers to a range of innovations that implements the use of IBS to shorten project duration, reduce cost, and minimise labour requirement. This system has been acknowledged by CIDB and applied in various projects throughout Malaysia.

1.8 Significance of the Study

The definition of several stakeholders in an IBS construction is as follows:

a) Construction Industry Development Board (CIDB)
Based on the amendment made to the Construction Industry Development Board Act (Act 520), namely the principal Act, a key function of the Board is to regulate the implementation of IBS construction industry.

b) Local Authorities (PBTs)
Local Authorities refer to state government agencies responsible for administration, approval, project monitoring, and issuance of Certificate of Completion and Compliance (CCC).

c) Developer
The developer is the project owner and is responsible for ensuring that both contractors and consultants comply with the requirements stipulated in CIDB on IBS.

d) Producer / Distributor of IBS
It is a manufacturer or distributor of IBS components registered in the list of IBS Producers List certified by CIDB. The three categories of accreditation / certification under CIDB are:
i - Manufacturer of IBS Status (IBS Status Manufacturer)
ii - Distributor / Supplier of IBS Status (IBS Status Distributor / Supplier)
iii - Manufacturer of IBS Status Site (IBS Status on Site Manufacturer)

Certification / recognition is classified based on the following six major groups:
i - Precast Concrete System
ii - The Steel Frame System
iii - Repeated Reference System (Formwork)
iv - Prefabricated Timber Framing Systems
v - Block System
vi - Innovative System

e) Contractor

The IBS construction contractor conducts the IBS construction based on the specifications set by CIDB. The contractor must ascertain that the IBS components are used in construction and installed by recognised IBS installers.

f) Consultant

Consultants, engineers, materials surveyors, and architects involved in IBS construction assist in ensuring that the construction is carried out by adhering to the specifications set by CIDB.

g) IBS installer

The IBS component installer must be recognised by the CIDB. The IBS installer is trained by CIDB acknowledged IBS producer / distributor.

h) Transporter

The transporter refers to an IBS component transportation or logistic service provider.

CHAPTER 2

INDUSTRIALISED BUILDING SYSTEM VERSUS CONVENTIONAL METHOD

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INDUSTRIALISED BUILDING SYSTEM VERSUS CONVENTIONAL METHOD

2.1 Construction Cost in Australia and Malaysia: A three-storey residential building

A case study was conducted on a building at Octavia Street in St. Kilda suburb, Melbourne. The study assessed a single-level basement and two above-ground floors that had a 1,154 square meter built-up area. The concrete panel walls were also precast. In examining a residential building in Melbourne using prefabricated hollow core boards with prefabricated inverted-T beams, Yong (2010) found significant variances in cost between pre-cast concrete and conventional reinforced concrete solution in situ. The contractor obtained a cost estimate of the structure for supplying and installing all precast components. Upon comparing the two methods, an alternative post-tensioned slab and beam system was developed, in which cost-cost based on cost indices was published in Rawlinsons (2010). The adoption of an option for post-tensioned band beam and slab was to ascertain that the same column and beam layout may be used for both precast and post-tensioned systems.

Table 2.1 presents two significant cost structural observations. First, the supply of prefabricated components is cheaper than the supply of materials and forms in Melbourne. In Malaysia, the supply of prefabricated materials and forms is more than double the cost of materials and forms. Second, the cost of site labour for cast in-situ construction is two-fold that of prefabricated construction in both contexts.

Table 2.1. Comparison of construction costs in Australia and Malaysia

Case Study Items	Australia Unit cost (AU$, %) (per sq.m)	Malaysia Unit Cost (RM, AU$, %) (per sq.m)
Precast System (Slab and Beam)	AU$ 416 (100%)	RM 411, AU$ 129 (100%)
- Manufacture and Supply of Materials	AU$ 302 (73%)	RM 360, AU$ 113 (88%)
- Site Labour	AU$ 63 (15%)	RM 23, AU$ 7 (6%)
- Crane Rental	AU$ 51 (12%)	RM 28, AU$ 9(7%)
In-situ P/T or RC Suspended Slab and Beam	AU$ 539 (100%)	RM 250, AU$ 78 (100%)
- Supply of Materials and Forms	AU$ 356 (66%)	RM 175, AU$ 55 (70%)
- Site Labour	AU$ 126 (23%)	RM 59, AU$ 18 (24%)
- Crane Rental	AU$ 56 (11%)	RM 16, AU$ 5 (6%)

2.1.1 Manufacturing Costs

The cost of formwork has been the key driver for the greater use of precast components. In Malaysia, the supply and installation of sawn timber formwork cost approximately RM 7 or 12% of the total cost of reinforced concrete slab suspended. Clearly, the supply and installation of formwork is an integral percentage of Australia's total slab cost, to the extent that it exceeds the cost of slab material.

Table 2.2. Cost Comparison for Cast In-Situ Slab Construction

Cast In-Situ Slab Construction	Unit cost (per sq.m)	Cost Break down (%)
In-situ PT Suspended Slabs (Australia, AU$)	AU$ 243	
- Supply and fix concrete, steel and PT system	AU$ 90	37 %
- Supply and fix formwork	AU$ 153	63 %
In-situ RC Suspended Slabs (Malaysia, RM, AU$ equiv.)	RM 53 (AU$ 17)	
- Supply and fix concrete and steel	RM 47 (AU$ 15)	88 %
- Supply and fix formwork	RM 7 (AU$ 2)	12 %

2.1.2 Labour Costs

High daily wages for Australian tradesmen contribute to the high cost of conventional construction, mainly because the process is extremely labour intensive. On the contrary, the low wage offered in Malaysia directly contributes to lower costs of conventional construction methods with cast in-situ concrete. Shaari (2003) asserted that the construction firms in Malaysia have continually adopted labour-intensive practices due to the availability of cheap migrant labour, instead of investing in plant and equipment for prefabricated component manufacturing.

Table 2.3. Daily Wages for Construction Workers

Worker Level	Reported Daily Wage
AU-CW Level 1(new worker)	A$ 115 (573.00 per wk)
AU-CW Level 3 (certified tradesman)	A$ 128 (637.60 per wk)
AU-CW Level 9 (tradesman level II)	A$ 150 (750.40 per wk)
MY-General CW (Foreign)	RM 50 (AU$ 16)
MY-General CW (Local)	RM 60 (AU$ 19)
MY-Skilled CW (Foreign)	RM 100 (AU$ 31)
MY-Skilled CW (Local)	RM 150 (AU$ 47)

Source: Fair Work Australia (2010)

2.1.3 Comparison between Malaysian and Australian case studies

The case studies between Malaysia and Australia illustrate the technological trade in concrete building production between capital and labour. Construction firms may opt to increase their capital input and decrease labour input to minimise costs in a developed economy with high labour rates. In the case of a developing economy with access to cheap migrant labour, construction firms can choose to slash construction costs by employing higher labour inputs. The comparison of costs exemplifies that the choice of construction inputs is driven by the market, while financial incentives to increase the adoption of prefabricated components must be coupled with reduction in supply of cheap migrant labour. The labour policy of engaging cheap migrant labour in Malaysia has led to extremely low wage rate for construction labour. As a result, this has discouraged the entry of local workers into the sector, thus leading to net cash outflow through remittances and creating numerous social issues due to the presence of immigrants in a huge number. The financial incentives offered by the government to construction are insufficient to overcome the higher investment costs of prefabrication systems. Hence, additional measures to increase the amount of prefabrication may include ensuring a sustained demand for prefabricated components for public projects, instilling greater awareness on the advantages of prefabrication and viable tax incentives for capital investments, as well as establishing more collaboration between designers and construction companies.

2.2 IBS Score

Malaysia has a high demand for construction activities. This demand has attracted volumes of foreign workers into this country to take up employment on site as unskilled labour to perform manual jobs. Despite their contributions, the country has turned into a quicksand with multiple issues, including low quality work, delays, wastages, social ills, and diseases. In order to standardise the measurement of IBS usage in buildings, CIDB Malaysia had introduced the Manual for IBS (IBS Score) in 2005 and followed by a revised edition in 2010. The initial edition of the manual introduces a systematic and structured evaluation system that measures the use of IBS in a consistent manner. Upon weighing in cutting-edge technologies, policies, business environment, and inputs from the construction industry stakeholders, CIDB Malaysia had published the latest edition of the Manual; CIS 18: 2018.

The 2018 edition of the IBS Score Manual replaces the CIS 18: 2010. The primary objective of the manual is to provide a well-structured assessment system that calculates the IBS Score. It sets out the IBS Score formula based on IBS Factor for each element used in a building, methods of calculating the IBS Score, explanatory notes, and sample calculations. It serves as a complete guideline for every professional to evaluate the IBS Score for any building project.

2.2.1 Prefabrication and Standardisation (P&S)

Although P&S benefit the building construction industry, quantifying those benefits has been proven to be challenging. The initial cost when using P&S will not necessarily be lower from the conventional construction methods. Instead, rapid construction, savings in the use of standardised panels and modules, as well as better product quality, are some of the main potential benefits. A method for combining these hard-to-quantify savings with costs is discussed. The potential for further use of P&S was analysed by incorporating building type and component. In order to distinguish standardisation from prefabrication, a third term is introduced – customisation (see Figure 2.1). This describes that estimation of the potential for P&S presented in this report is not additive. Some form of standardisation may be attained via prefabrication, but others, such as the same floorplan used for side-by-side townhouses, may be achieved on-site.

Standardisation is the repeated production of standard sizes or layouts of components or complete structures. This includes modular bathrooms, standard kitchen cabinet sizes, standard prison cell or classroom designs, standard window sizes or wall panel sizes, and finishes. Such repeated production of identical components or structures may occur on-site (a form of standardisation), or off-site (a form of prefabrication). Meanwhile, prefabrication denotes off-site production of standardised or customised components or complete structures. This includes pre-cutting and prevailing of wall framing and roof trusses, or off-site construction of wall panels or bathrooms, whereby they are either standardised or customised. Prefabrication may be for bespoke (customised) components and structures (off-site production) or standardised components and structures (standardisation).

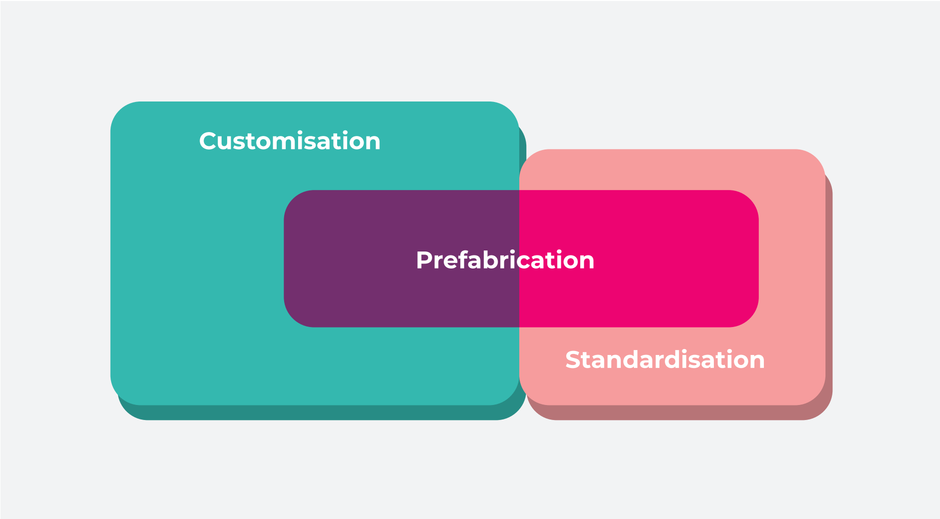


Figure 2.1. The Relationships among Customisation, Prefabrication, and Standardisation

2.2.2 IBS Scoring System in Malaysia

Prosperity and high economic growth in Malaysia have led to the escalating demand for construction activities. The IBS scoring system was initiated in January 2005 with its initial revision in April 2010. The objective of this scoring is to provide a systematic and structured assessment system to consistently measure the use of IBS. Some attributes emphasised in the IBS Scoring System are illustrated in Figure 8. A high IBS score signifies a reduction in site labour, lower wastage, less site materials, a cleaner environment, better quality, a neater and safer construction site, rapid project completion, and lower total construction cost. The method of identifying the IBS Score is a simple and effective process. Points are awarded based on the IBS Factors of the structural and wall elements used. High repetition in the design and other simplified construction solutions contributes to the total score. The points are summed to obtain the IBS Score of the entire building. The IBS score for a whole development project that consists of a group of buildings may be determined as well.

Table 2.4. Components of IBS Score

	PART 1		PART 2	PART 3
	Structural Systems (50 IBS Points	Roof	Wall Systems (20 IBS Points)	Other Simplified Construction Solution (30 IBS Points)
Full IBS Factors	Precast Concrete Columns, Beams & Slabs, Prefabricated Steel Structures and Timber Framed System	Precast Concrete Columns, Beams & Slabs, Prefabricated Steel Structures and Timber Framed System	Precast Concrete Panel Wall Cladding, Prefabricated Timber Panel, Full Height Glass Panel, Dry Wall System and Pre-Assemble Blockwall	
Partial IBS Factors	Reusable System Formwork for *in-situ* concrete structure	Reusable System Formwork for *in-situ* concrete structure	*In-situ* Concrete with Reusable System Formwork (Blockwork System)	
Nill IBS Factors	Timber Formwork	Timber Formwork	Common Brickwall	
Emphasis on				Utilisation of MS1064 Guidelines • Horizontal & Vertical Repetition • Buildability

The IBS Score formula is listed in the following:

IBS SCORE = SCORE FOR STRUCTURAL SYSTEMS
+
SCORE FOR WALL SYSTEMS
+
SCORE FOR OTHER SIMPLIFIED CONSTRUCTION SOLUTIONS

Or in detail:

$$50 \sum \left[\frac{Q_S}{Q_{ST}}\right] F_S + 30 \sum \left[\frac{Q_W}{Q_{WT}}\right] F_W + S$$

Where:

Q_S	-	Floor area of a structural system
Q_{ST}	-	Total construction area of building
F_S	-	IBS Factor for structural system
Q_W	-	Length of a wall system (external or internal wall)
Q_{WT}	-	Total wall length (external and internal wall)
F_W	-	IBS Factor for wall system
S	-	IBS Score for other simplified customer solutions

$$\sum \left[\text{IBS SCORE FOR BUILDING} \times \frac{Q_{ST\ (building)}}{Q_{ST\ (project)}}\right]$$

Figure 2.2. IBS Score Formula

In promoting the implementation of IBS, a number of incentives and regulatory requirements have been introduced. An example of a regulatory requirement refers to the minimum percentage of IBS use in government building projects. The way to target higher IBS scoring is presented in Figure 2.3.

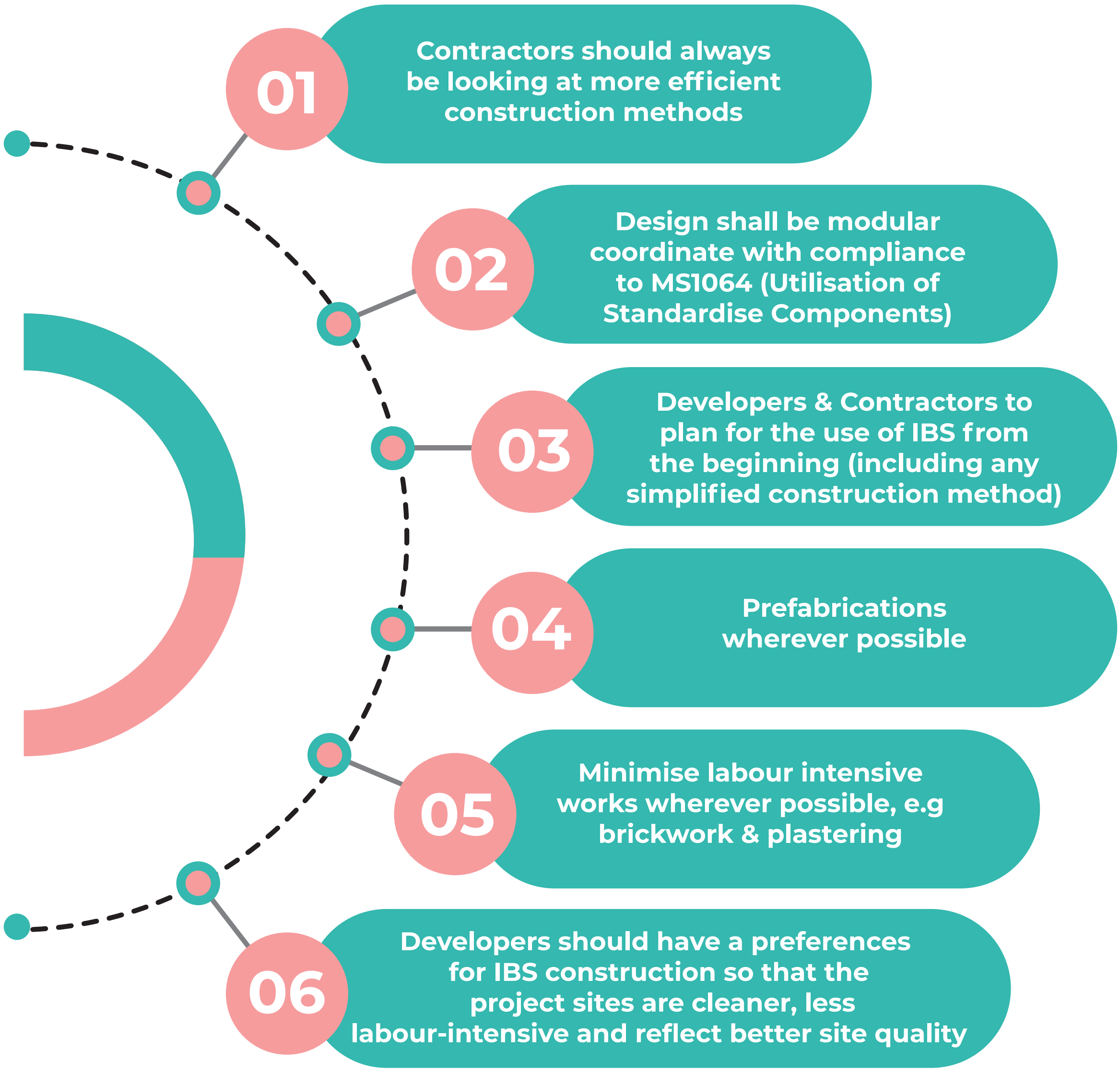


Figure 2.3. Methods of targeting Higher IBS Scoring

Source: CIS18:2018 (CIDB, 2018)

2.3 Productivity in Construction Industry

Based on the Asian Productivity Organisation and Malaysia's Productivity Corporation, productivity reflects the belief in human progress. It denotes a state of mind that aims at perpetual improvement. It is a ceaseless effort to apply new technology and methods for the welfare and bliss of mankind. It also indicates the training of the minds and the development of attitudes amongst people as a whole, which determines if a country can realise high productivity and an affluent life or otherwise, low productivity and poverty. Increment in market value stems from alteration in the form and location or availability of a product/service; excluding brought-in materials or services. Company wealth is generated by its own and the efforts of employees. Financial value may be generated by the internal activities of an enterprise in the process of production, which are embedded to the original raw materials purchased from outside.

Productivity has been gaining recognition as a major factor amidst multiple issues of the public concern, such as economic growth, inflation, distribution of income wage reform, and global competitiveness. Typically, productivity is defined as the ratio between output and input volumes. In precise, it measures how efficiently production inputs, such as labour and capital, are applied in an economy to generate a pre-determined output level. Productivity is a key source of economic growth and competitiveness, hence, is basic statistical information for numerous international comparisons and country performance assessments.

Productivity data, for example, have been used to examine the impacts of product and labour market regulations on economic performance. Productivity growth constitutes as a vital element to model the productive capacity of economies. It enables analysts to determine capacity utilisation, which in turn, allows one to gauge the position of economies in the business cycle, besides forecasting economic growth. Production capacity has been employed to assess demand and inflationary pressures.

> "Productivity is not everything, but in the long run, it is almost everything. A country's ability to improve its standard of living over time depends almost entirely on its ability to raise its output per worker."
>
> (Krugman, 1994)

The following are some case studies on productivity comparison between IBS and conventional construction carried out by CREAM and CIDB in 2017.

2.3.1 Storey Cluster House at Indah Heights, Skudai, Johor

The case study for performance comparison between IBS and conventional construction was provided by Kimlun Group. The building is a three-storey cluster house (see Figure 2.4) located at Indah Heights – a residential housing development in Skudai, Johor.

Skudai is located 8 km, 4 km, and 16 km from Kulai, Senai, and Johor Bahru city, respectively. It is a rapidly expanding suburb of Johor Bahru, wherein part of it is located in the new corridor of southwest Johor, including the Senai International Airport, the Tanjung Pelepas Port, and Bandar Nusajaya; the proposed administrative capital of Johor. The population of Skudai ranges from 160,000 to 210,000. It is the headquarters of the Johor Bahru Central Municipal Council and home to Universiti Teknologi Malaysia (UTM) campus.

Figure 2.4. Building for Comparison Study

Indah Heights has 45 acres of prime land and is host to a collection of three-storey Semi-D, cluster, and bungalow homes. The cluster house assessed in the case study derived from phase 2B, where there are 60 units of three-storey cluster house with standard land size, a built-up area of 38’ x 70’, and 3,280 sq. ft. Table 8 lists the specifications of the three-storey cluster house.

At the latter stage after the market was confirmed, 48 units (B-01 to B-12) were constructed with IBS. To note, the in-situ units C1, C2, and C3 refer to Semi-D. This case study offers a good comparison between conventional and IBS construction, primarily because all the units are located within the same area, subject to the same environmental factor, and managed by the same administration and management.

Table 2.5. The Specifications of the three-Storey Cluster House

Structure	Reinforced concrete frame	
Walls	Concrete wall/Brick wall with skim coat and cement plaster finished	
Roofing Tile	Concrete roof tiles	
Roofing Structure	Galvanized steel structure/Reinforcement concrete roof	
Ceiling	Gypsum plaster board/Skim coat finished	
Windows	Alumunium framed glass windows	
Doors	Solid timber door/Timber flush door/Alumunium framed sliding glass door	
Lock	Selected quality locksets	
Sanitary fittings	Selected quality sanitary wares	
Staircase	R.C. Staicase with ceramic tiles finished	
Ironmongery	Quality Locksets	
Floor Finishes	Foyer/Living/Dining/Meals/Bedroom 5/Utility/Kitchen/car Porch Balcony/Driveway/Patio/Lifestyle Deck	Homogeneous tiles
	Bedroom 1,2,3,4/Family area/Study room	Timber Finished
	Closet	Tile Finished
	All bathrooms	Porcelain tiles
Wall Finishes	All Bathroom - Wall tiles to ceiling height Kitchen - Wall tiles to ceiling height Other Areas - Skim coat/Cement Plaster & Paint	
Electrical Installation	13 Amp Power Point	34
	Lighting Point	39
	Telephone Outlet Point'	3
	TV Outlet Point	3
	Ceiling Fan Point	9
	Air conditioner Point	6
	Heater Point	3
	Bell Point	1
	Auto Gate Point	1
	Gate Light Point	2
Gate	M.S. gate with brick pier c/w letter box	
	1650mm high mild steel/brick fence	

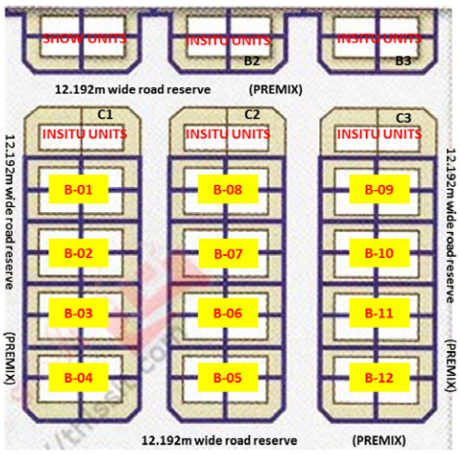


Figure 2.5. Detailed Site Plan of Indah Heights Phase 2B

Table 2.6 presents the differences between conventional and IBS construction of three-storey cluster house at Indah Heights Phase 2B, in terms of (i) construction period, (ii) number of labourers, (iii) machinery, (iv) quality, (v) material wastage, and (vi) feedback from purchasers. The comparison only looked into on-site construction work, while excluding work done in the factory.

Table 2.6. Comparison between Conventional and IBS Construction

Description	Conventional	IBS
Gross Floor Area (GFA) for one unit of 3 storey cluster house	304.86m^2 (3281 ft^2)	304.86m^2 (3281 ft^2)
Construction period		
Structure (superstructure) *Archi (i.e brickwork, plastering, skim coat, door/window installation, tiling, painting*	8 weeks 19 weeks	6 weeks 12 weeks
Number of labour		
Carpenter *Barbender* *Concretor* *Installer* *Labour for architectural work*	15 7 10 - 47	10 5 10 5 26
Machinery	Mobile crane for concreting	Mobile crane and crawler crane for concreting and the installation of precast panel
Quality (QA/QC Assessment)	80%	80%
Material wastage	11%	3%
Feedback from purchasers	- Wall finishing got hair line crack - Painting off white - Easy renovation - Got water seepage	- Smooth wall finishing - Wall tile hollow - Limited tile hollow - Got water seepage

One of the key drivers to use IBS is reduction of construction build time. The IBS project has been proven to complete faster, when compared to the conventional construction project due to the use of standardised components and simplified construction process. The use of large structural panels speeds up the structural work, thus enabling other work (e.g., painting, electrical wiring, and plumbing) to start sooner. Table 2.6 portrays the structural work of constructing a block or four units of three-storey cluster houses that took eight weeks for conventional construction, while only six weeks for IBS with use of precast panel and slab system. Certain parts of the house, such as staircase and topping, were constructed using the conventional method. Much time was saved in architectural work, mainly because the IBS construction joint section was the only part grouted that eliminated the requirement of plastering. Besides, less brick work was required for IBS-constructed houses, as the internal partitions were mostly precast panel that only necessitated skim coat for finishing. In the case of conventional construction, longer build time was taken for architectural work as it involved brickwork, plastering, skim coat, door/window installation, tiling,

and painting. Therefore, IBS construction is sure to save valuable time and minimises the risk of project delay or possible monetary losses.
Two Units of Apartment (1000SF/Unit)

Setia Precast conducted a case study for productivity comparison between IBS and conventional construction. The case study featured two units of apartment (1,000 sqft each) using precast column, beam, and panel. Referring to Table 2.7, which lists the comparison outcomes, a 40% reduction of labour intensity was noted from 108 man-days required for CIS construction to 65 man-days for pre-cast construction.

Table 2.7. Productivity Comparison between CIS and Pre-Cast Construction Methods

Conventional			
Column (23 Nos)	Carpenters	9p x 1 day	9MD
	Bar Benders	7p x 1 day	7MD
	Concretors	5p x 0.5 day	2.5MD
Beam/Slab (174MR/185m²)	Carpenters	9p x 3 day	27MD
	Bar Benders	7p x 2 day	14MD
	Concretors	5p x 0.5 day	2.5MD
Brickwalls/Plastering (174MR/185m²)	Brickwall	6p x 3 days	18MD
	Plasters (Ext & Int)	8p x 3 days	24MD
M&E Works	Electrician	4p x 1 day	4MD
		Total	**108MD**
IBS			
Production (52m3 - 2units/day)	Mould setting rebar setting concreting, manson, touch-up panel dispatch	30p x 1 day	30MD
Panel transportation (65pcs - 2units/day)	Trailer operators	3p x 1.5 day	4.5MD
Panel erection (65pcs - 2units/day)	Foreman, Rigger, Installer, Welder, Mortar setting	8p x 1.5 day	12MD
Typical floor slab (185m² -3days)	Carpenters	5p x 1.5 day	7.5MD
	Rebar	4p x 1 day	4MD
	Concretors	6p x 0.5 day	3MD
Sealant (2units/day)	Sealant applicators	2p x 1 day	2MD
Electrician (at PC Yard)	Semi skill workers	2p x 1 day	2MD
		Total	**65MD**

2.4 Study on Cost Comparison between IBS Method and Conventional Method in Malaysian Construction Industry

The IBS may be classified into several types based on country. Each country has different types and terms for IBS. In Malaysia, IBS is a construction method that can upgrade the quality and the productivity of the construction work through use of better or less machineries, equipment, materials, and extensive project planning. The five types of IBS commonly used in Malaysia for structural elements (e.g., wall, roof truss, beam, column, and slab) are precast concrete, reusable formwork, steel framing, prefabricated timber framing, and block work systems.

Nevertheless, only a handful of contractors in Malaysia prefer using the IBS method in their construction projects due to the barriers of executing the IBS. One of the barriers for IBS implementation in Malaysia faced by most of the construction industry players refers to the negative thought that IBS implementation is cost ineffective, when compared to conventional method. Table 2.8 presents a comparative study between IBS and conventional methods for school, residential, and institutional construction projects in Malaysia.

Table 2.8. Comparison study between IBS and conventional methods that focused on school, residential, and institutional construction projects in Malaysia

Case study	Research method	Construction components/ measurement	Result	Researcher
School project	1. Technical data collection 2. Questionnaire surveys	Half slab -IBS Slab structure-Conventional	- IBS resulted in better reduction than conventional - Floor Slab-11.9%	Ramli, Hanipah,Zawawi, etc. (2006)
School project	1. Elemental Cost Analysis technique. 2 Interview session	Measure on cost, time and improvement in construction productivity	Improved productivity and quality, rapid construction time for completion, and managed to complete within cost of the projects	Aziz.Z (2012)

Residential project and institutional building	1. Case studies 2. Questionnaire Survey	T test analysis	Significant difference of cost saving for the conventional system as compared to the IBS method	Haron, (2002)
Residential project	1. Questionnaire survey -100 respondents	Analysis of variance (ANOVA)	- 22 workers for conventional, while 18 workers for IBS - The cycle time of 17 days per house for conventional system, but only four days for IBS	M.r.Abdul Kadir, W.P.Lee, M.S.Jaafar (2006)
Residential project-Pulau Pinang	1. Physical layout measurement 2. Questionnaire survey	Waste index Timber Steel bar Miscellaneous Tiles Mortar Concrete Brick	The hierarchy of different types of waste produced by both sites are similar. The two most generated wastes are steel and timber. Tiles, mortar, concrete, and miscellaneous waste are almost equal in the perspective of the respondents.	H. M. Muhaidin, and H. B. Chan (2005)

The first case study that focused on school construction project was carried out to determine the cost comparison based on technical data collection and analysis between IBS (using half slab) and conventional method (slab structure). Additionally, the study captured the perceptions from the industrial players on IBS and conventional methods via questionnaire surveys. The outcomes revealed difference (in percentage) for both construction methods, whereby the percentage of reduction in cost for the calculated floor slab was 11.9%. This highlights that IBS offers a good reduction in cost, when compared to conventional system.

Malaysia's construction industry is experiencing a transitional change from a project-based industry to a more systematic and mechanised product-based technology, namely IBS. The IBS construction method can increase productivity and quality of work through use of systematic machinery, equipment, materials, and extensive pre-project planning. Nevertheless, cost impact has been a major barrier that hinders contractors to execute IBS. The perceived high cost of IBS solutions, unless balanced by an understanding of value, may result in continuous reluctance by the industry from adopting the IBS approach. Thus, good cost comparison data, as well as a holistic and thorough valued-based comparative system is required by the industry to highlight the true benefits of IBS for any project setting to support the decision making in opting IBS over conventional system. The construction cost of a building using IBS should look into its overall context of the product. Time saving is emphasised as well. If properly designed and executed, the precast method can generate better quality work. The overall cost impact of IBS construction should incorporate these factors. As such, the objectives of the second case study is to propose a comparative cost study of IBS versus conventional system for school building projects based on Elemental Cost Analysis. The study assessed the effectiveness of IBS school building projects in terms of cost, time, and improvement in construction productivity. The data were gathered from interviews. The case study concluded that although the building cost of IBS school project exceed that of the conventional system, IBS offered better quality in terms of productivity and quality, rapid construction completion time, as well as adherence to project cost.

The third case study compared building costs between conventional system and IBS (IBS A, IBS B, and IBS C). It gave detailed building cost to display cost savings between the two methods. Data were collected via questionnaire survey and case studies, which consisted of residential and institutional buildings. The t-test method was used. As a result, a significant difference of cost saving was noted for the conventional system, when compared to IBS.

The fourth case study looked into cost comparison between IBS and conventional methods using the Analysis of Variance (ANOVA). Labour usage is a critical element in Malaysia's construction industry due to severe shortage of local workers. Data were gathered from 100 residential projects via questionnaire survey in 2005. In total, 100 respondents participated in the study. The ANOVA results indicated that the actual labour productivity comparison between conventional and IBS systems significantly differed. Comparison of crew size indicated that the conventional building system of 22 workers significantly differed from the IBS of 18 workers. Similarly, the cycle time of 17 days per house for conventional system significantly differed from the four days for IBS. However, the conventional building system insignificantly differed from the IBS for structural construction cost. The study outcomes may be used by project planners to estimate labour input, control costs, and project scheduling. The results can also be used to determine the most appropriate structural building system for executing a construction project at the conceptual stage.

The rapid development of construction projects has generated volumes of construction wastes. This has become a concern to many parties involved in the construction industry. The fifth case study compared construction wastes produced by conventional method against IBS. The objectives of the study were to compare construction wastes produced by conventional method against IBS method, and to determine the hierarchy of wastes produced at sites. The objectives of the study was achieved through physical layout measurement and questionnaire survey. The study results indicated that IBS produced less waste than conventional method, wherein steel waste was more than timber waste.

The literature depicts that the IBS method is more effective than the conventional method. The IBS is an innovative process that applies mass-produced industrialised systems, incorporating both off-site and in-situ production in a controlled manner. It comprises of logistic and installation aspects by involving well-coordinated production aspects through systematic plans and integration (Kamar, 2009). Hence, the IBS is a building process composed of components, techniques, products, and building systems. The building systems comprise of processes of providing prefabricated building components and installation work, which are carried out at the construction site. A stakeholder may benefit vastly by implementing the IBS, when compared with in-situ conventional building systems.

According to Idrus (2008), IBS has been proven to be economical as it saves costs, reduces incompetent labour, minimises building materials, and is comparatively efficient, safe, and cleaner with improved quality. Bon and Hutchinson (2002) emphasised that IBS provides benefits that include enhanced building quality, long term profits, and satisfying customer demands in terms of affordability, comfort, and flexibility. The implementation of IBS has encouraged the production of good quality materials within shorter duration, as well as lower material and labour costs (Sadafi, 2012).

While IBS can increase both the productivity and efficiency in the construction industry, the main objectives are to enhance the overall quality of construction products and to reduce dependency on foreign labour in the context of Malaysia (Mohammad, 2009). The IBS implementation maintains a consistent level of quality in construction projects by meeting the demands of contractors and clients. The three main benefits of IBS implementation identified through the course of this study are increased construction site productivity, reduction in time for in-situ concrete mixing activities, and decreased overall construction duration. The common denominator among these three main benefits is the capability of IBS to reduce the timeframe for construction product completion. Concurrently, IBS implementation leads to better construction site environment with absence of massive in-situ wet concrete work. Clearly, the capacity of this industry may be enhanced by using the IBS approach.

The industry may generate better products that may be implemented in other industries and sectors. This, in turn, will spur a positive economic growth that benefits developing countries, such as Malaysia. The IBS significantly reduces the reliance on in-situ concrete mixing activities, which have long dominated the conventional methods, thus enabling contractors to complete their work in a better timeframe to the satisfaction of their clients.

CHAPTER 3

METHOD OF COMPARISON BETWEEN IBS AND CONVENTIONAL STUDY

CHAPTER 3

METHOD OF COMPARISON BETWEEN IBS AND CONVENTIONAL STUDY

3.1 Introduction

Primary data were gathered from case studies of single storey, double storey, and apartment units in Malaysia. The questionnaires were distributed to respondents, including consultants, developers, contractors, and manufacturers. The data were analysed using SPSS.

3.2 Case Study

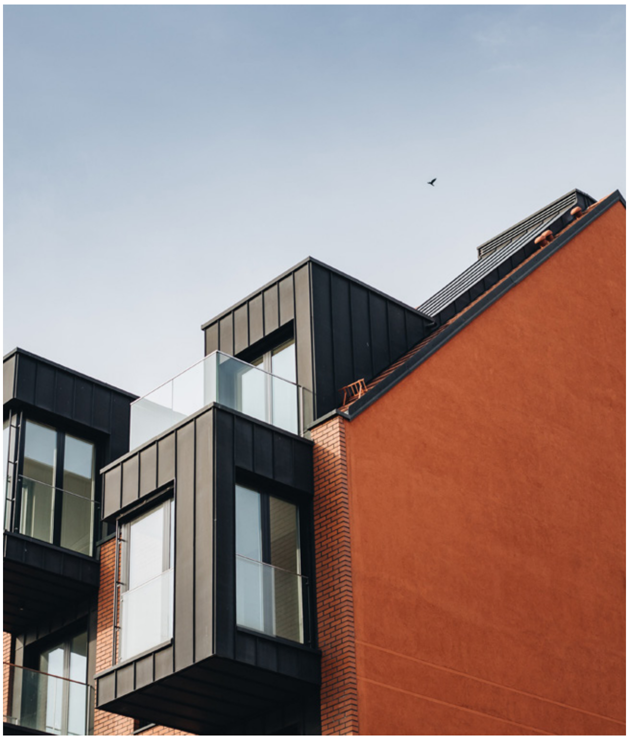
Case study refers to a method, methodology, or a research design (Bassey, 1999; Merriam, 1988; Orum, Feagin, & Sjoberg, 1991; Yin, 1994). It is used as a catch-all category for a range of research methods, methodologies, and designs; thus losing its meaning. Case study is a transparadigmatic and transdisciplinary heuristic that involves careful delineation of a phenomenon, for which evidence is collected (event, concept, programme, process, etc.). In this research work, the case study focused on residential construction in Malaysia involving single storey, double storey, and apartment (strata) units, as follows:

i) Single Storey: Rumah Mesra Rakyat 1 Malaysia (RMR1M)
ii) Double Storey: Avanti Residences Two-Storey House and Darul Hana
iii) Apartment: Pangsapuri Aurora Seksyen U17, Shah Alam

3.3 Questionnaire Survey

The survey method is a commonly used technique to gather information about a population of interest. The population may be composed of a group of individuals (e.g., children under age five, kindergarteners, parents of young children) or organisations (e.g., early care and education programmes, k-12 public, and private schools).

There are many different types of surveys, several ways to administer them, and varied methods to select the sample of individuals or organisations for participation. Some surveys collect information on all members of a population, while others collect data on a subset of a population. Examples of the former are the National Centre for Education Statistics Common Core of Data, as well as the Administration for Children and Families Survey of Early Head Start Programmes (PDF).



A survey may be administered to a sample of individuals (or to the entire population) at a single point in time (cross-sectional survey), or the same survey may be administered to varied samples from the population at different time points (repeat cross-sectional). Some surveys include the same sample of individuals at different time points (longitudinal survey). The Survey of Early Head Start Programme is an instance of a cross-sectional survey, while the National Household Education Survey Programme is a repeat cross-sectional survey. Instances of longitudinal surveys include the Head Start Family and Child Experiences Survey, and the Early Childhood Longitudinal Study, Birth and Kindergarten Cohorts.

Questionnaire—a predefined series of questions used to collect information from individuals.

Sampling—a technique in which a subgroup of the population is selected to answer the survey questions. Based on the sampling method, the gathered data may or may not be generalised to the entire population of interest.

In this present study, questionnaires were distributed to 300 respondents, including 60 developers and contractors each, 65 consultants and quantity surveyors (QSs) each, and 50 manufacturers.

3.3.1 Questionnaire Design

The two commonly used survey questions are closed-ended and open-ended questions.

i) Closed-Ended Questions

The respondents are given a list of predetermined responses from which to choose their answer.

The list of responses should include every possible response, and the meaning of the responses should not overlap.

A Likert scale is commonly used as the set of responses for closed-ended questions. Closed-ended questions are usually preferred in survey research due to the ease of counting the frequency of each response.

ii) Open-Ended Questions

Survey respondents are asked to answer each question in their own words. An example is as follows: “In the last 12 months, what was the total income of all members of your household from all sources before taxes and other deductions?” Another would be, “Please tell me why did you choose that particular childcare provider?”

A question may be either open-ended or close-ended, depending on how it is asked. In the previous instance, if the question on household income asked the respondents to choose from a given set of income ranges instead, it would be considered as a close-ended question.

In this study, close-ended questions were selected as the medium. The questionnaire was developed by incorporating the Likert scale to easily gather information from the respondents in comparing the IBS system with the conventional method in Malaysia’s construction industry.

CHAPTER 4

CASE STUDY DATA ANALYSIS AND FINDINGS: COST COMPARISON ON RESIDENTIAL HOUSING

CHAPTER 4

CASE STUDY DATA ANALYSIS AND FINDINGS: COST COMPARISON ON RESIDENTIAL HOUSING

4.1 Case Study

This present study explored several ongoing and completed projects throughout Malaysia. This was performed by engaging and collaboration with Syarikat Perumahan Negara Berhad (SPNB), Daya Builders Sdn. Bhd. and Johawaki Sdn. Bhd. to gain access to the cost taken for each project. The case studies were done hypothetically to achieve a better comparison. Four case studies were conducted for three types of houses which are single storey, double storey, and strata high rise. Each case study was compared between conventional and IBS methods.

The projects were selected based on the availability of suitable projects at the time of the study. The cost given for this case studies was included labour, materials and finishing cost, however this case studies only focus on the building cost. Hence, they should not be interpreted as representative of the cost of the overall project that includes cost of land ownership, cost of infrastructure, cost of sub-structure, IBS setup cost and IBS transportation cost. This is because of due to many variable factors which can be misinterpreted to the extent that one can conclude that the cost is a representative of the overall project cost.

4.1.1 Single-storey house

PROJECT A: RUMAH MESRA RAKYAT 1 MALAYSIA (RMR1M)

In this case study, the house is located at East region in Malaysia. This housing development consists of a unit rural bungalow single storey. Under the development of Syarikat Perumahan Negara Berhad (SPNB), it an initiative taken by the government to provide affordable houses for low income group. It was built using the conventional method in July 2017.

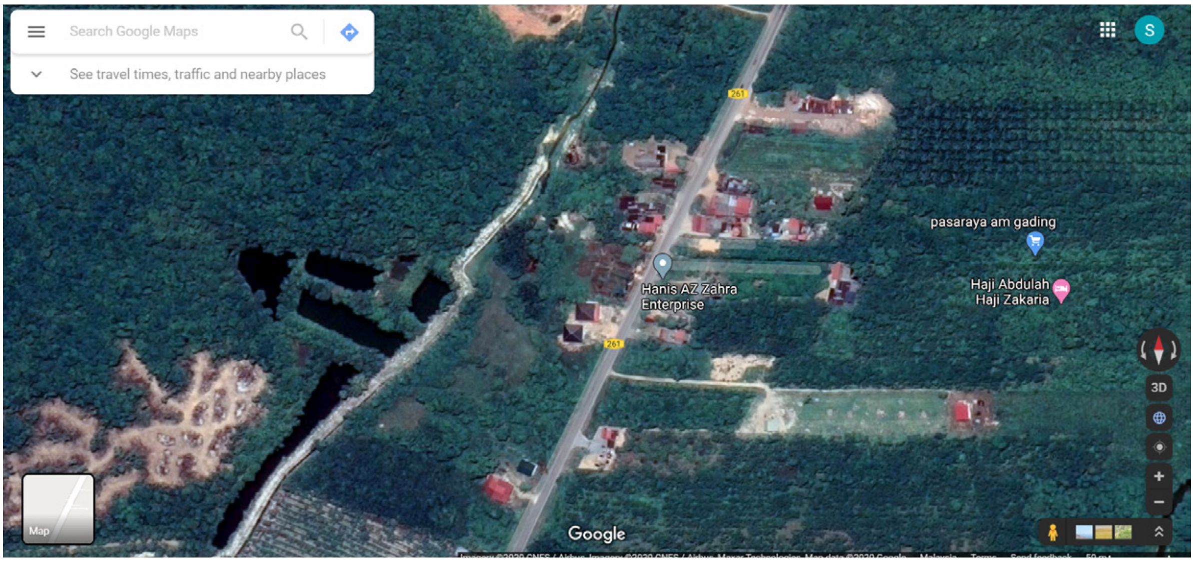


Figure 4.1. Location of SPNB house (Google Map)

A single unit with 1000 sqft consist of three bedrooms and two bathrooms. The total building cost for a unit was RM 50,800.00. The structural cost for this building was RM 12,700.00 Using conventional reinforced concrete frame, in comparison to precast that amounted to RM 17,000.00 using precast wall panel. This shows that the precast wall higher by 25.29%.

For architectural work, the cost for conventional was RM 13,600.00 while RM 8,500.00 for precast wall which is 60% lower. Thus, the total cost using precast was lower by 1.60% which was RM 50,000.00 when compared to RM 50,800.00 for conventional.

Table 4.1. Comparison of conventional and precast methods

Item	Precast wall	Conventional	Comparison (Precast wall vs Conventional)	Percentage Comparison
Structural	RM17,000.00	RM12,700.00	RM4,300.00	25.29%
Architectural	RM8,500.00	RM13,600.00	-RM5,100.00	-60.00%
Total	RM25,500.00	RM26,300.00	-RM800.00	-3.14%
Total Cost per unit (including door, window, electrical and fittings)	RM50,000.00	RM50,800.00	-RM800.00	-1.60%

Additionally, various IBS systems were executed such as IBS blockwork and IBS blockwork load bearing wall as listed in the following table. As for blockwork, the structural cost was RM 4,445.00 higher than that for conventional, whereas the cost for architectural was slightly higher by RM 354.06 when compared to conventional. Thus, the total cost of blockwork for IBS was RM 4,799.06 higher than that for conventional.

Table 4.2. Comparison of conventional and Blockwork

Item	IBS Blockwork	Conventional	Blockwork Load Bearing Wall	Comparison (IBS Blockwork vs Conventional)	Comparison (Blockwork Load Bearing Wall vs Conventional)
Structural	RM17,145.00	RM12,700.00	RM17,000.00	RM 4,445.00	RM 4,300.00
Architectural	RM13,954.06	RM13,600.00	RM8,500.00	RM 354.06	-RM 5,100.00
Total	RM31,099.06	RM26,300.00	RM25,500.00	RM 4,799.06	-RM 800.00
Total Cost per unit (including door, window, electrical and fittings)	RM55,599.06	RM50,800.00	RM50,000.00	RM 4,799.06	-RM 800.00

On the other hand, IBS blockwork load bearing wall for structural was RM 4,300.00 higher than that for conventional. For architectural, the blockwork load bearing wall was RM 5,100.00 lower than the conventional system. As a result, the total cost for blockwork load bearing wall was slightly lower by RM 800 when compared to the conventional system.

4.1.2 Double-storey house

PROJECT B: AVANTI RESIDENCES TWO-STOREY HOUSE

Figure 4.2. Avanti Residence

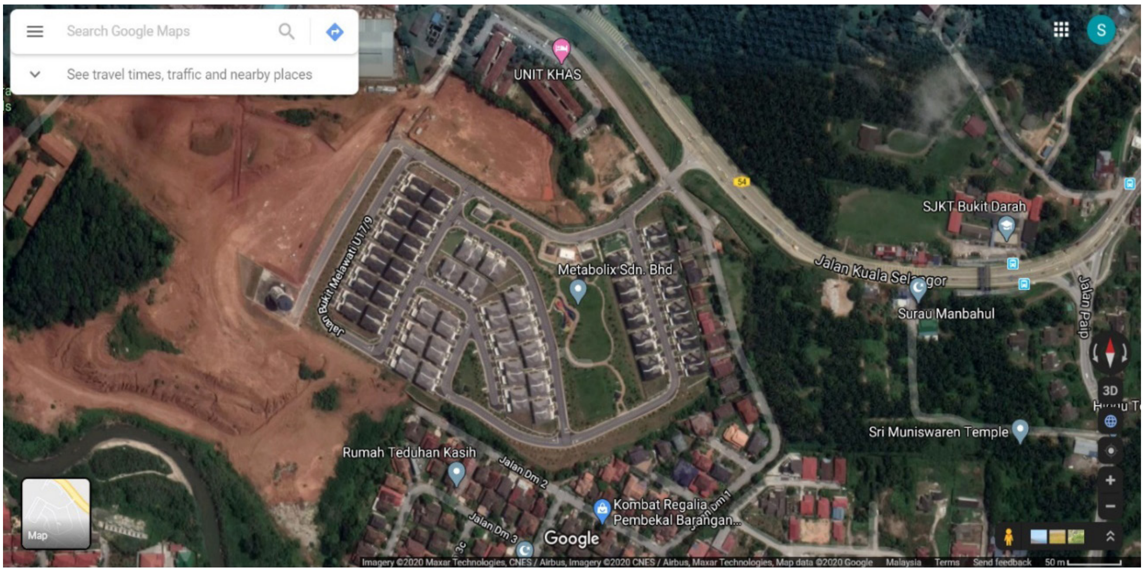


Figure 4.3. Location of Avanti Residence (Google Map)

Avanti is a semi-detached double-storey house that has a built-up size of 2,750 sqft with a total of 84 units. It has six bedrooms and five bathrooms. Using the conventional method with a build-up cost of RM 320,000 per unit, Avanti was developed by Johawaki Development located at USJ 19 Shah Alam.

The conventional method for structural was RM 49,351.95 while the precast wall method was RM 70,244.26, the conventional was 29.74% lower. As for architectural cost, RM 28,383.30, and RM 60,034.00 for precast wall and conventional systems, respectively making conventional 111.51% higher when compared to precast wall. In conclusion, the total cost for conventional was RM 347,371.20 per unit, while RM 336,612.81 per unit for precast wall, thus making the conventional unit more expensive by 3.20% than precast wall.

Table 4.3. Comparison of conventional and precast systems (Avanti Residence)

Item	Precast	Conventional	Comparison (Precast vs Conventional)	Percentage/ Precast	Percentage/ Conventional
Structural	RM70,244.26	RM49,351.95	RM20,892.31	29.74%	-24.48%
Architectural	RM28,383.30	RM60,034.00	-RM31,650.70	-111.51%	-52.72%
Total Saving	RM98,627.56	RM109,385.95	-RM10,758.39	-10.91%	-39.98%
Total Cost per unit (including door, window, electrical and fittings)	RM336,612.81	RM347,371.20	-RM10,758.39	-3.20%	-12.59%

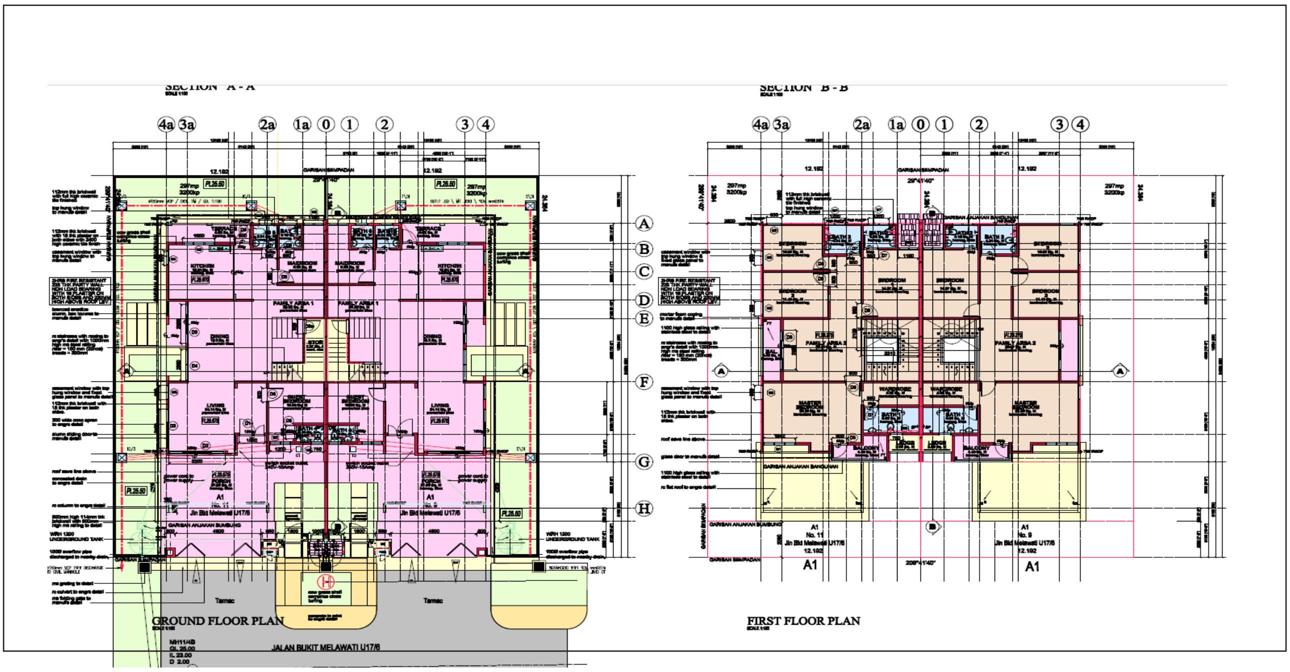


Figure 4.4. Typical layout for Avanti Residence

PROJECT C: DARUL HANA TWO-STOREY HOUSE

Figure 4.5. Darul Hana two-storey house

The 60 units of double-storey house located at Jalan Sultan Salahuddin, Kuching, were assessed in this study, which had been built using the precast wall method under Daya Builders Sdn. Bhd. which is one of the Sarawak state Government-Link Companies (GLC). The Darul Hana development has a 1,406 sqft with a build-up cost of RM 160,000.00 consist of three bedrooms and two bathrooms.

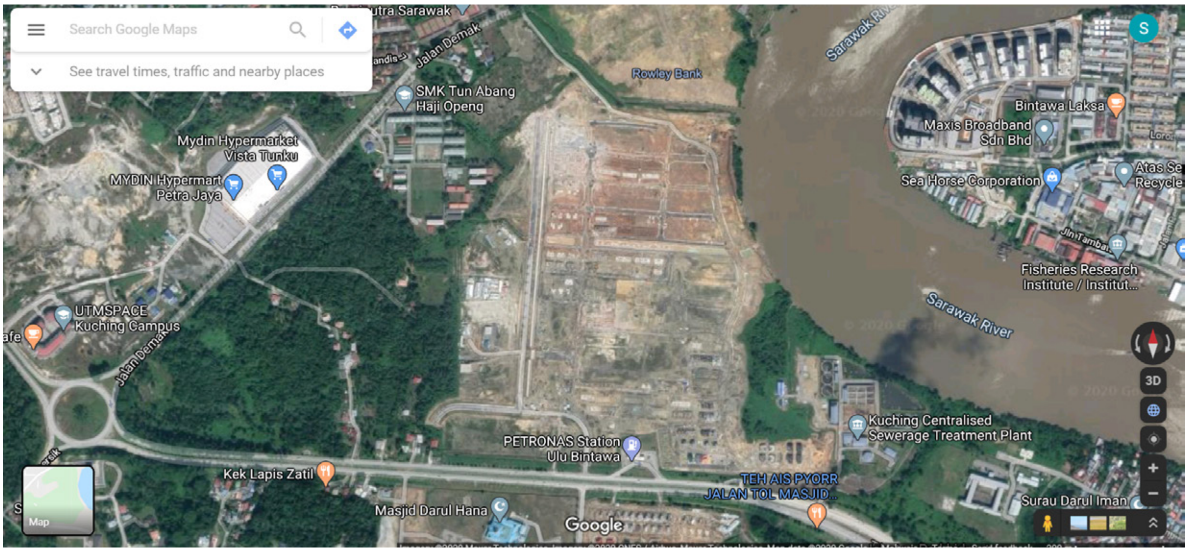


Figure 4.6. Location of Darul Hana development (Google Map)

Darul Hana is located at Kuching, Sarawak which is northwest Borneo Island. This development has completed two phase of the project using conventional method. However, the third phase of this project will be using IBS which is now at the construction stage.

Figure 4.7. Typical layout for Darul Hana

Table 3.2 shows that the precast wall on the structural part was 3.44% higher (RM 49,073.87), when compared to the conventional method (RM 47,388.00). As for the architectural part, the cost for precast wall was 38.17% lower than that of conventional at RM 19,137.00 and RM 26,442.00, respectively. Hence, the total cost for precast wall was lower than that of conventional by 3.51%, given RM 160,000.00 for precast wall and RM 165,619.13 for conventional.

Table 4.4. Comparison of conventional and precast (Darul Hana)

Item	Precast wall	Conventional	Comparison (Precast wall vs Conventional)	Percentage Comparison
Structural	RM49,073.87	RM47,388.00	RM1,685.87	3.44%
Architectural	RM19,137.00	RM26,442.00	-RM7,305.00	-38.17%
Total	RM68,210.87	RM73,830.00	-RM5,619.13	-8.24%
Total Cost per unit **(including door, window, electrical and fittings)**	RM160,000.00	RM165,619.13	-RM5,619.13	-3.51%

4.1.3 Strata high-rise residential

PROJECT D: PANGSAPURI AURORA SEKSYEN U17, SHAH ALAM

Aurora, which is located at Seksyen U17 in Shah Alam, is a local government initiative that offers affordable house through the Rumah Selangorku programme under the Johawaki development. At present, it is at the tender stage using conventional method for 90 units with a built-up size of 800 sqft per unit.

Figure 4.8. Pangsapuri Aurora

Figure 4.9. Typical layout for Pangsapuri Aurora

As the project is still under the tender stage at the time of this study, the overall cost was estimated. This constrain has limited the case study for undergoing the cost by element part. However, the cost was estimated in consideration that IBS would be implement for this project. The cost for conventional may reach RM 5,057,778.90 for overall development of this project, while RM 5,004,432.65 using precast wall. Hence, the precast wall is 1.07% lower than the conventional method.

Table 4.5. Comparison of conventional and precast (Pangsapuri Aurora)

Item	Precast wall	Conventional	Comparison (Precast wall vs Conventional)	Percentage Comparison
Total Cost (including door, window, electrical and fittings)	RM5,004,432.65	RM5,057,778.90	-RM53,346.25	-1.07%

4.1.4 Conclusion

The four case studies illustrated the cost comparison between IBS method and conventional method. The Malaysian construction industry is experiencing a shift from conventional to IBS, though it is not fully exploit especially in housing development due to cost impact.

Based on this case studies, all the structural parts, the cost indicates IBS method is higher compare to conventional method. This is because most of the IBS method uses more concrete and reinforcement in comparison to the conventional method that only designed in frame to minimise the usage of concrete and reinforcement. As for the architectural part, except for the IBS blockwork in Seroja, the IBS method displayed lower cost than the conventional method did. The conventional system used of brick wall and plaster finish, while IBS had already consisted of wall panel for structural and finish with a layer of skim coat, thus indicating significant cost reduction for architectural part. Although this have not been captured on this research, but the IBS method also can minimal up to almost 0% of wastage which have been a common problem for using a conventional method which eventually give a significant cost impact for the whole project. The overall cost indicate that IBS method is lower than the conventional method except for blockwork system in Seroja which was vice versa. In conclusion, the total cost of building can be reduced through the execution of the IBS method. Hence, the IBS method should be implemented by all developers in Malaysia to benefit all parties.

CHAPTER 5

QUANTITATIVE DATA ANALYSIS AND FINDINGS: PERSPECTIVE FROM STAKEHOLDERS ON COST COMPARISON

CHAPTER 5

QUANTITATIVE DATA ANALYSIS AND FINDINGS: PERSPECTIVE FROM STAKEHOLDERS ON COST COMPARISON

5.1 Introduction

This chapter presents the study outcomes. The profile of the respondents is presented to support the data gathered from 300 respondents comprising of developers, manufacturers, consultants, and contractors. All the respondents had more than a decade of experience in the construction domain.

5.2 Questionnaire Survey

5.2.1 Response Rate

Three weeks were taken to disseminate the questionnaires to 300 respondents (see sample in Table 5.1). The respondents were composed of managers, executives, engineers, and technicians. The managers included Design Managers, Construction Managers, Technical Managers, and Project Managers.

Table 5.1. List of Respondents

Respondent	No. of respondents
Developer	60
Manufacturer	50
Consultant	65
Contractor	65
Quantity Surveyor	60
Total	**300**

Reliability Statitstics

Cronbach's Alpha	N of Items
.923	43

Table 5.2. Cronbach alpha

Referring to Table 5.2, the alpha coefficient for the four items was .923, reflecting that the items have relatively high internal consistency. The reliability coefficient of .70 or greater is considered as "acceptable" in most social science research studies. The Cronbach's alpha determines the reliability of multiple-question Likert-scale survey. A "high" value for alpha does not imply that the measure is unidimensional. After that, exploratory factor analysis was employed to ascertain the aspect of dimensionality. It is noteworthy to highlight that Cronbach's alpha is not a statistical test, but merely a coefficient of reliability (or consistency).

5.2.2 View of Respondents on Cost Comparison

The respondents were comprised of architects, assistant managers, civil engineers, design engineers, construction officers, engineer consultants, managers, site supervisors, drafters, quality surveyors, and others. The respondents claimed to have working experience in the construction industry from 5 to 20 years.

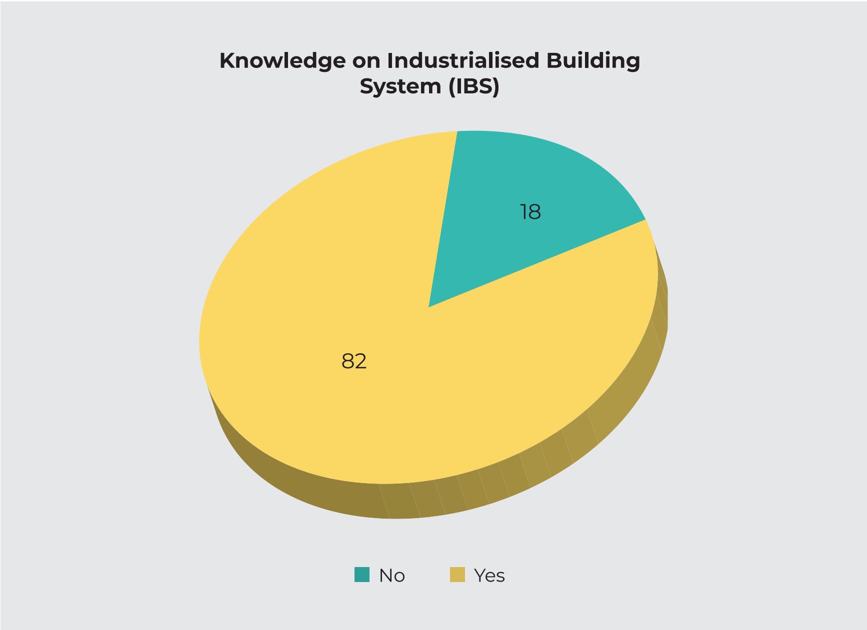


Figure 5.1. Knowledge on Industrialised Building System (IBS)

Figure 5.1 illustrates that 82% of the respondents knew about IBS in the construction sector, while 18% of the respondents were clueless about IBS.

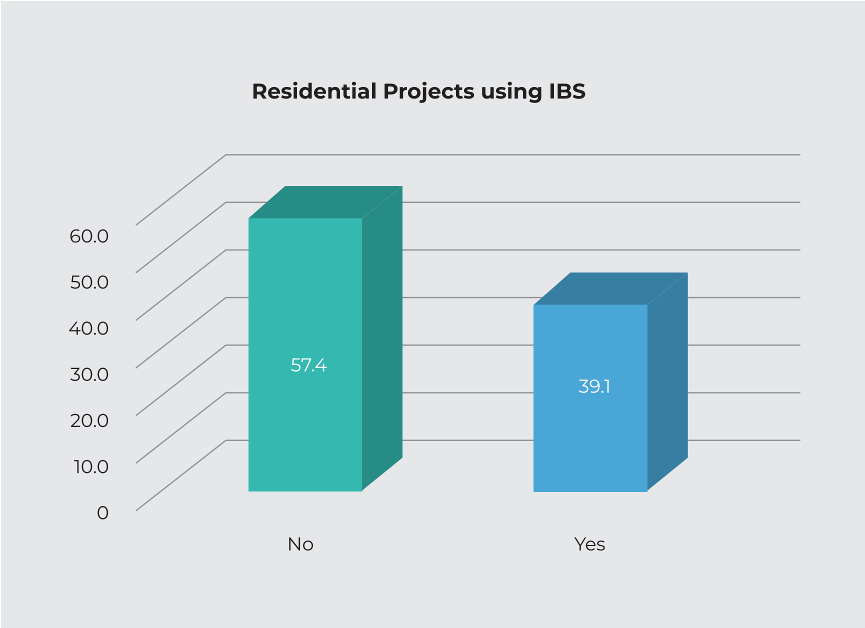


Figure 5.2. Residential Projects using IBS

Figure 5.2 displays the distribution of residential projects using IBS in the construction industry. In total, 39.1% of the residential projects implemented IBS, while 57.4% used conventional method. This showed that most respondents were unfamiliar with IBS method.

Figure 5.3. Number of Residential Projects using IBS

About 51% of the residential projects had used IBS 1-10. The second highest percentage was 23.5% with 21-30 projects had executed IBS. Next, 17.6% denoted 11-20 projects using IBS, while the lowest was more than 31 projects (7.8%).

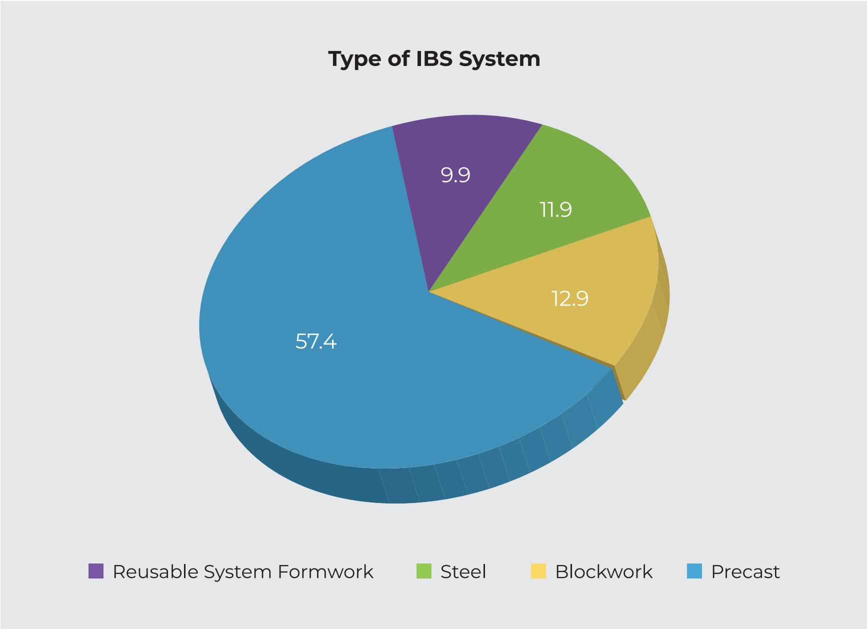


Figure 5.4. Type of IBS System

Figure 5.4 displays that the types of IBS system used in residential projects were reusable, formwork, steel, blockwork, and precast systems. The highest type of IBS system was precast with 57.4%, whereas the lowest type was reusable system formwork with 9.9%. Blockwork system was essential at 12.9%, while 11.9% was recorded for steel system.

Table 5.3. Previous Projects using the IBS System

	IBS System	Percentage	Frequency
1.	Precast load bearing wall system	15%	37
2.	Precast frame system	15%	20
3.	Reusable system framework	15%	19
4.	Steel framing system	15%	19
5.	Blockwork	15%	23

Table 5.3 presents the previous projects using IBS system, including Precast load bearing wall system, Precast frame system, Reusable system framework, Steel framing system, and Blockwork. All the IBS systems recorded the same percentage, which was 15%. The highest frequency was precast load bearing wall system with 37, while blockwork was 23. Reusable system framework and Steel framing system exhibited the same frequency - 19.

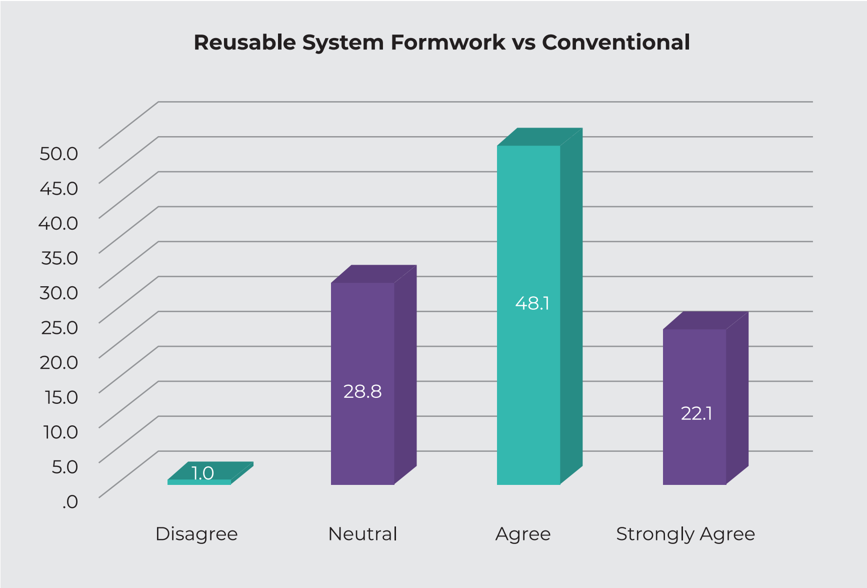


Figure 5.5. Reusable System Formwork Vs Conventional (Time)

Figure 5.5 illustrates reusable system formwork versus conventional method. The respondents agreed (48.1%) that the reusable formwork system could save more time than did the conventional method, while 22.1% strongly agreed to the statement. However, only 1% of the respondents disagreed with the statement that reusable system formwork saves more time, when compared to the conventional system.

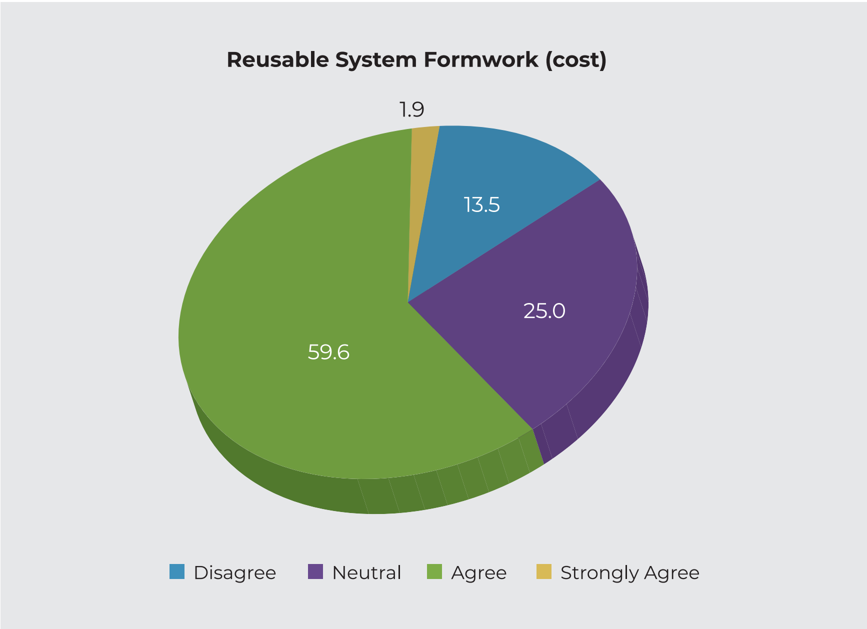


Figure 5.6. Reusable System Formwork Vs Conventional (Cost)

Figure 5.6 shows reusable system formwork versus conventional method. About 59.6% of the respondents agreed that reusable formwork system saves more cost than conventional method, while 1.9% and 13.5% strongly agreed and disagreed that the statement.

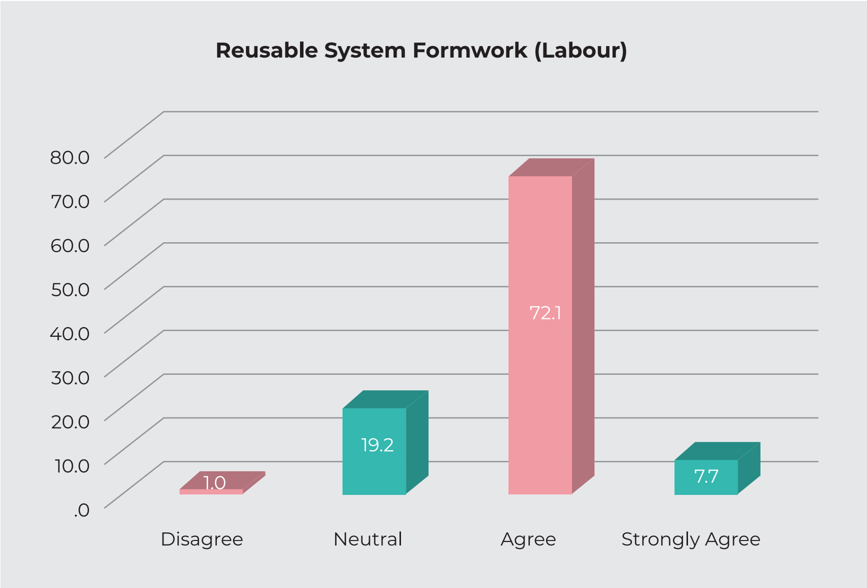


Figure 5.7. Reusable System Formwork Vs Conventional (Labour)

Figure 5.7 shows the reusable system formwork versus the conventional method. In total, 72.1%, 7.7%, and 1.0% of the respondents agreed, strongly agreed, and disagreed, respectively, with the statement that reusable formwork system saves more labour than does the conventional method.

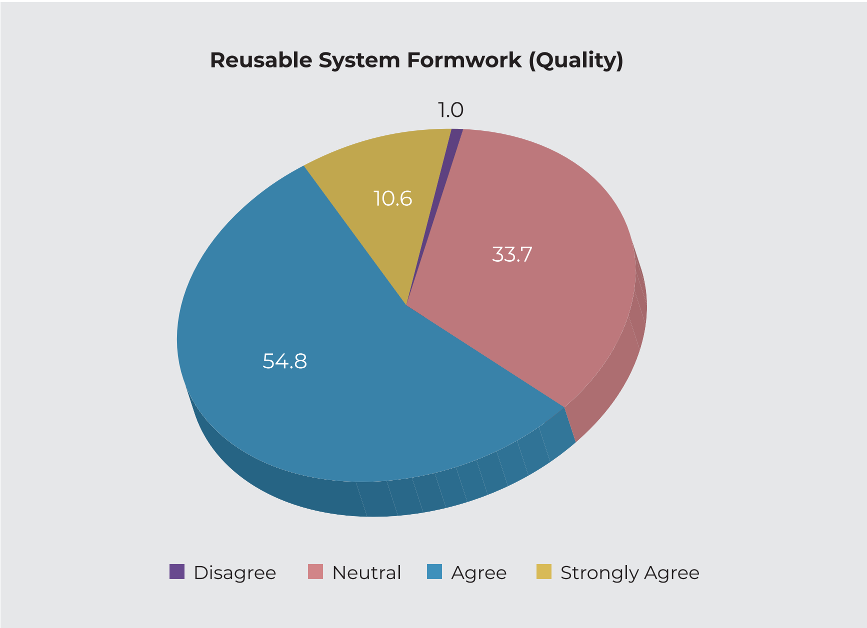


Figure 5.8. Reusable System Formwork Vs Conventional (Quality)

Figure 5.8 portrays reusable system formwork versus conventional method. About 54.8% of the respondents agreed that reusable formwork system generates better quality than conventional method, while 33.7% and 1.0% strongly agreed and disagreed, respectively, with the statement.

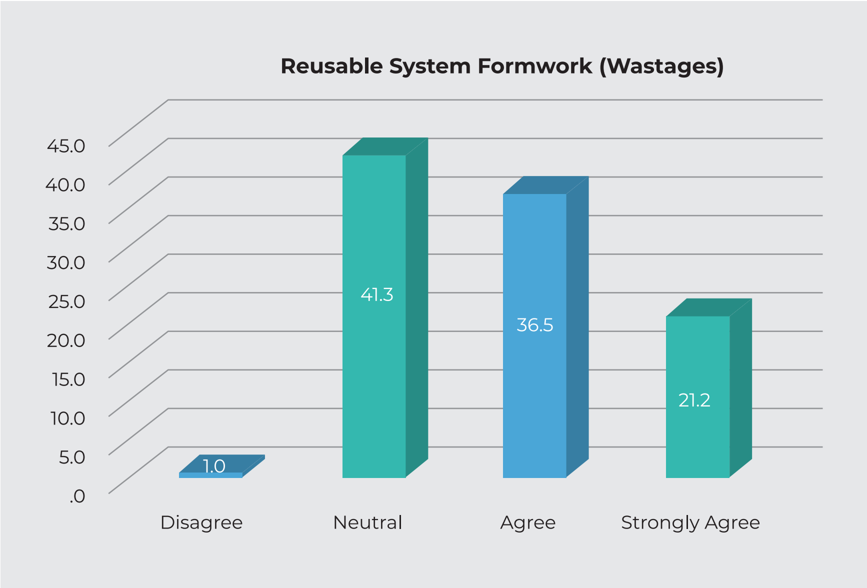


Figure 5.9. Reusable System Formwork Vs Conventional (Wastages)

Figure 5.9 shows reusable system formwork versus conventional method. About 36.5% and 21.2% of the respondents agreed and strongly agreed, respectively, that reusable formwork system can better hinder wastage than the conventional method. Most of the respondents were neutral at 41.3%, while 1.0% of the respondents disagreed with the statement.

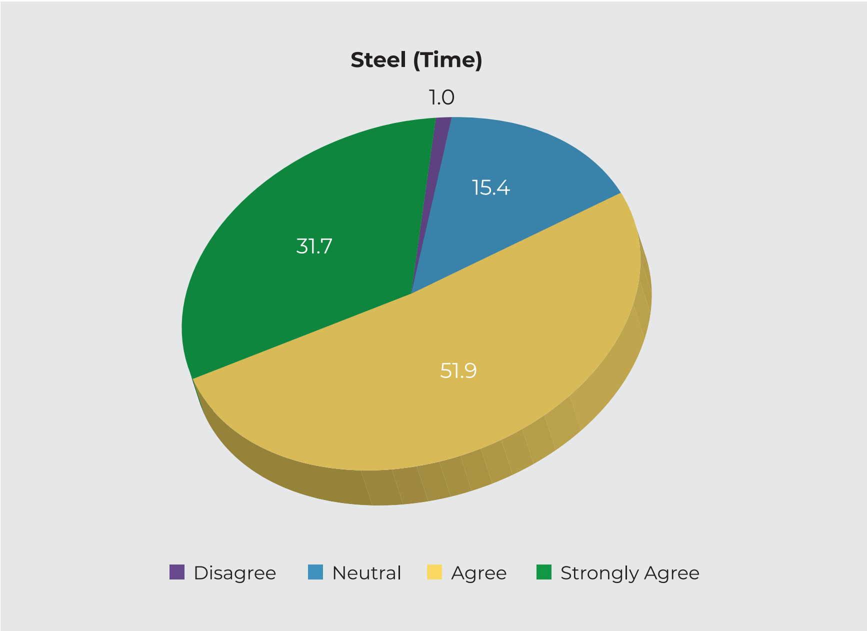


Figure 5.10. Steel Vs Conventional (Time)

Figure 5.10 presents steel system versus conventional method. In total, 51.9% and 31.7% of the respondents agreed and strongly agreed that the steel system can save more time than the conventional method. Meanwhile, 1.0% of the respondents disagreed with the statement.

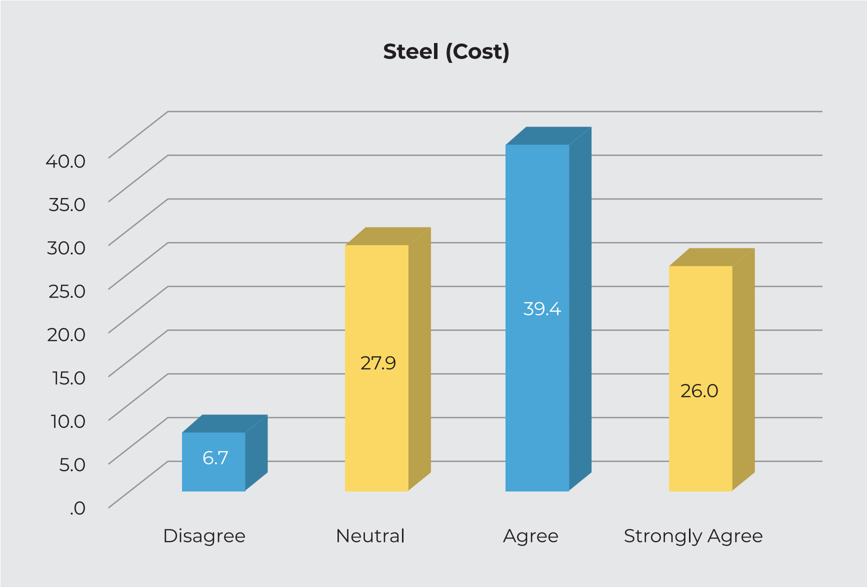


Figure 5.11. Steel Vs Conventional (Cost)

Figure 5.11 shows steel system versus conventional method. Most of the respondents (39.4%) agreed that steel saves more cost than conventional method, while 26.0% and 6.7% strongly agreed and disagreed, respectively, with the statement.

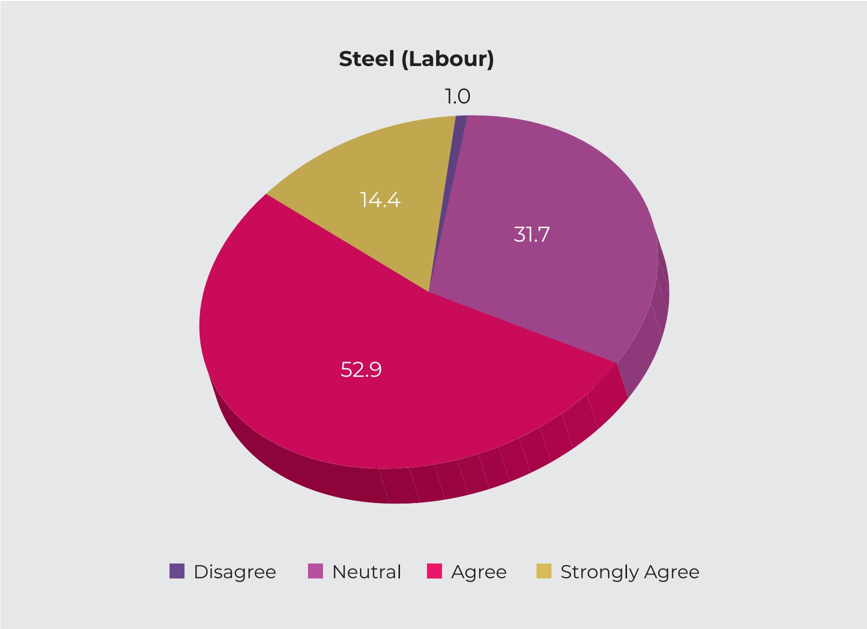


Figure 5.12. Steel Vs Conventional (Labour)

Figure 5.12 shows steel system versus conventional method. In total, 52.9% and 14.4% of the respondents agreed and strongly agreed, respectively, that steel saves more labour cost than conventional method, whereas 1.0% disagreed with the notion.

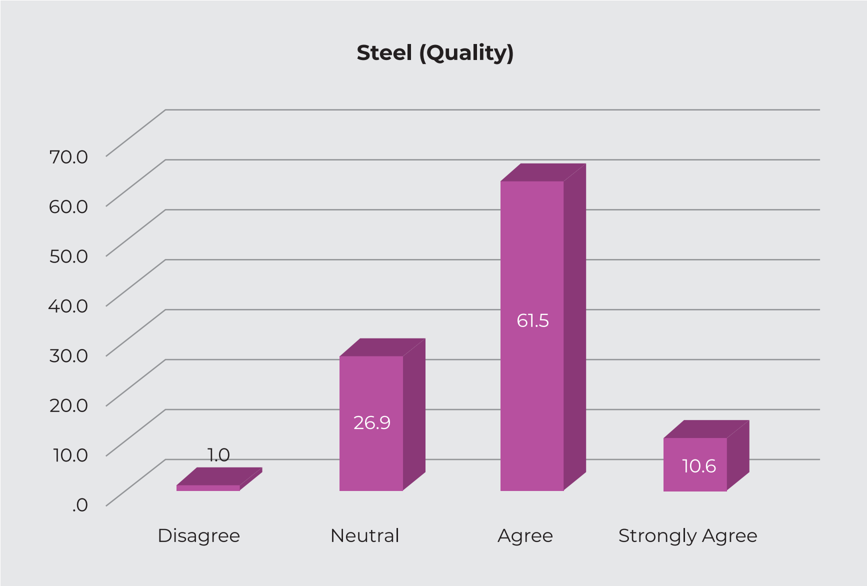


Figure 5.13. Steel Vs Conventional (Quality)

Figure 5.13 shows steel system versus conventional method. Respondents who agreed that steel offers better quality than conventional method were 61.5%, whereas 10.6% and 1.0% strongly agreed and disagreed, respectively, with the statement.

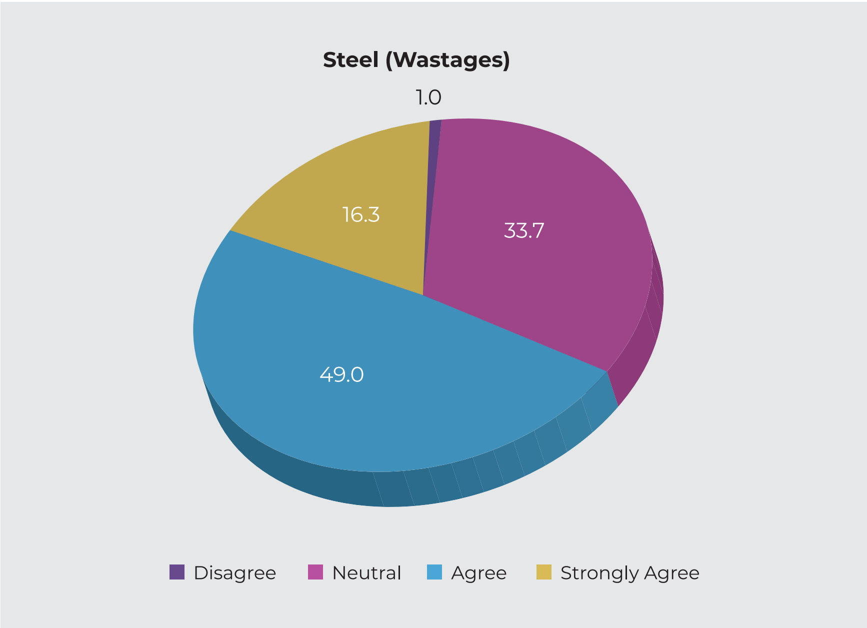


Figure 5.14. Steel Vs Conventional (Wastages)

Figure 5.14 shows steel system versus conventional method. About 49.0% and 33.7% agreed and strongly agreed that steel prevents more wastage than conventional method, while 1.0% of the respondents disagreed with the statement.

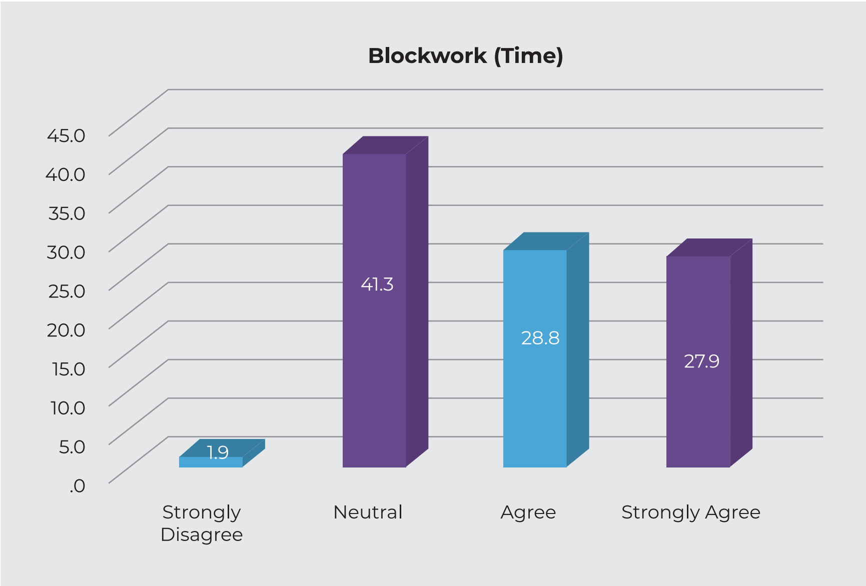


Figure 5.15. Blockwork Vs Conventional (Time)

Figure 5.15 presents blockwork system versus conventional method. Respondents who agreed and strongly agreed that blockwork saves more time than conventional method were 28.8% and 27.9%, respectively. However, 1.9% of the respondents mentioned otherwise.

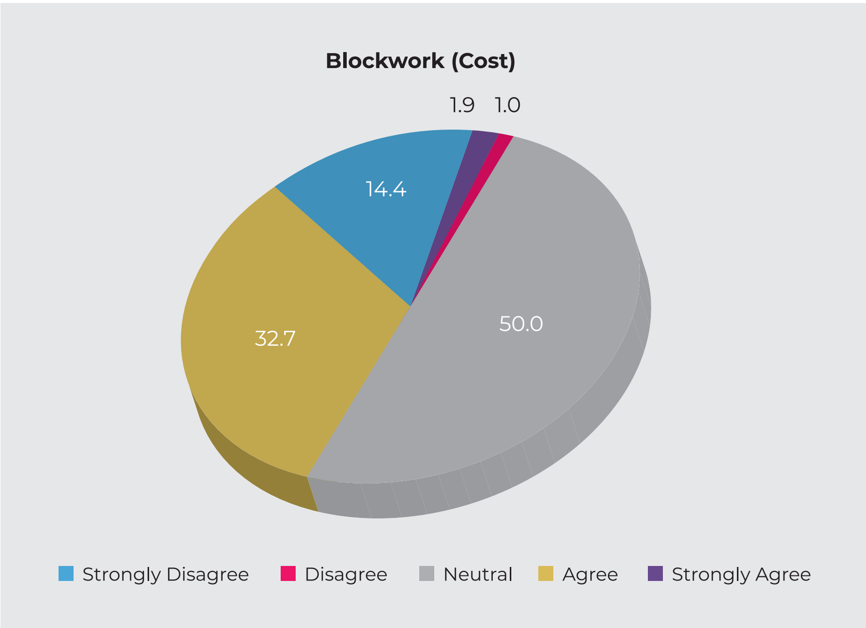


Figure 5.16. Blockwork Vs Conventional (Cost)

Figure 5.16 illustrates blockwork system versus conventional method. About 32.7% and 14.4% of the respondents agreed and strongly agreed that blockwork saves more cost than conventional method, respectively, but 1.9% of the respondents disagreed with the statement.

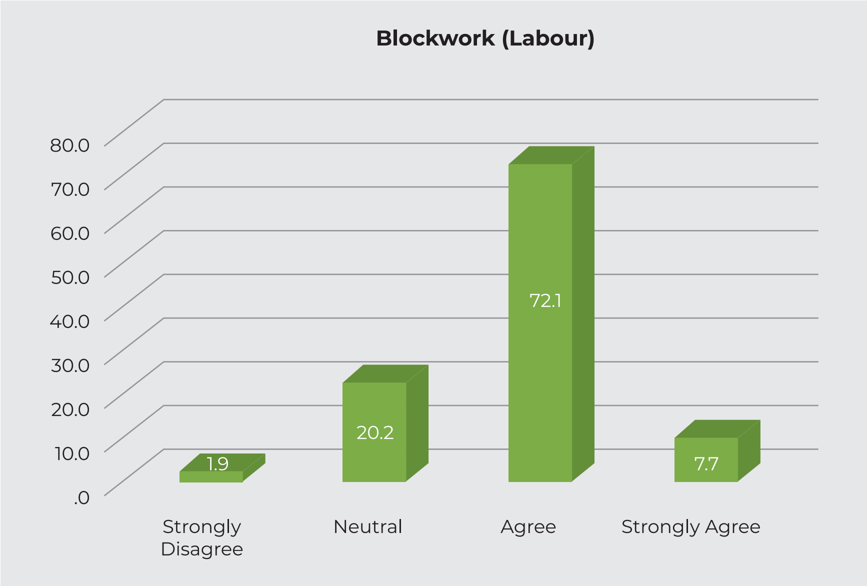


Figure 5.17. Blockwork Vs Conventional (Labour)

Figure 5.17 shows blockwork system versus conventional method. About 70.2% of the respondents agreed that blockwork saves more labour than conventional method, while 7.7% and 1.9% of the respondents strongly agreed and disagreed with the statement.

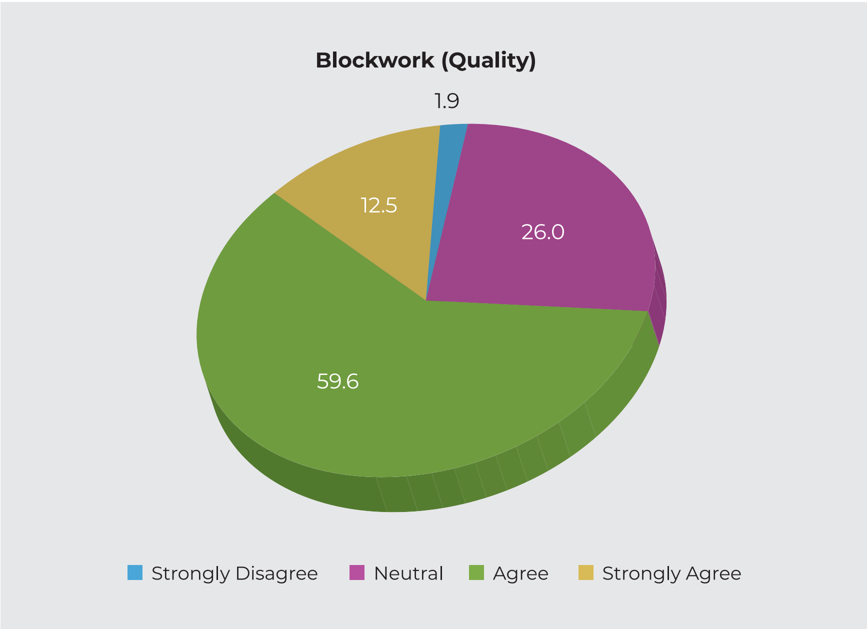


Figure 5.18. Blockwork Vs Conventional (Quality)

Figure 5.18 shows blockwork system versus conventional method. A majority of 59.6% of the respondents agreed that blockwork offers better quality than conventional method, whereas 12.5% and 1.9% of the respondents strongly agreed and disagreed with the notion.

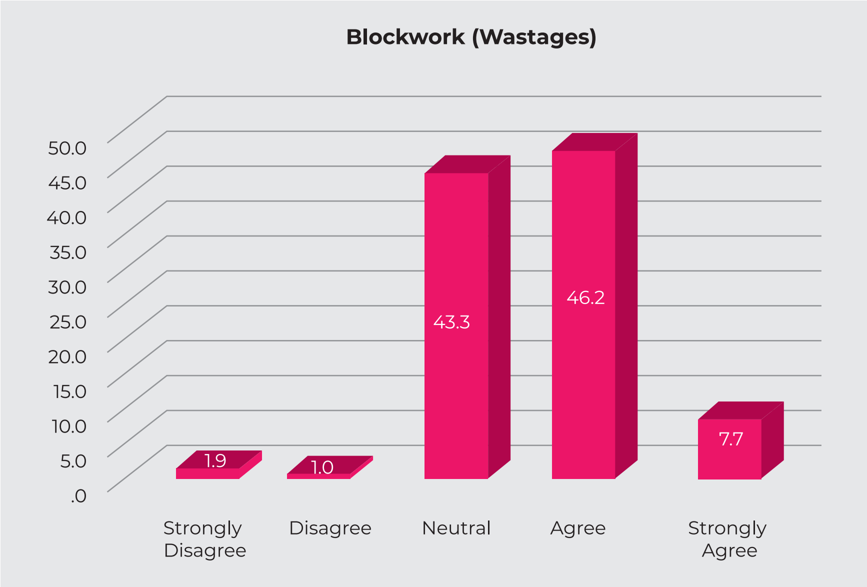


Figure 5.19. Blockwork Vs Conventional (Wastages)

Figure 5.19 shows blockwork system versus conventional method. About 46.2% of the respondents agreed that blockwork hindered more wastage than conventional method, but 7.7% and 1.9% strongly agreed and disagreed, respectively, with the statement.

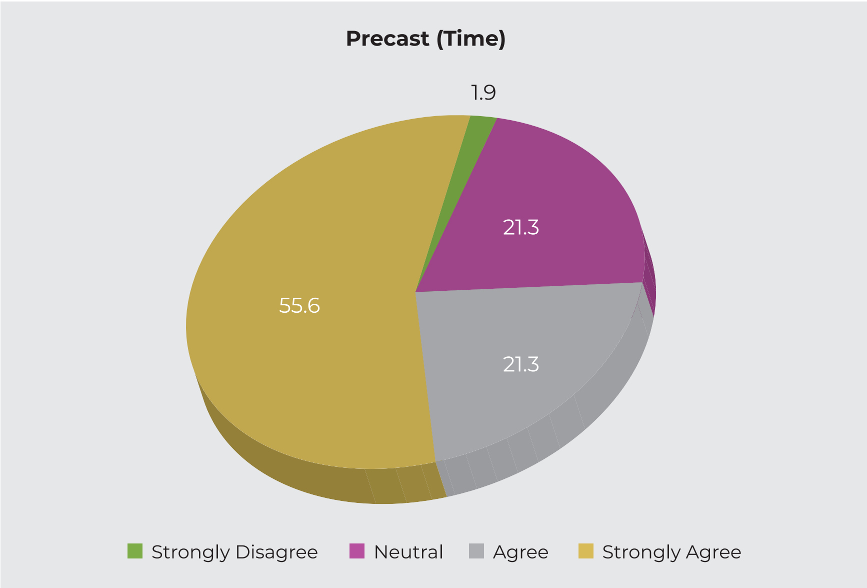


Figure 5.20. Precast Vs Conventional (Time)

Figure 5.20 shows precast system versus conventional method. Most of the respondents (55.6%) strongly agreed that precast saves more time than conventional method, while 21.3% and 1.9% of the respondents agreed and disagreed, respectively, with the statement.

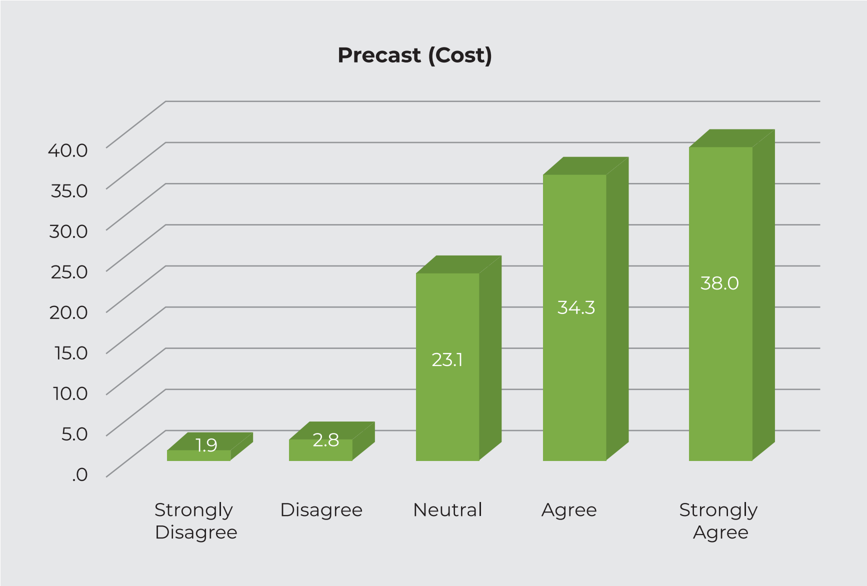


Figure 5.21. Precast Vs Conventional (Cost)

Figure 5.21 shows precast system versus conventional method. In total, 34.3%, 38.0%, and 1.9% of the respondents agreed, strongly agreed, and disagreed, respectively, the notion that precast saves more cost than conventional does.

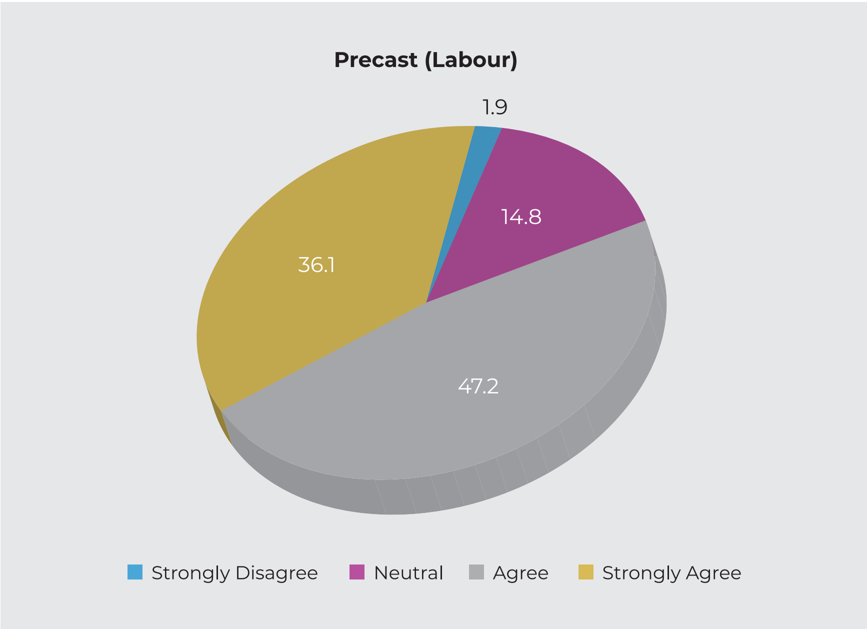


Figure 5.22. Precast Vs Conventional (Labour)

Figure 5.22 shows precast system versus conventional method. About 47.2% of the respondents agreed that precast saves more labour than conventional method, while 36.1% and 1.9% of respondents strongly agreed and disagreed, respectively, with the notion.

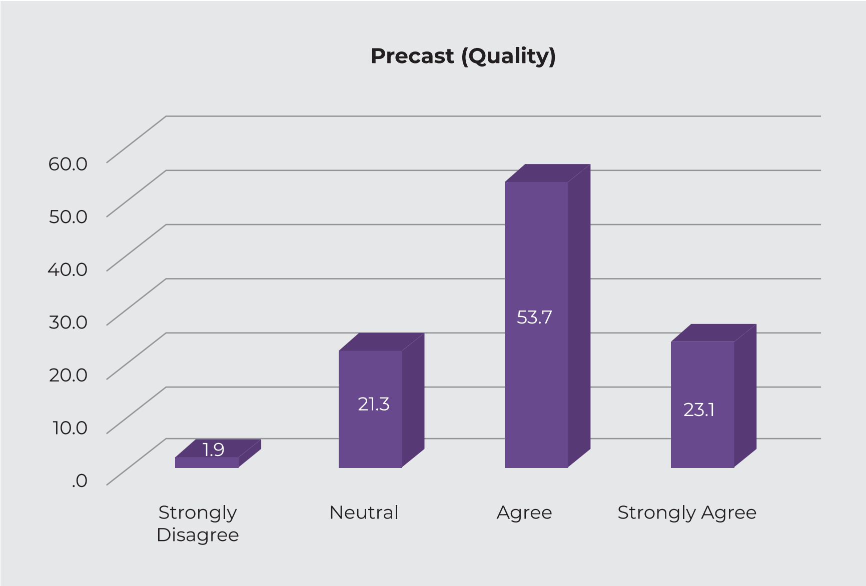


Figure 5.23. Precast Vs Conventional (Quality)

Figure 5.23 shows precast system versus conventional method. In total, 53.7% and 23.1% agreed and strongly agreed, respectively, that precast offers better quality than conventional method, while 1.9% of the respondents disagreed with the statement.

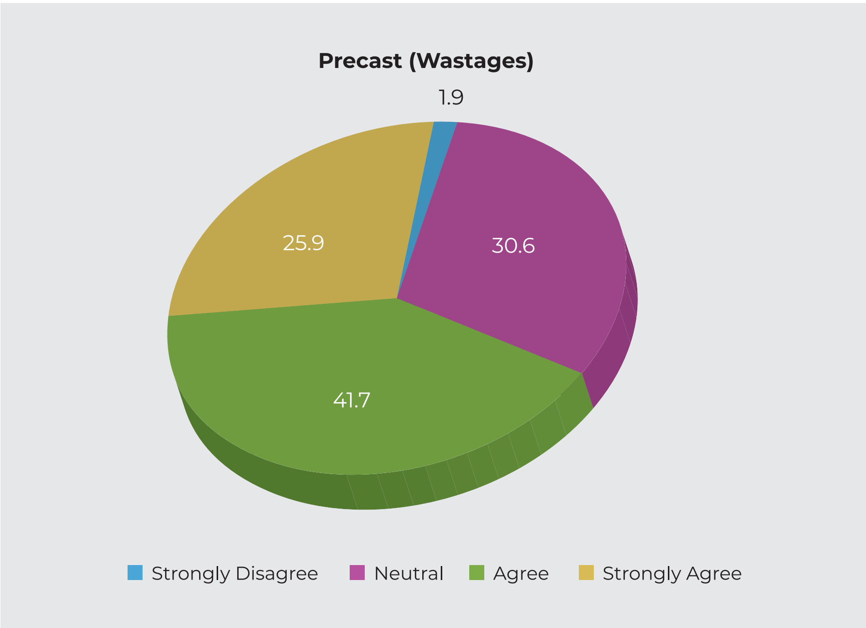


Figure 5.24. Precast Vs Conventional (Wastages)

Figure 5.24 shows precast system versus conventional method. Respondents who agreed that precast reduces more wastage than conventional method was 41.7%, while 25.9% and 1.9% of the respondents strongly agreed and disagreed, respectively, with the notion.

i) Single-Storey House

Table 5.4. Cost incurred using IBS vs conventional method in construction project

IBS System	IBS cost higher (tick)	IBS cost lower	Percentage	Frequency
a) Precast load bearing wall system	55.7%	44.3%	45%	12
b) Precast frame system	72.2%	27.8%	30%	14
c) Reusable system formwork	50.6%	49.4%	60%	21
d) Steel framing system	30.8	69.2	35%	14
e) Loadbearing Blockwork system	35.1%	64.9%	40%	13
f) innovative system (pls state)	40.7%	59.3%	39%	6

Table 5.4 shows the cost incurred using IBS versus conventional method in construction industry for single-storey house. The highest cost incurred using IBS was precast frame system at 72.2%, while conventional at 27.8%. The percentage incurred was 30%. Precast Load Bearing Wall was 55.7% for IBS cost higher and 27.8% for IBS cost lower, with 45%. The lowest cost incurred in IBS was Steel Framing System at 30.8% for IBS cost higher and 69.2% for IBS cost lower with 35%. The highest and the lowest frequencies were reusable system formwork (21) and innovative system, respectively. The respondents agreed that the precast frame system was costlier using IBS than conventional for single-storey house.

ii) Double-Storey House

Table 5.5. Cost incurred using IBS vs conventional method in construction project

IBS System	IBS cost higher (tick)	IBS cost lower	Percentage	Frequency
a) Precast load bearing wall system	47.1%	52.9%	49%	16
b) Precast frame system	44.7%	55.3%	38%	16
c) Reusable system formwork	35.6%	64.4%	38%	15
d) Steel framing system	54.7%	45.3%	80%	10

e) Loadbearing Blockwork system	51.9%	48.1%	69%	9
f) innovative system (pls state)	31.8%	68.2%	30%	3

Table 5.5 shows the cost incurred using IBS versus conventional method in construction industry for double-storey house. The highest cost incurred using IBS method was steel framing system (54.7%), when compared to conventional (45.3%). The percentage incurred was 80%. Loadbearing Blockwork System was 51.9% for IBS cost higher, while 48.1% for IBS cost lower, with 69%. The lowest cost incurred in IBS method was innovative system at 31.8% for IBS cost higher, while 68.2% for IBS cost lower at 30%. The highest frequencies were Precast load bearing wall system and precast frame system (16 each), while the lowest frequency was innovative system (3). The respondents agreed that steel framing system incurred more cost for IBS than conventional for double-storey house.

iii) Apartment

Table 5.6. Cost incurred using IBS vs conventional method in construction project

IBS System	IBS cost higher (tick)	IBS cost lower	Percentage	Frequency
a) Precast load bearing wall system	50%	50%	70%	16
b) Precast frame system	39.5%	60.5%	74%	16
c) Reusable system formwork	51.3%	48.7%	40%	15
d) Steel framing system	64%	36%	68%	8
e)Loadbearing Blockwork system	31.6%	68.4%	36%	16
f)innovative system (pls state)	59.3%	40.7%	62%	7

Table 5.6 shows the cost incurred using IBS versus conventional method for construction of apartment. The highest cost incurred using IBS was steel framing system at 64%, while 36% for conventional. The percentage incurred was 68%. Innovative system was 59.3% for IBS cost higher, while 40.7% for IBS cost lower, with 62%. The lowest cost incurred in IBS was Loadbearing Blockwork system with 31.6% for IBS cost higher and 68.4% for IBS cost lower, with 36%. The highest frequencies were Precast load bearing wall system, Loadbearing Blockwork System, and Precast frame system (16 each), while the lowest frequency was steel framing system (8). The respondents agreed that steel framing system was costlier with IBS than conventional for apartment.

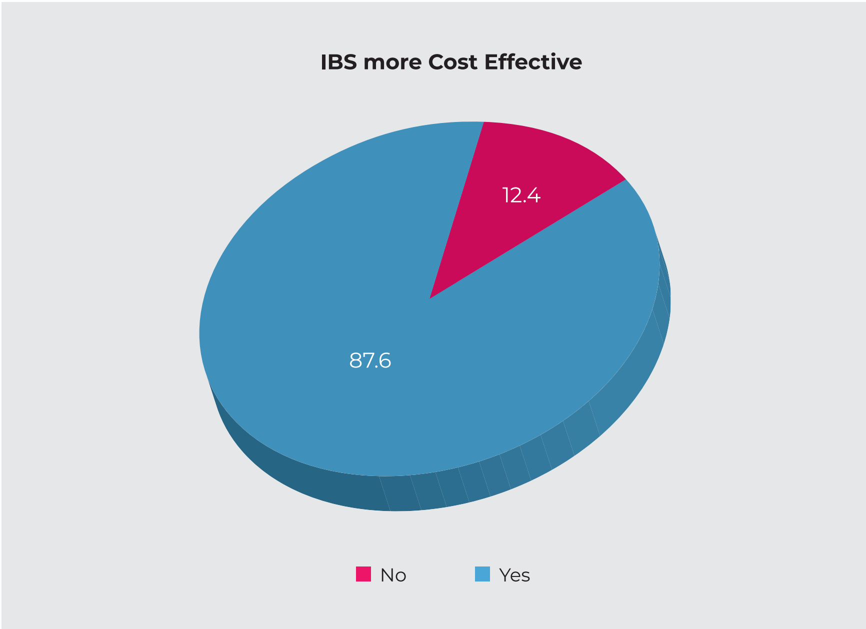


Figure 5.25. IBS being more Cost Effective

Based on Figure 5.25, the respondents agreed that the IBS method is more cost-effective than the conventional method. The results showed that 87.6% of the respondents agreed with the statement above, while 12.4% disagreed. Hence, IBS implementation is crucial in the construction industry to save costs for lengthy construction period.

CHAPTER 6

RECOMMENDATIONS AND CONCLUSION

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RECOMMENDATIONS AND CONCLUSION

6.1 Introduction

The construction industry in Malaysia has begun embracing a more effective construction method – the IBS. In the Twelve Malaysia Plan, the government has encouraged the usage of IBS as an alternative to the conventional construction method. The objective of this present study is to compare the IBS system and the conventional method in residential housing in Malaysia. Three case studies were selected, comprising of single-storey house, double-storey house, and apartment. The design of housing from the three case studies was employed to calculate the costs, in order to compare the IBS system with the conventional method. Quantitative data were collected to support the case studies. The questionnaires were distributed to relevant stakeholders to capture their responses.

The IBS is a construction method that assembles separate structural components on the site. Suitable sizes of beams and columns are critical for the IBS method. Besides, the type of connection between the structural elements plays a key role to ensure that the building is functional, economic, and safe. The structural member and the connection used should be able to transfer any load applied without imposing severe damage.

The Malaysia's government, through CIDB, has a strategic plan to improve the effectiveness and the productivity of its construction sector. This can be achieved by introducing the IBS into the construction industry. For example, CIDB Malaysia has introduced IMPACT, a testing and certification programme for IBS. The IMPACT programme is based on the CIDB standard called Construction Industry Standard (CIS) 24:2018 IBS Manufacturer & Product Assessment & Certification. The CIS 24:2018 marks a significant milestone in the country's effort to enhance the local IBS ecosystem. It serves as a standard reference point for the construction industry to ensure the quality of IBS products and components in a systematic manner. The IMPACT programme is a holistic system that encompasses verification, validation, testing, and certification of IBS products and components based on CIDB standards. With the implementation of this new system, the construction domain can be assured that IBS end-products are of high quality as they meet the specified requirements.

6.2 Case Study: Residential Construction

The four case studies illustrated the cost comparison between IBS method and conventional method. The Malaysian construction industry is experiencing a shift from conventional to IBS, although the latter has yet to be fully exploited, especially in housing development, due to cost impact.

Referring to the case studies, all of the structural parts, the costs indicated that the IBS method was higher than that using the conventional method. This is because; most of the IBS methods applied more concrete and reinforcement, in comparison to the conventional method that only designed in frame to minimise the usage of concrete and reinforcement. As for the architectural part, except for the IBS blockwork in Seroja, the IBS method displayed lower cost than the conventional method did. The conventional system used brick wall and plaster finish, while the IBS had already consisted of wall panel for structural and finish with a layer of skim coat, thus indicating a significant cost reduction for architectural part. The overall cost indicated that the IBS method gave lower cost than the conventional method, except for blockwork system in Seroja, which was vice versa. In conclusion, the total cost of a building can be reduced through the execution of the IBS method. Hence, the IBS method should be implemented by all developers in Malaysia to benefit all parties.

6.3 Survey on IBS versus Conventional Method

According to CIDB Malaysia (2001), the IBS is a construction process that utilises techniques, products, components, and building systems that incorporate prefabricated components and on-site installation. Based on the structural aspect of the system and the survey analysis, IBS can be classified into four major groups based on priority from time, cost, labour, quality, and wastage:

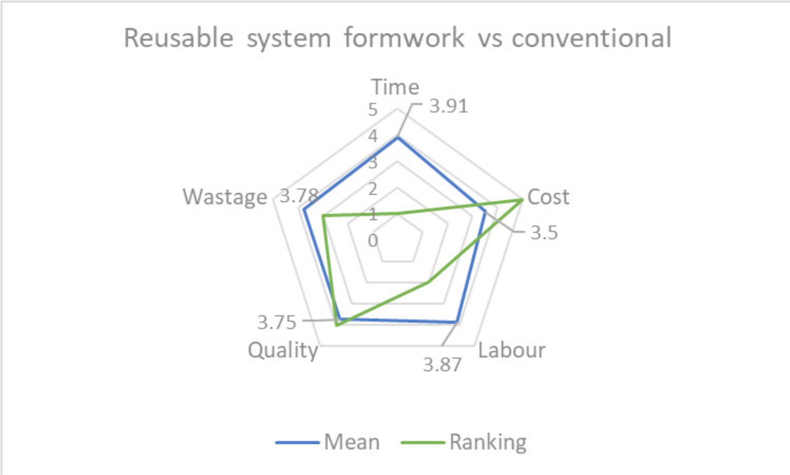

Figure 6.1. Reusable system formwork vs conventional

The highest ranking is time with 3.91 rather than wastage, labour, quality, and cost based on reusable system formwork vs conventional. This result suggested to user of choices factor if need use reusable system formwork for time saving factor.

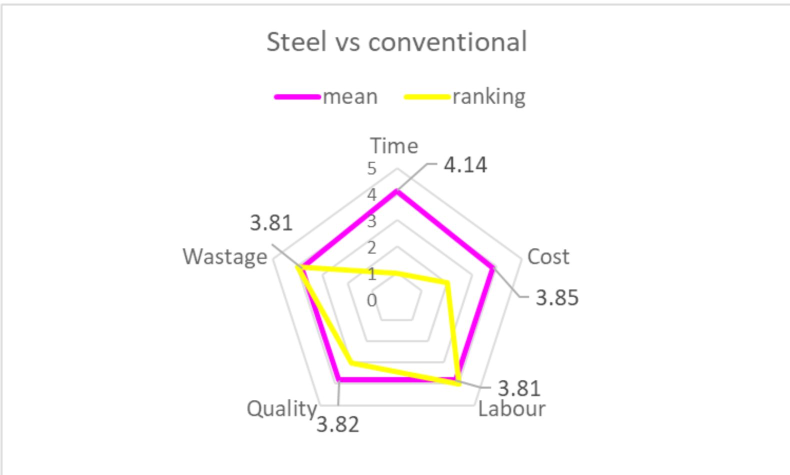

Figure 6.2. Steel system vs conventional

The highest ranking is cost with 3.85 rather than wastage, labour, quality, and time based on steel vs conventional. This result suggested to user of choices factor if need use steel system for cost saving factor.

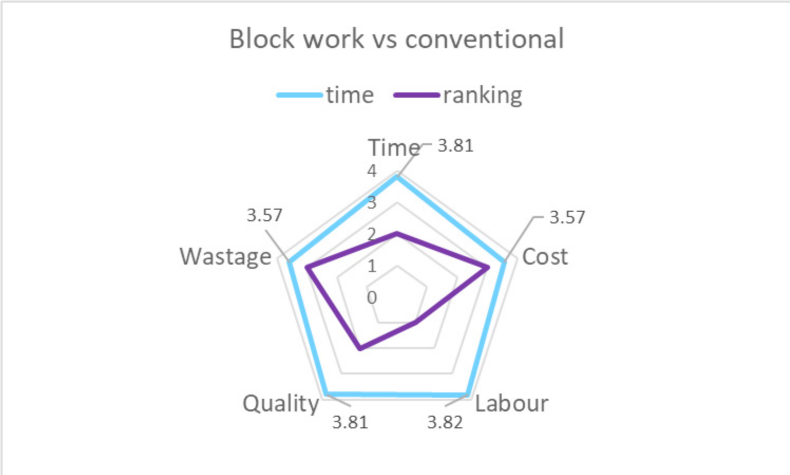

Figure 6.3. Block work system vs conventional

The highest ranking is time and quality with 3.81 rather than wastage, labour, cost, and time based on block work system vs conventional. This result suggested to user of choices factor if need use block work system for time and quality saving factor.

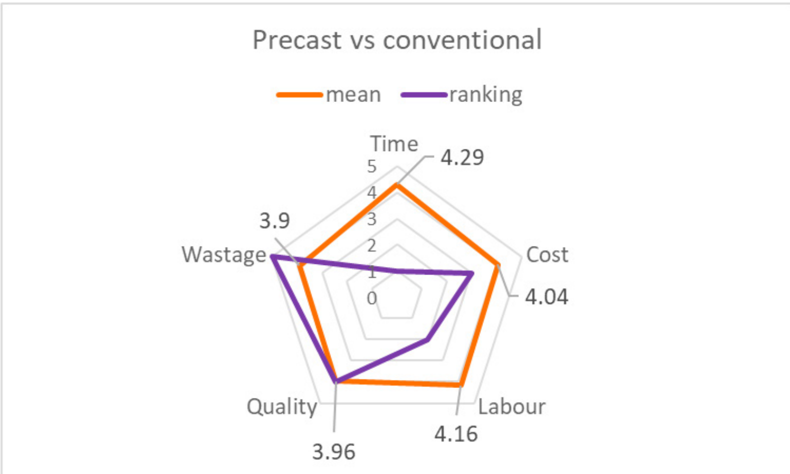

Figure 6.4. Precast system vs conventional

The highest ranking is time with 4.29 rather than wastage, labour, cost, and quality based on precast system vs conventional. This result suggested to user of choices factor if need use precast system for time saving factor.

However, figure 6.1 until 6.4 presents a comparison between IBS and conventional methods based on priority of time, cost, labour, quality, and wastage. The IBS system of Reusable System Formwork, steel, and precast showed the same priority of time, which appeared crucial and had an impact on the IBS system. The formwork system generally involves site casting, thus subjected to structural quality control. It is considered as the "low level" or the "least prefabrication" IBS type. However, this system does offer high quality finishes and fast construction with less site labour and material requirement. These include tunnel forms, tilt-up systems, beam and column moulding forms, as well as permanent steel formwork such as metal decks (CIDB, 2001). The steel system is commonly used with precast concrete slabs, steel columns, and beams. This system has always been the popular choice and used extensively in the fast-track construction of skyscrapers. A recent development of this IBS type includes the increased use of light steel trusses. It consists of cost-effective profiled cold-formed channels and steel portal frame systems as alternatives to the heavier conventional hot-rolled sections (CIDB, 2001). Precast concrete elements are the most common IBS type. There are precast concrete columns, beams, slabs, walls, lightweight precast concrete, and permanent concrete formworks. It also consists of 3D components, such as balconies, staircases, toilets, lift chamber, and refuse chamber (CIDB, 2001).

According to Wisam (2005), the IBS system rapidly completes a project due to advance off-site preparations and simplified installation process. Manageable construction schedule is further enhanced through use of planning control, estimated lead time, and forecasted down time (Noraini 2009). Off-site production can start while the construction site is under earthwork. This offers earlier occupation of building and minimises interest payment (Peng, 1986).

For blockwork components versus conventional, the highest ranking referred to labour factor. According to Warszawski (1999), IBS system helps to save labour cost at the construction site (about 40-50%, when compared to the conventional method). Referring to the study outcomes, it can be concluded that the main advantages of IBS are reduction in overall construction timeframe, slash in cost, enhanced building quality, minimum solid waste, reduced number of workers at site, and a decrease in air pollution at the construction site.

References

Abd Rahman, A. B., & Omar, W. (2006). Issues and challenges in the implementation of industrialised building systems in Malaysia. *Proceedings of the 6th Asia-Pacific Structural Engineering and Construction Conference*, *September*, C-45-C–53. http://eprints.utm.my/529/

Chan, T. K. (2011). *Mechanisation in Construction – A Malaysian Perspective*.

CIDB; IBS Roadmap. (2010). Roadmap for Industrialised Building System in Malaysia (IBS) 2011–2015. In *Ministry of Works, Malaysia* (Issue 72).

CIDB. (2004). *Industrialised Building Systems (IBS) Roadmap 2003-2010, Kuala Lumpur, Malaysia.*

CIDB. (2008). *"Malaysia Report", Construction Industry Development Board (CIDB), Asia Construct Conference.*

CIDB. (2018). *Construction Industry Standard, CIS 18:2018*.

CIDB. (2019). *Construction Industry Standard, CIS 26:2019*.

Fair Work Australia. (2010). *Building and Construction General On-site Award 2010, Australia.*

Foo, H. C., Hamid, Z. A., Din, M. I., & Norman, M. R. (2015). Study on industrialised building system (IBS) adoption level and contractors' readiness in Malaysia 2013. *Malaysian Construction Research Journal*, *17*(1), 1–19.

Haron, N. A., Hassim, I. S., Abd. Kadir, M. R., & Jaafar, M. S. (2005). Building Cost Comparison Between Conventional and Formwork System: A Case Study of Four-storey School Buildings in Malaysia. *American Journal of Applied Sciences*, *2*(4), 819–823. https://doi.org/10.3844/ajassp.2005.819.823

Jabatan Perumahan Negara, K. P. dan K. T. (2019). Dasar Perumahan Mampu Milik Negara. In *Journal of Chemical Information and Modeling*. https://doi.org/10.1017/CBO9781107415324.004

Khan, R. A., Liew, M. S., & Ghazali, Z. Bin. (2014). Malaysian Construction Sector and Malaysia Vision 2020: Developed Nation Status. *Procedia - Social and Behavioral Sciences*, *109*, 507–513. https://doi.org/10.1016/j.sbspro.2013.12.498

Mohamad Kamar, K. A., Alshawi, M., & Abd Hamid, Z. (2009). Barriers To Industrialized Building System (Ibs): the Case of Malaysia. *Built and Human Environment 9th International Postgraduate Research Confrence*, *2009*, 1–16.

Oostra, M., & Jonsson, C. (2007). Best Practices: Lessons learned on building concept. In *Open Building Manufacturing Open Building Open Building Manufacturing Manufacturing Core Concepts and Industrial Requirements*. http://www.cinark.dk/archive/media/303.pdf

Othuman Mydin, M. A., Sani, N. M., & Taib, M. (2014). Industrialised building system in Malaysia: A review. *MATEC Web of Conferences*, *10*, 1–9. https://doi.org/10.1051/matecconf/20141001002

Rahim, A., & Qureshi, S. (2018). A Review of IBS Implementation in Malaysia and Singapore. *Journal of the Malaysian Institute of Planners*, *16*(2), 323–333.

Rawlinsons. (2010). Rawlinsons Australian Construction Handbook 2010. In *Rawlhouse Publishing Pty Ltd, Australia*.

Shaari, S. N. (2003). IBS Survey: Survey on the Usage of Industrialised Building Systems (IBS), Malaysian Construction Industry. *Construction Industry Development Board, Kuala Lumpur, Malaysia*.

Trikha, D. (1999). Industrialized building systems. *Prospects in Malaysia Proceedings World Engineering Congress: Malaysia, 1999*.

Warszawski, A. (1999). *Industrialized and automated building systems*. E & FN Spon. http://site.ebrary.com/id/10164549

Yong, T. N. (2010). Feasibility of Precast Concrete Construction System in Malaysia. *A Comparative Study between Australia and Malaysia, Research Project Report, The University of Melbourne, Ausatralia*.

Appendix

DEVELOPMENT OF COST COMPARISON BETWEEN IBS METHOD AND CONVENTIONAL METHOD IN HOUSING PROJECTS IN MALAYSIA

INSTRUCTIONS

1. Please respond to all questions.
2. Each respondent is only eligible to send one feedback. Please discuss the answer with your other colleagues, if necessary.
3. To reduce potential mistake in our analysis, please use only one method (e.g. ticking) to respond and please respond only once.
4. You are encouraged to insert additional attributes in the remarks column for each criterion if deemed appropriate.

1. SECTION A

Please tick () the following:

i) Have you heard about Industrialised Building System (IBS)? If No, please proceed to question ix).

Yes	No

ii) Are you involved in any residential project using IBS? If No, please proceed to question ix).

Yes	No

iii) If Yes, how many of the residential projects had implemented IBS?

1-10	11-20	21-30	< 31

iv) What type of IBS system was used?

Reusable System Formwork	Steel	Blockwork	Precast

v) In percentage (%), what is your score from your previous projects using IBS system?

a.	Precast load bearing wall system	
b.	Precast frame system	
c.	Reusable system framework	
d.	Steel framing system	
e.	Blockwork	
	Total	100%

iv) In your opinion, is IBS method more saving when compared to conventional system based on certain parameters (e.g., time, cost, labour, quality, and wastage)? Note: 1 (IBS is not recommended) to 5 (IBS is highly recommended)

No.	Items		1 Strongly disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly agree
1.	Reusable System Formwork vs conventional	Time					
		Cost					
		Labour					
		Quality					
		Wastage					
2.	Steel vs conventional	Time					
		Cost					
		Labour					
		Quality					
		Wastage					

3.	Blockwork vs conventional	Time					
		Cost					
		Labour					
		Quality					
		Wastage					
4.	Precast vs conventional	Time					
		Cost					
		Labour					
		Quality					
		Wastage					

viii) In your experience, what is the cost incurred using IBS vs conventional method in your construction project? (in percentage)

	Method	**IBS cost higher (tick)**	**IBS cost lower**	**Percentage (%)**
Single storey house	a) Precast load bearing wall system			
	b) Precast frame system			
	c) Reusable system formwork			
	d) Steel framing system			
	e) Loadbearing Blockwork system			
	f) Innovative system (pls state)			
Double storey house	a) Precast load bearing wall system			
	b) Precast frame system			
	c) Reusable system formwork			
	d) Steel framing system			
	e) Loadbearing Blockwork system			
	f) Innovative system (pls state)			

Apartment	a) Precast load bearing wall system			
	b) Precast frame system			
	c) Reusable system formwork			
	d) Steel framing system			
	e) Loadbearing Blockwork system			
	f) Innovative system (pls state)			

ix) In your opinion, is IBS more cost-effective than conventional method?

Yes	No

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