SUSTAINABILITY FACTORS INFLUENCING INDUSTRIALISED BUILDING SYSTEM (IBS) PROSPECTS FOR POST-DISASTER BUILDING RECONSTRUCTION FROM PRODUCTIVITY AND QUALITY ASPECTS

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I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

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ABSTRAK

Pelan Induk Industri Pembangunan (2006-2015) bertujuan untuk menangani kelestarian industri pembinaan Malaysia dengan matlamat globalisasi pasaran. Dengan meningkatnya kesedaran kelestarian di peringkat global, industri pembinaan berada di bawah tekanan untuk meningkatkan kecekapannya. Perlaksanaan Sistem Bangunan Industri (IBS), yang komponennya dibina di luar tapak, mempunyai potensi untuk mempromosikan pembangunan kelestarian. Walau bagaimanapun, terdapat persaingan yang tinggi antara kaedah IBS dan kaedah konvensional memandangkan IBS adalah kaedah pembinaan baru. Sistem IBS mempunyai kelebihan dan keistimewaan tersendiri dalam industri pembinaan antaranya mengawal persekitaran pengeluaran yang lebih baik, meminimakan sisa pembinaan, menggunakan tenaga bahan bangunan yang cekap, dan menstabilkan keadaan kerja. Kajian ini memberi tumpuan kepada projek-projek yang menggunakan sistem IBS sebagai kaedah pembinaan. Projek ini bertujuan untuk menentukan hierarki faktor kelestarian yang berkait dengan aspek produktiviti dan kualiti. Terdapat empat (4) faktor kelestarian yang dikategorikan iaitu persekitaran, ekonomi, sosial dan teknologi. Setiap faktor kelestarian mempunyai kesan ke atas aspek produktiviti dan kualiti yang mempengaruhi pembinaan semula selepas bencana. Diakhir kajian ini, hierarki tertinggi untuk aspek produktiviti adalah faktor persekitaran manakala hierarki tertinggi untuk faktor kualiti adalah teknologi. Penyelidikan lanjut tentang faktor kelestarian perlu dijalankan untuk mempromosikan penggunaan IBS ke atas aspek produktiviti dan kualiti.

ABSTRACT

The *Construction Industry Master Plan (2006–2015)* is intended to address sustainability in the Malaysian construction industry with the objective of globalising its market. As the sustainability awareness rises globally, the construction industry is under pressure to improve its efficiency. The adoption of Industrialised Building Systems (IBS), for which its components are built off-site, has the potential of promoting sustainability development. However, there is high competitive between IBS method and conventional method since IBS is a new method of construction. IBS system comes with its own advantages and specialty in construction industry which is better control of production environment, minimizing construction waste, using efficient building material energy, and stabilising work conditions. This research focuses on projects that use IBS system a method of construction. This project aims to determine the hierarchy sustainability factors into different productivity and quality aspects. There are four (4) sustainability factors that had been categorized which are environment, economy, social and technology. Each of the sustainability factors has their effects on productivity and quality aspects that influence to building reconstruction after a disaster. End of this research, the highest of hierarchy for productivity aspect is the environment factors while the highest hierarchy for quality factors is technology. Throughout this project, further research on sustainability factors should be conducted to promote IBS adoption on productivity and quality aspect.

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LIST OF ABBREVIATIONS

IBS	**I**ndustrialised **B**uilding **S**ystem
CIDB	**C**onstruction **I**ndustry **D**evelopment **B**oard
CITP	**C**onstruction **I**ndustry **T**ransformation **P**lan
CIMP	**C**onstruction **I**ndustry **M**aster **P**lan
CMU	**C**oncrete **M**asonry **U**nit
DID	**D**epartment of **I**rrigation and **D**rainage
EIA	**E**nvironment **I**mpact **A**ssessment
EMP	**E**nvironmental **M**anagement **P**lan
JKR	**J**abatan **K**erja **R**aya
JPS	**J**abatan **P**engairan dan **S**aliran
MERCY	**M**edical **R**elief **S**ociety **M**alaysia
MIDF	**M**alaysian **I**ndustrial **D**evelopment **F**inance
PPE	**P**ersonal **P**rotection **E**quipment
RII	**R**elative **I**mportance **I**ndex
RMK	**R**ancangan **M**alaysia **K**e-sebelas
SPSS	**S**tatistical **P**ackage for the **S**ocial **S**cience

NOMENCLATURES

ai Constant, Weighing Factor

xi Variables Representing Respondents Frequency of Response

CHAPTER 1

INTRODUCTION

1.1 Background

Automation and mechanization as well as further research and development (R&D) for technology development, adoption and localization are recommended to be the focus areas to ensure the Malaysian construction industry continuously strives to adopt modern and innovative construction methods and processes throughout the value chain. According to the Construction Industry Development Board of Malaysia (CIDB), greater technology adoption in human capital development and R&D will be a transformative step change for the industry and will raise the quality of the workforce and create higher income jobs (CIDB, 2016).

The initiatives of IBS adoption are expected to tackle issues in the construction industry holistically, including the economic, regulatory, operational, technological, human capital and innovation aspects in order to achieve the transformative outcomes. There are four strategic thrusts that have been identified to focus the Malaysian Construction Industry Transformation Plan (CITP, 2016-2020) initiatives in order to be all-encompassing of the critical issues which are quality, safety and professionalism, environmental sustainability, productivity and internationalisation.

The introduction of Industrialised Building System (IBS) as a new construction method to be used in the post-disaster building reconstruction is considered as an optimistic choice which suits sustainability factors. IBS is a solution for a speedy recovery to the project or building. Industrialized Building System (IBS) is the term to represent the prefabrication and construction industrialization concept in Malaysia. The term was developed to reflect the paradigm shift from the typical conventional construction methods to a prefabricated system. There is a requirement for effective decision-making in the adoption of IBS by construction stakeholders, especially project developers and contractor (Abdullah and Egbu, 2011), thus developing IBS as an innovative constructive method for post-disaster reconstruction.

IBS has been introduced as a construction method with better productivity, quality and safety (Kamar and Hamid, 2011). According to Malaysian Industrial Development Finance, IBS is a system or method of construction in which its components are manufactured in controlled condition which is manufactured or constructed, transported and installed at construction site with minimal employee use (MIDF, 2014). In Malaysia, the major types of IBS system are precast concrete, formwork systems, steel framing, timber framing, block and innovation system (CIDB, 2016). As IBS is considered as a new system, it is still involving in the acceptance issues from the companies, contractors, consultants, house owners, workers and the mass public. The acceptance of IBS system for post-disaster building reconstruction still uncertain, thus requiring a further research in this matter. Fundamentally, IBS has an advantage in reducing the construction time, better site management and, reduce the wastage that will ultimately produce better quality of products for the customers (Bari *et al.*, 2012).

The post-disaster building reconstruction using IBS as a new technology has many advantages that also relates to the sustainability factors of infrastructure development. As Malaysia is going towards achieving sustainable development, IBS is one of the transformation strategy to achieve this aspiration. IBS technology adoption is also related to the aspects of sustainable consumption and production concept. The Eleventh Malaysia Plan (RMK-11, 2016-2020) stated that Malaysia has a major interest in stepping up its pledge to the environment and long-term sustainability. Therefore, IBS technology is a preferred technology that comes with a sustainability factors namely, environment, economy, technology and social.

The consideration of IBS to reconstruct building offers the fast or speed system of construction process to restore housing needs to be operated as usual after a disaster. Therefore, the construction industry should introduce the IBS to be applied as system in the after disaster building re-construction to overcome the difficulties of conventional or traditional construction which involves high wastage, low quality of the products and project delays. These difficulties may be caused by the environment factors such as climate factors such as rains and windy which cause the delay of construction work. This study adopts a questionnaire survey method that involved the mass public. Additionally, interview surveys were conducted amongst professionals in the IBS systems such engineers who practice the IBS systems on-site.

1.2 Problem Statement

This study intends to relate sustainability factors that influenced the adoption of IBS technology prospects for post-disaster building reconstruction. This study develops with a fundamental problem that is underlying the research which is the implementation of IBS technology for post-disaster building reconstruction is still not well adopted.

This is since there are risks involved in adopting IBS in construction project after a disaster as IBS technology involves high initial costs. This risk also relates to the aspect of quality and productivity of the building projects. However, this risk outweighs IBS benefits as IBS is considered as a fast track system compared to the conventional construction methods. Charlett and Maybery Thomas (2013) discover that building-technology advancements have been developing because the construction industry requires rapid, labour-efficient, cost-effective and quality solutions and that building projects struggle to keep up with such developments.

Moreover, post-disaster building reconstruction also requires fast track construction method which can be fulfilled by IBS technology. As time becomes a crucial problem in a project implementation, IBS can be an effective solution to this problem. Therefore, it is important to determine the acceptance of IBS for timing purposes from the companies, contractors, consultants, house owners, workers and the mass public. Consequently, the aspects of productivity and quality pertaining IBS should be incorporated due to the importance of these two aspects. In addition, sustainability factors must also be considered in the issue of disaster management. Hence, there is a gap in IBS research as the combination of both perspectives is still lacking, in terms of sustainability factors and IBS prospects for post-disaster building reconstruction. The sustainability factors are divided into four categories which are environment, economy, technology and social.

1.3 Objectives

The primary aim for this research is to evaluate the perception of construction stakeholders towards sustainability factors that influence the adoption of IBS technology for post-disaster building reconstruction from the perspectives of productivity and quality aspects. In order to meet the aim of research mentioned above, the research objectives of this study are as follows:

I. To determine the suitability of chosen IBS as an efficient system for a recovery project which provide an improving in quality and productivity on sustainability of the projects.

II. To determine the sustainability factors which involved in the construction project that implemented the IBS system from quality and productivity perspective.

III. To evaluate construction stages that are relevant to sustainability factors in using IBS for post-disaster building reconstruction.

IV. To propose as a conceptual model for IBS to be used after a disaster that provides a fast recovery system.

1.4 Research Questions

Based on the above research objectives, this study attempts to answer the following research question:

- How do sustainability factors influence IBS prospects for post-disaster building reconstruction from the perspectives of quality and productivity?

1.5 Scope of Work

The scope of this research is focusing on the investigation of sustainability factors that relates to IBS technology which influenced post disaster building reconstruction. The literature review through different materials are adopted to obtain insights into sustainability relates to this matter. The research was performed using questionnaire and interview surveys to obtain data that support the whole research. The close-ended questionnaires were distributed to the construction stakeholders. While the interview survey was conducted by interviewing the respondents who are contractors, project stakeholders and professional engineers. Data collected was focused on IBS projects in Perlis state in between January 2017 and March 2018.

1.6 Benefits and Importance of Research

The importance and benefits of this research project is to obtain a better evaluation on sustainability factors that influenced the IBS prospects for post disaster building reconstruction based on the exploration of IBS characteristics and types. Besides, this research is based on opinions on IBS system and applications from the perceptions of construction professionals. This is important in determining the most significant sustainability factors that are related to IBS adoption after a disaster. Thus, the IBS can be proven to be prospective building or construction method that is valuable in disaster management, compared to the conventional construction. A conceptual model that evolves from this study can be used to assist construction stakeholders in decision-making, policy making, system improvements and market expansion pertaining IBS adoption and disaster management.

1.7 Dissertation Outline

This study is focusing on sustainability factors that influence IBS prospects for post-disaster building reconstruction. The study has five chapters as follows:

Chapter 1 gives an introduction of the current construction industry, the implementation Industrialized Building System (IBS), the benefits and its problem, besides problem statement, objectives of study, research question and scope of study.

Chapter 2 consists of the literature review of IBS technology adoption, the list or types of disaster and the related solutions. The sustainability factors namely environment, economy, technology and social are also included with their relations to the quality and productivity aspects.

Chapter 3 discusses about the methods used in this research. It includes the structure of questionnaire and the assessment of the research location and the survey process and analysis. It also includes interview surveys to support the quantitative survey.

Chapter 4 discusses the results of questionnaires and interview surveys. Those factors on sustainability were classified into quality and productivity aspects and the hierarchy of these factors were also outlined.

Chapter 5 presents the conclusion of the research results. A conceptual model is presented and described with some suggestions for future study are also recommended.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter reviews the previous literatures of relevant studies. A literature review is a search and evaluation of an existing literature in a selected topic area. This study assimilates an existing discovery from the literature and then considers the applicability of these literatures to this study. This study was implemented by researching characteristics and types of IBS that can be used after a disaster for building reconstruction which relate to sustainability factors. The adoption of IBS is based on a new method of construction as a resolution of innovation to speed up construction process. There are some benefits to reduce the construction time or duration such as to ensure better construction quality and productivity as buildings are reconstructed to fulfil disaster victims needs on an urgency and emergency mode. In changing an emergency scenario to a normal one, the adoption of IBS technology can take place as an efficient and effective building system. The fabrication of IBS components is ready-made as it is produced in factory and will be delivered to the construction site for installation (Kamar and Hamid, 2011). The benefits of IBS to the construction industry for post disaster building reconstruction is in terms of improving the level of construction quality and productivity which are also related to sustainability factors instead of the improvement of projects performance only. Hence, IBS technology has the potential to give positive impacts based on sustainability factors such as environment, economy, technology and social, besides IBS contribution towards better quality and productivity levels. These impact positive impacts are expected to support Malaysia towards achieving an industrialised nation.

2.1 Development of Industrialized Building Systems (IBS)

According to Construction Industry Development Board (CIDB), IBS was first introduced in the early 1960's in the world's construction industry. Malaysia first started implementing the IBS system in 1964. The first project was Pekeliling Flats in Kuala Lumpur in 1964 and the second project was Taman Tun Sardon, Gelugor, Penang in 1965 (CIDB, 2016). However, although it has been four decades since the introduction of IBS in Malaysia, the adoption of this method in the local construction industry is still relatively low compared to some other countries. The Malaysian Industrial Development Finance stated that it is because the conventional construction methods are still in practice despite the perennial problems such as time delay, cost overrun and waste generation (MIDF, 2014).

The Malaysian government however considers IBS technology as the new system that improves the construction industry. This is based on the IBS Strategic Plan which was launched in 1999 while the IBS Roadmap 2011-2015 was introduced in 2011. As presented in the latest Construction Industry Transformation Plan (CITP, 2016-2020), IBS is a construction process that utilizes techniques, products, components or building systems which involve prefabricated components performed off-site but implementing on-site installation. Moving towards the dynamic direction, there is a paradigm change in accepting and adopting IBS in the Malaysian construction industry. Moreover, the Construction Industry Development Board stated that the government has mandated that each government projects will have to adopt the IBS starting from this 2018 (Kamar et al., 2012).

2.2 Definition of Industrialized Building Systems (IBS)

Industrialised Building System (IBS) is defined as a technique of construction whereby components are manufactured in a controlled environment, either on-site or off-site, and transported, positioned and assembled into construction works (Mydin *et al.*, 2014). IBS is the term to represent the prefabrication and construction industrialization concept in Malaysia (Kamar and Hamid, 2011). Whereby, industrialisation process requires investment in equipment, facilities and technology with the objective of maximising production output, minimising labour resource and improving quality while a building system is define as a set of interconnected element that joint together to enable the designated performance of a building (Warszawski, 1999).

CIDB Malaysia (2003) describes the objective of IBS policy is to impose higher standard which intends to achieve positive outcomes in IBS implementation. Specifically, there are five main IBS groups identified in Malaysia (CIDB, 2006), which are :

- Pre-cast Concrete Framing, Panel and Box Systems – pre-cast columns, beams, slabs.
- Formwork Systems – tunnel forms, EPS-based forms, beams and columns, moulding forms, permanent steel formworks, etc.
- Steel Framing Systems – steel beams and columns, portal frames, roof trusses, etc.
- Prefabricated Timber Framing Systems – timber frames, roof trusses, etc.
- Block Work Systems – interlocking concrete masonry units (CMU), lightweight concrete blocks, etc.

The construction industry plays a crucial role to continuously undertake measures in increasing the efficiency, quality and productivity in order to stimulate an international economic activity and enhance the development. Towards the end, the use of the IBS is an exact step in recognizing the objective (IBS Roadmap, 2011-2015). The new policy objective is to impose the high level intended outcomes of implementing IBS. Therefore, this study focuses on the adoption of IBS for the purpose of post or after disaster building reconstruction which is influenced by sustainability factors with an improvement in quality and productivity aspects.

2.3 Types of disaster in Malaysia and its management

Normally, disaster can be classified into natural disasters, man-made disasters and subsequent disasters (Shaluf, 2007). Natural disaster are catastrophic events resulting from natural causes such as floods, landslide, mudslides, earthquakes and etc, which humans have no control on this. Whereas, the man-made disasters have been classified into technological disasters, transportation accidents, public places failure and production failure. As for the subsequent disaster such as displaced people and haze, it is a disaster triggered by a man-made disaster. In recent years, human casualties and economic losses caused by natural disasters in Malaysia have been increasing, indicating that the population and economic assets of the area are becoming concentrated in disaster-prone areas (Guha-Sapir and Vos, 2011).

This study focuses on any kind of disasters that strike which cause building damages that require reconstruction works. (Shaluf and Ahmadun, 2006) pointed out that the world has witnessed many hydrological disasters (floods and cyclones) and geological disasters (earthquake, volcanic eruptions and landslides). Although Malaysia is not a disaster-prone country in terms of earthquakes and tropical cyclones, it still exposed to other kind of disasters such as flood, landslide and wind. There is increasing evidence that disasters caused by natural hazards are becoming both more frequent and more severe (Guha-Sapir et al., 2012).

Malaysia is a country which is prone to flood events every year. According to Razi et al. (2010), the most frequent natural disaster that occurs in Malaysia is flood. Throughout Malaysia, flood is the most devastating natural disaster experienced including Sabah and Sarawak. There are total of 189 river basins (89 of the river basins are in Peninsular Malaysia, 78 in Sabah and 22 in Sarawak), with the main channels flowing directly to the South China Sea and 85 of them are prone to become recurrent flooding. The estimated area vulnerable to flood disaster is approximately 29,800 km2 or 9% of the total Malaysia area, and is affecting almost 4.82 million people which is around 22% of the total population of the country (DID, 2009).

Flood occurs when water over flows from the river banks and inundates the closest plain where water was not prevalent earlier. Normally, this overflow happens when heavy rain takes place non-stop for a duration of several days at certain locations (Hussain et al., 2014). In this case, areas that are normally dry will be overflowed with water that can also cause floods. During flood season, water flows will lead to property damages. Flooding contributed to about 39.26% of worldwide natural disasters and caused USD 397.3 billion worth damage between 2000 and 2014 (Ran and Nedovic-Budic, 2016).

Flood causes damage to buildings. Some damages are severe and need full reconstruction while some only need minimum repair. Malaysia has a long history of flood as the country is exposed to monsoon rainfall all year round. More than about 10%

of the country area is flood-prone. In Malaysia, there are few affected areas which usually tend to catch the flood during monsoon season. Sometimes flood struck because of the windy season or also can be caused by the Malaysia's topography. Besides, rapid urbanization of floodplains such as those in Kuala Lumpur, Penang and Sarawak, and upstream development of hill land have rendered many areas vulnerable to hazardous flash floods (MERCY Malaysia, 2015).

Besides floods, Malaysia is also subjected to landslides. Malaysia has experienced various landslides problems throughout the country. Farming activities involving indiscriminate clearing of land, coupled with continuous downpours, were partly blamed for landslides (Kazim et al., 2017). These landslides may strike near business and residential areas and may cause buildings and infrastructures such as school, hospital, clinic or police station to be destructed or damaged which affect their normal functions. Therefore, faster recoveries for these building are required to continue their operations.

The recovery phase is vital, as it returns infrastructural systems back to their minimum operating standard. Recovery phase involves various activities that are designed to return life back to normal or to improve life after a disaster. Disaster recovery is a stage of re-construction that aims to make improvements from the effects of significant negative events (Aldrich, 2012). The recovery involving the two stages of recovery are short-term and long-term recovery. As a new set of sustainable assistance, it involves the long-term view of sustainable infrastructure development to be constructed. During this long-term recovery phase, there is an opportunity to change the development patterns, economies, cultures and societies to a new and better one.

IBS technology has proven as a short-term recovery method for building reconstruction particularly in foreign countries. Advances in building technologies have substantially impacted on project performance in terms of speed, time and quality (Cennamo et al., 2012) and IBS is one of the advances. With the consideration of sustainability factors in the adoption of IBS technology, it can be a reliable building technology that can also serve a mechanism to achieve higher productivity and quality level. Those four sustainability factors that relates to IBS are the environment, economy, technology and social. Each factor has its advantages that support the adoption of IBS technology. Building technologies such as IBS technology adoption, are rapidly becoming the subject of project development, where sustainable aspects are considered as universal issues (Ding and Shen, 2010).

2.4 Duration for Post-Disaster Building Reconstruction

The conventional construction methods have been considered to be less productive and dangerous due to the process of constructing buildings. It is important for the Malaysian construction industry to develop and be ready for the globalization era whereby increase of quality and productivity are compulsory and the reduction of cost and construction period must be taken into account. These new methods of construction industry will be less time taken to rebuild a building. The less time taken, the less cost will be cash out. The benefits of IBS technology adoption are not limited to projects in remote areas, as many domestic projects located near major populations are being constructed, with significant cost- and time savings, by using IBS technology (Li et al., 2011).

The IBS construction will save time and helps to reduce the risk of project delay and monetary losses. The design and production of components can be started while the construction site is under survey or earthwork. Due to the controlled environment of the manufacture area, the production of the IBS components is unaffected by weather conditions. The usage of large structural panels can speed up the structural works, while other trades such as painting, electrical wiring and plumbing works can be conducted simultaneously. The time for a complete house using IBS construction technology is faster than the conventional technology (Adenan and Bakar, 2015).

When disaster strikes, the construction industry is targeted for its expertise in fast-track rebuilding efforts. Therefore, damaged buildings need to be reconstructed in a short period of time. In this case, time factors are also related to quality and productivity of the building projects. IBS technology adoption can also be influenced by cost factors, but client-related elements other than price such as timing and quality assurance are becoming increasingly significant (Groak, 2013).

2.5 Quality of IBS Technology

IBS technology offers a better alternative way in construction industry other than conventional methods and labour intensive in-situ construction. IBS technology comes with high quality components and aesthetical value of building products (Adenan and Bakar, 2015). IBS products are manufactured in a casting area where critical factors including temperature, mix design and stripping time can be closely checked and controlled. IBS technology focuses on quality feature because components are manufactured in a controlled environment to ensure better quality monitoring and checking. Temperature control for instance, is essential to avoid structural cracking and to prevent weather related delays. The concrete mix design and stripping time can be controlled, monitored closely or accelerated using additives or steam curing. This will ensure that the qualities of the precast products are better than the cast in situ concrete (Rahman *et al.*, 2015).

Apart from the building process, end-users often perceive IBS technology adoption as representing an environmentally friendly mode of production as well as having certain intrinsic quality and safety characteristics (Kajikawa et al., 2011). Therefore, the implementation of IBS technology provides a good quality aspect of building products, since the materials will be delivered to the site in the right quantities and in a controlled environment, that are ready for the assembly process.

2.6 Productivity of IBS Technology

Malaysia's construction industry has been heavily depended on unskilled foreign workers especially from Indonesia, Bangladesh, Vietnam and etc. Using conventional building method which is more labour intensive can impede the process of automation in the industry. Thus, this can delay the development of the construction industry and it can cause a huge loss in term of cost especially in the long run. Thus, in response to productivity matters from conventional construction methods, the construction industry too is increasingly adopting building solutions as a part of strategic decisions to create intelligent buildings (Ralegaonkar and Gupta, 2010), and IBS is one of the solutions.

Kadir et al. (2006) discovered that costs should be a major impediment to IBS adoption due to the abundance of cheap foreign workers in Malaysia. In another way, IBS implementation can reduce the number of unskilled foreign workers in the construction industry. Consequently, money outflow to foreign countries can be minimised and this will benefit the local economy.

With less labour involved in the IBS construction, overall construction time can be reduced as the advantages of automation. This enables building constructors to save on the overhead costs of a building project. Consequently, productivity increases in this way. Fundamentally, a building project should be properly managed in order to complete it in time, within budget and with required specification (Lindebaum and Jordan, 2012). In terms of productivity, shorter working time based on IBS adoption will enable workers to work at ease without much congestion and at the same time can reduce workforce such as concreter, brick layer, plasterer, carpenter, electrician, plumber and etc. Thus, building components have to be assembled on-site with less exposure to harmful environment (CIDB, 2009).

IBS technology is considered as safe because the potential of a workers to be exposed to the harmful on-site is lesser compared to conventional construction methods. Besides the weather condition that can also cause sickness to construction workers, other danger related factors at the construction site itself should be considered as a risky working environment. Boyd et al. (2012) reported that there is a stricter safety policy on this issue and the realisation is that IBS technology adoption, by moving components off-site, not only improves safety for contractors’ employees and supply- chain partners, but also for the general public. Prefabricated elements used in IBS will reduce the usage of nails and bricks which are the main cause of accidents in construction tasks. In conventional construction for instance, brick laying starts as soon as the strip form is completed. However, in some cases, bricks will arrive on site before the completion of strip form. This will cause the congestion between the carpenters and the brick layer, thus the workers are at risk of falling formwork. These means that the IBS technology are proved to be more safety than the conventional (Shahrin and Zakaria, 2016).

Besides the issue of less wastage, IBS leads to less pollution which also give a positive impact towards increasing construction productivity. These is because, by reducing construction waste on site, the site is cleaner and eco-friendlier. Begum et al. (2010) presented a relatively strong view about the critical importance of waste management at site and its implications for sustainable development in the construction industry. Furthermore, noise pollution can also be reduced as IBS components are assembled on site.

2.7 Related Sustainability Factors

Sustainable development is an improvement that meets the needs of the present without compromising the ability of the future generations to meet their own needs (World Commission on Environment and Development, 1987). "Sustainability" is often talked about and interpreted differently by different parties. The construction industry in Malaysia takes the subject seriously as more buildings and projects are rated green. The concept of sustainability focuses on the preservation of the environment while critical development-related issues are designed into a construction project. Turner (2014) underlines the three key pillars for sustainability, which are economic development, environmental protection and social equity. As for this study that involves IBS technology adoption, technology element is also included as a part of sustainability setting as illustrated in Figure 2.1.

Figure 2.1: Sustainability factors

Furthermore, a more dynamic construction industry involves the reduction of regulatory obstacles and encouraging greater investment into the economy. Initiatives in environmental sustainability will deliver buildings and infrastructures constructed with eco-friendly requirements that are more energy-efficient, more responsible in their emissions of carbon and more resilient to natural calamities, all assisting to reduce the lifetime cost of the buildings and infrastructures. Sustainability factors namely environment, economy, technology and social are related to each other and they also have the potential to influence the quality and productivity of IBS adoption for post disaster building reconstruction (CIDB, 2016).

2.7.1 Environment

The international trend is moving towards higher demand for environment impact assessment (EIA) (Morrison-Saunders and Retief, 2012). Turner (2014) stated that the environmental interpretation of sustainability focuses on the overall viability and health of living systems. CITP (2016-2020) aims for Malaysia's environmentally sustainable construction to be a model for the emerging world, and especially ASEAN countries. This Environmental Sustainability Thrust as outlined in the CITP (2016-2020) is in line with the fourth strategic thrust of RMK11 which is 'Pursuing green growth for sustainability and resilience'.

There are three specific issues identified to be addressed under environmental sustainability:

- Lack of sustainability-rated construction; buildings and infrastructure are not always resilient to natural calamities.
- High carbon emissions and energy usage of buildings
- High volume of construction and demolition waste dumping

Through above issues highlighted by the CITP (2016-2020), they are expected to be solved through the implementation of IBS technology. IBS has the potential to solve the natural calamities as it has faster production of components using machineries that manufactures high and good quality of IBS building components with less wastage. IBS systems can reduce the use of natural resources or materials that can also reduce carbon emissions which care for the environment. Moreover, by reducing the volume of wastage on-site, there will be less waste pollution and has a better site condition compared to conventional construction methods due to an easier mechanism of construction sites. Besides, the practical of energy efficiency gives a better outcome of workmanship. IBS serves as an environmentally friendly method of construction. Moreover, the design of building projects through IBS systems which is based on building codes and standard with environmental requirements leads to the quality and productivity of building projects.

2.7.2 Economy

There is an adverse effect on the economy by choosing IBS as system to be applied on site. Through IBS, project cost can be saved in a long run, particularly in labour costs. As IBS technology adoption takes short period of time, this means that the cost to pay the construction workers also would be less. IBS reduces labour consumption which lead to reduction in cost and conflict. The outflow of money could be saved as the payment for labour can be reduces as well. Besides, as IBS components are ready-made in the factory, site workload also can be reduced. The components of IBS itself could be used many times such as the formwork, thus the cost also could be saved. The construction waste also could be recycled as an income. IBS technology adoption offers an opportunity to improve a variety of project performance indicators, particularly cost (Pasquire and Gibb, 2002).

Moreover, there is a greater understanding of the need for a more holistic approach if the construction industry is to contribute to an efficient and sustainable economy in the future (Myers, 2013). Besides, IBS offers moderate logistic costs and will offer better project price as compared to conventional construction methods thus contributes to economic sustainability (Mahazir and Viknesh, 2015)..

2.7.3 Technology

Among the topical scope included within each sustainability area covered in this rating scheme are energy and water efficiency (under economic), environmental protection and indoor environmental quality (under environmental) as well as other 'green' features (under technology). Blismas et al. (2010) acknowledged that in IBS technology adoption, innovation goals are notified and become a promising project accomplishment through cooperative innovations in IBS technology adoption. Adoption of IBS as a new technology in building construction is another strategy to sustain in the future.

Moreover, IBS technology is also related to energy, water and building material saving. In order to ensure technology sustainability, these components are made in the factory using machineries or an automation system. As these components are made in a casting area, a controlled environment can be strictly maintained, thus it would be easier to control on the mix, placement and curing of IBS components. IBS technology can reduce mistakes and rework time. IBS technology in terms of its performance is likely to be able to cope with its dynamics (Demiral et al., 2012).

2.7.4 Social

Social development usually refers to improvements in both individual well-being and the overall social welfare, which resulted from an increase in social capital. Turner (2014) describes the pillar representing social equity for sustainability as an entity that corresponds to areas of management that involve people such as leadership, public relations and human resources. Social sustainability aims to enhance the quality of life, create tools to carry products and services in a fair and equal way in its operational area, and make society well conducted (Chasey and Agrawal, 2013). IBS technology that reduces the dependency of foreign workers and reduces money outflow can also contributes towards overcoming social problems, low quality works, delays, and diseases (Oliewy, 2009).

Consequently, by highlighting several practical limitations in human energy, applying the economic sustainability rule comes together additional environmental and social safeguards. Moreover, IBS has the potential of considering social issues in the design and construction process such as project strategy, project management, people and communities, land use and landscape. Specifically, when construction time taken is shorter, this creates a positive impact on the society living around the construction sites. In addition, people are less exposed to the risks of dangerous environment as working on-site can be reduced with the reduction of heavy tasks, massive use of human operators and the pressure of hard physical or monotonous work. As for IBS technology, it can assist those tasks that are beyond human capabilities, thus provides a better outcome of work which resulting in good quality and productivity level.

2.8 Related Project Stages

Project stages are important to determine to progress of work and make sure each work can be completed by the dateline. Therefore, each stage play a different role of construction activities. In this research, a number of construction stages is involved such as design, planning, feasibility, construction and operation. During the construction stages, parts of the predicted benefits of IBS adoption are quality and productivity of construction, the reduction of unskilled workers and reliance on manual foreign workers, less wastage, less volume of building materials, speedier construction time, increased environmental and construction site cleanliness, reduced risk by improving health and safety, proper coordination and management.

2.8.1 Design

Design of IBS project will be different from the conventional method. It requires an IBS engineer and architect expertise in ensuring the success of an IBS project. This is because IBS design comes with a new standard or standardization and building codes.

Design team of a building project has to think ahead about logistics coordination during the design phase in order to avoid any problems during the transportation of IBS panels (Kassim et al., 2017).

According to Construction Industry Development Board, for achieving sustainable development in Malaysia and transforming the construction industry to be one of the best in the world, the framework of the Malaysian Construction Industry Master Plan fosters the implementation of IBS in building projects (CIDB, 2011). However, several construction and engineering aspects related to the IBS are yet to be fully realized in actual practice. As stated by (Kamar and Hamid, 2011), a majority of the current IBS applications both in design and prefabrication mainly support conventional building forms.

2.8.2 Planning

Implementing a building project requires a proper planning so that construction progress can run smoothly according to the required specifications. A very good planning helps the progress of building project becomes easier and faster. IBS requires new skills, procedure, business approach, investment planning and careful financial planning. In order to implement IBS technology into building construction, the project has to consider its strong capability in IBS design (Hamid et al., 2011).

During the planning and designing of a project, most architects and consultants are concerned with new materials and innovation to improve project efficiency (Schumacher, 2012). Shen et al. (2010) discover that building projects which are technologically driven, are based on a particular project planning. Therefore, as IBS technology involves a new paradigm in building construction, what more if it is to be