INDUSTRIALISED BUILDING SYSTEM (IBS) QUALITY TESTING FOR DISASTER RESILIENCE FROM TECHNICAL AND NON-TECHNICAL PERSPECTIVES

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By

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Date

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ABSTRAK

Industri pembinaan memainkan peranan penting dalam pembangunan sosio-ekonomi negara membangun. Industri ini merupakan sektor ekonomi yang khusus yang memberi sumbangan langsung kepada pertumbuhan ekonomi negara dan juga menyediakan asas kepada perkembangan sector-sektor lain. Peningkatan penggunaan Sistem Bangunan Industri (IBS) merupakan salah satu usaha galakan yang dibuat oleh kerajaan Malaysia untuk meningkatkan industri pembinaan. IBS merujuk kepada teknik pembinaan di mana komponen bangunan dihasilkan dalam persekitaran terkawal, sama ada di tapak atau di luar tapak, dan kemudian dipasang atau didirikan ke dalam pembinaan. Matlamat utama penyelidikan ini adalah untuk mengenalpasti ujian kualiti IBS sama ada ia berdaya tahan terhadap bencana dari perspektif teknikal dan bukan teknikal. Kajian ini berhasrat untuk mengenalpasti factor-faktor keutamaan dalam ujian kualiti IBS daya tahan bencana dalam proek-projek pembinaan dari perspektif pihak berkepentingan dalam industi pembinaan. Kajian ini dilakukan dengan menjalankan penyelidikan kuantitatif dan kualitatif dalam kalangan 40 responden. Pada akhir penyelidikan, kriteria bahan dan ketahanan merupakan kriteria keutamaan di bawah kategori faktor teknikal manakala produktiviti dan ekonomi adalah kriteria peringkat tertinggi di bawah kategori bukan teknikal. Adalah disimpulkan bahawa faktor teknikal dianggap sebagai lebih dominan dari segi ujian kualiti IBS untuk daya tahan bencana manakala faktor-faktor yang bukan teknikal turut memainkan peranan mereka tetapi kurang signifikan berbanding dengan faktor teknikal untuk ujian kualiti IBS. Di masa akan datang, adalah diharapkan IBS boleh ditambahbaik dari segi kuanlitinya dan meluaskan pasarannya di peringkat antarabangsa dalam pengurusan bencana.

ABSTRACT

The construction industry plays an important part in the socio-economic development of a developing nation. This industry is a distinct sector of the economy which makes direct contribution to the country's economic growth and also provides the basis upon which the other sectors can grow. Increased adoption of the Industrialised Building System (IBS) is one of the rapid encouragement efforts made by the Malaysian government to enhance the construction industry. IBS refers to a construction technique whereby building components are manufactured in a controlled environment, either on-site or off-site, and then installed or erected into construction. The main goal of this research is to determine IBS quality testing whether it is disaster resilient in terms of technical and non-technical perspectives. This research to determine the priority factors in IBS quality testing for disaster resilience in building projects from the perspective of stakeholders in the construction industry. This research was performed by conducting a quantitative and qualitative research among 40 respondents. At the end of the research, materials and durability criteria are ranked as the priority criteria under the technical factor category while productivity and economics are the highest ranked criteria under the non-technical category. It is concluded that the technical factors are perceived to be more dominant in terms of IBS quality testing for disaster resilience while non-technical factors also play their roles but are less significant compared to technical factors for IBS quality testing. Based on this research, it is expected that IBS can be further improved in terms of its quality and expand its market at the international level in disaster management.

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CIDB	**C**onstruction **I**ndustry **D**evelopment **B**oard
CITP	**C**onstruction **I**ndustry **T**ransformation **P**rogram
ETP	**E**conomic **T**ransformation **P**rogram
IBS	**I**ndustrialised **B**uilding **S**ystem
MOF	**M**inistry **o**f **F**inance
RMK11	**R**ancangan **M**alaysia **K**esebelas (Eleventh Malaysian Plan)
UNISDR	**U**nited **N**ation **I**nternational **S**trategy for **D**isaster **R**eduction

CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter gives an introduction to the research topic. It includes a background to the study and the research problem that is intended to be solved. Besides that, this chapter also includes the research objectives, scope and limitation of the study, benefits of the study and the dissertation outline. This chapter gives an overview to the overall aspects of the research study and justifies its relevance and importance to the construction industry.

1.2 Background

The construction industry plays an important part in the socio-economic development of a developing nation. This industry is a distinct sector of the economy which makes direct contribution to the country's economic growth and also provides the basis upon which the other sectors can grow. Abdullah and Egbu (2010) acknowledge that over the last four decades Malaysia has successfully transformed from a nation with a traditional industrial economy to a developing nation with a modern economy.

As stated in a quotation by former Prime Minister of Malaysia, Dato' Seri Najib Tun Razak,“ The importance of the construction industry to Malaysia's economy cannot be overstated as this industry has traditionally been a substantial driver of growth, and looking to the future, we expect this trend to continue and expand” (CIDB, 2016). The construction industry is an investment-led sector, hence the government has continuously invested time and fund to future enhance this industry. Both the Eleventh Malaysia Plan

(RMK11) and the Economic Transformation Program (ETP) calls for significant physical infrastructure developments to achieve Malaysia’s ambition of becoming a high-income nation by 2020. Hence, the Construction Industry Development Board of Malaysia (CIDB) has proactively developed a master plan, which is the Construction Industry Transformation Program (CITP) 2016-2020 to empower and strengthen the construction industry as espoused in the thrusts of the Eleventh Malaysia Plan (CIDB, 2016).

Increased adoption of the Industrialised Building System (IBS) is one of the rapid encouragement efforts made by the Malaysian government to enhance the construction industry. IBS refers to a technique of construction whereby building components are manufactured in a controlled environment, either on-site or off-site, and then installed or erected into construction (CIDB, 2016). Benefits of IBS in construction has been well-documented such as improved quality of workmanship and material precision, but despite high-profile projects such as the Petronas Twin Towers and Putrajaya, both of which include pre-fabricated components, uptake of IBS solutions in the Malaysian construction industry has been slower than expected.

Malaysia is located in a geographically stable region as it is outside the Pacific Rim of Fire, hence it is relatively free from extreme natural disasters such as earthquakes, tsunami, cyclones, floods and etc. Figure 1.1 indicates the frequency of occurrence of natural disasters in Malaysia between the years 1990-2014. According to the figure, the most or frequently occurring natural disaster in Malaysia are flood, storm and landslides.

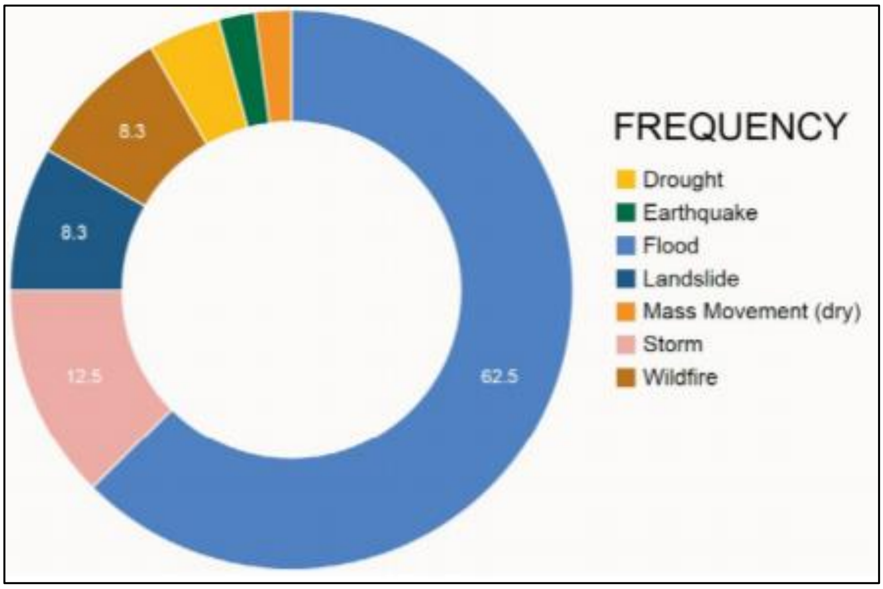

Figure 1.1: Frequency of Natural Disasters in Malaysia between years 1990-2014.(CFE-DM, 2016)

The typical management for disasters in Malaysia are through a government-centric top—down approach which is illustrated in Figure 1.2 which shows the integrated involvement of relevant agencies in Malaysia.

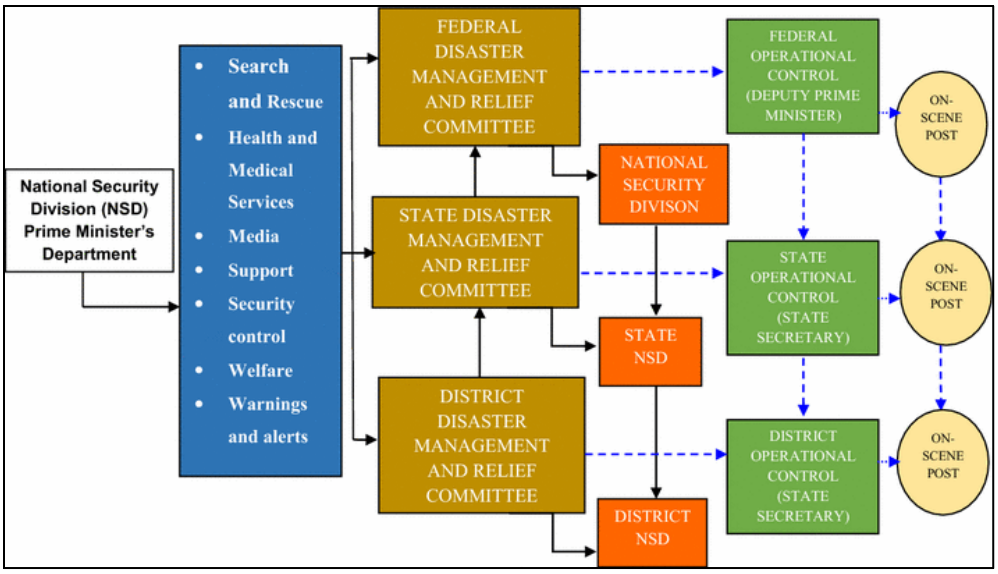

Figure 1.2: Disaster Management Level/ Executive Committee (Zawawi et al., 2018)

However, Khalid and Shafiai (2015) have stated that the pre-disaster system in Malaysia requires some improvements to prevent negative impact and damage of disaster in the future because of changing climate with different pattern.

Resilience is defined as the ability of the built system to sustain its function under expected and unexpected conditions (Hollnagel, 2014). Generally, disaster risk management is a reactive strategy post-disaster, however a resilient-built environment can ensure that the built assets abilities are maximised and it will be a more robust version from its original (Bosher, 2008). Thus, a more holistic shift of resilience is essential where greater pro-active and preparedness are required rather than just traditional reactive strategies. One of the ways to ensure built environment resilience is through structural mitigation. As explained by Bosher (2008), structural mitigation is the strengthening of buildings and infrastructure exposed to hazards via building codes, engineering design and construction practices (Bosher, 2008). Building resiliency can ensure that structures can stand the test of time and operate as function despite being exposed to destructive mechanisms and disasters (Aldrich, 2012).

1.3 Problem Statement

As defined by Kamaruddin et al. (2013), IBS is a construction technique where components are manufactured on or offsite, transported and then assembled into a structure with the minimum of work. In the CITP plan, increased implementation of IBS into new construction projects is greatly highlighted because of the low adoption rate in the construction industry. According to CIDB (2016) only 24 of target projects worth more than RM10 million achieve 70 IBS score despite Ministry of Finance (MOF) circular. Currently, many small contractors are reluctant to adopt IBS system and as they prefer to continue using the conventional method of construction (Nawi et al., 2011). This is due to the fact that contractors are familiar with the conventional system and the technology is suitable with small scale projects and therefore not willing to switch to IBS a mechanized based system (Mohamad et al., 2016). The CITP (2016-2020) plan also recognizes that one of the reason for the limitation in IBS adoption is due to the relatively small pool of IBS specialist and the lack of standards and guidelines for the testing of IBS products.

As the CITP (2016-2020) plan looks forward to increasing productivity at the construction site via IBS products and also has initiatives for internationalisation which is to make construction practices and standards as universal in line with the CITP key outcome by year 2020 which is to have more than 10 construction related companies exporting construction services in the global market. This research represents a case study to discover factors influencing the testing of IBS products to encourage the implementation of IBS in building projects.

1.4 Objectives

The main goal of this research is to explore quality testing in IBS components or products and whether it is disaster resilient. The perception and opinion of the respondents who are contractors and consultants that are actively involved in the construction industry using IBS products are important in order to achieve the goal of this study

Therefore, the research objectives of the study are as below:

1. To determine the technical and non-technical factors influencing IBS quality testing for disaster resilience in construction projects.
2. To conduct a comparative study on the ranking factor from technical and non-technical perspectives that influence IBS quality testing for disaster resilience for construction project.
3. To determine list of criteria that is relevant to ensure quality testing for disaster resilience in IBS for construction projects.
4. To prepare a conceptual model on technical and non-technical factors that influence IBS quality testing for disaster resilience in construction projects.

1.5 Research Question

There are various studies that have been performed on IBS implementation, building components tests and disaster resilience. However, literature review carried out (as discussed in Chapter 2) on IBS quality testing showed lack of studies on the opinion of construction-profession stakeholders regarding IBS quality testing for disaster resilience. Thus, in order to investigate the technical and non-technical factors in IBS quality testing for disaster resilience, the following research question has been formulated to guide this research:

> ***How does quality testing for disaster resilience IBS technology influence adoption from technical and non-technical perspectives?***

1.6 Scope of Work

The study is limited to the perception of a sample of local respondents who are stakeholders in the construction industry. This group of respondents vary from professionals amongst construction industry members who are involved or work with IBS technology. It is vital for the research to gather the perception of these stakeholders as their perception will be different than those who have not worked with IBS because of their working experience, knowledge, skills, construction experience, project exposure and background (Syed Zakaria, 2014). Data collected from the survey was analysed, interpreted and discussed as part of the findings of the study.

1.7 Benefits and Importance of Research

This study emphasises on the significant of IBS quality testing for disaster resilience Thus, the benefits of this study include to develop insight to IBS testing for overall product standardization. This is in line with one of the four strategic thrust of Construction Industry Transformation Programme (CITP) 2016-2020 which is internationalization. One of the key outcome under the internationalisation strategic thrust is that 10 more construction related companies export construction services in the global market (CIDB, 2016). The emphasis on quality testing for any product can improve its competitiveness, capability and capacity to foray internationally and ensure it achieves international standards. Hence it enables local IBS products with standardized testing to be marketed internationally.

Consequently, this study also fills the research gap in Malaysia for IBS testing. Through the qualitative and quantitative data collection method, the ranking for technical and non-technical factor to ensure IBS quality testing for disaster resilience can be evaluated. The questionnaire and interview survey explores the industry stakeholder's opinion regarding the importance of quality testing for IBS products and also the relevancy of disaster resilient built environment for upcoming construction projects in Malaysia.

1.8 Dissertation Outline

This research explores IBS on quality testing aspects for disaster resilience. The research has five chapters which are as follow

i. **Chapter 1** gives an introduction to the research topic, the objectives, scope of study and also the benefits of the study to the construction industry.
ii. **Chapter 2** comprises of the literature review on quality testing of Industrialised Building System (IBS), disaster resilience of IBS and importance of quality testing for the internationalisation of IBS. The details of each technical and non-technical factors are also highlighted.
iii. **Chapter 3** discusses regarding the methodology of the study. It comprises of the structure and list of questionnaire and interview, survey process and analysis method.
iv. **Chapter 4** discusses the result of the questionnaire and interview analysis. The classification and hierarchy of the technical and non-technical factors are outlined in this chapter.
v. **Chapter 5** present and draws the conclusion of the study results. A conceptual framework on quality testing for disaster resilience and some recommendations are suggested in this chapter for future study on IBS quality testing for disaster resilience in the construction industry.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

The main goal of literature review is to examine existing literatures such as books, scholarly articles, journals and etc. and to provide a description or evaluation of past works that are relevant to the research problem being investigated. It provides an up to date understanding and evaluation on the subject including the latest technologies and methods available in the construction industry pertaining IBS implementation. Besides that, it enables researchers to establish a theoretical framework for the study topic.

This chapter establishes and explains key terms such as Industrialised Building System (IBS), disaster resilience, quality testing and etc. It also explains the technical and non-technical factors through surveys on existing papers by credited scholars.

2.2 Industrialised Building System (IBS)

IBS is the focus of many government and private initiatives to increase the quality of the building and construction industry. Although the benefits of IBS are widely recognised, there are a number of issues to IBS implementation that should be handled in order to expand the adoption of IBS.

2.2.1 Definition of IBS

There are various definition for the term IBS that are formulated by different researchers. However, the current definitions of components qualifying as IBS is vague as there is a lack of standard for IBS components (CIDB, 2016). Generally, IBS is defined as a method of construction developed due to human investment in innovation and on rethinking the best ways of construction work deliveries based on the level of industrialization (Abdullah and Egbu, 2010). Meanwhile, the Construction Industry Development Board (CIDB) has defined IBS as a technique of construction whereby building components are manufactured in a controlled environment, either on-site or off-site, and then installed or erected into construction (CIDB, 2016). IBS is an innovative process of building construction using concept of mass-production of industrialised systems, produced at the factory or onsite within controlled environments, it includes the logistic and assembly aspect of it, done in proper coordination with thorough planning and integration (Kamar et al., 2011).

2.2.2 Overview of IBS in Malaysia

The usage of IBS system in Malaysia has been implemented since early 1960's. The two pilot projects for IBS in Malaysia are the 22.7 acre low cost housing scheme in Jalan Pekeliling, Kuala Lumpur in the year 1966 and the 1968 housing project at Jalan Rifle Range, Penang (Din et al., 2012). According to Din (2012), the popularity of IBS construction peaked in 1990's when many Malaysian infrastructures and mega projects were built such as the Bukit Jalil Sports Complex, Kuala Lumpur Convention Centre, Lightweight Railway Train (LRT) and the Petronas Twin Towers. These projects are now some of the national landmarks in Malaysia. Figure 2.1 presents the evolution of IBS implementation in the Malaysian construction industry from the year 1960 to 2015.

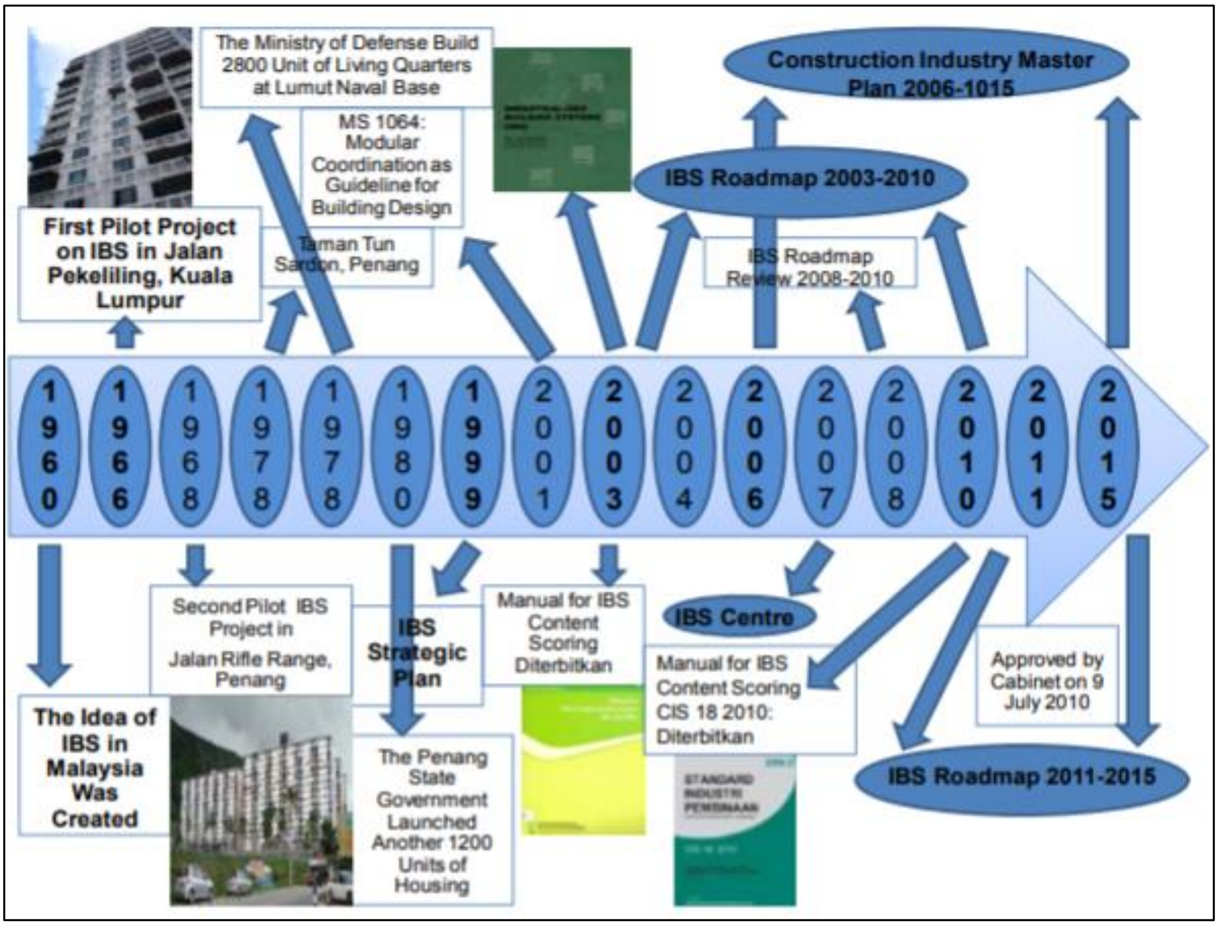

Figure 2.1: IBS Timeline in Malaysia (Abedi et al., 2011)

Even as IBS has been introduced in the Malaysian market well over 5 decades ago, the rate of adoption for projects are still low where only 24% of projects worth more than RM 10 million achieved 70% IBS score despite MOF circular (CIDB, 2016). Besides that, CITP 2016 reported that another factor that results in low adoption of IBS is that there is limited enforcement for IBS requirements which results in limited economies of scale. Hence, CIDB has launched a new strategic plan which is CITP 2016 and one of the expected key outcome is accelerated adoption of IBS mechanisms in construction practices (CIDB, 2016). Therefore, it has been encouraging for the construction entities to discover the opportunities of IBS growth, not only in terms of the breadth of geographic coverage, but through economics of scale.

2.2.3 Classification of IBS

According to the building system classification by CIDB, the six main groups of IBS that are popular in the Malaysian construction industry are as follow (MIDF, 2014):

a. Pre-cast concrete framing, panel and box system
   - This system consists of precast concrete columns, beams, slabs, walls, 3D components such as staircases, lightweight precast concrete and permanent concrete formwork

b. Steel formwork system
   - This system is made from tunnel forms, beams and column moulding forms and permanent steel formworks. MIDFR reports that this system has the least pre-fabrication among the other systems as it involves site casting. Hence, it requires stringent quality control, high quality finishes and fast construction with less site labour and material requirement.

c. Steel framing system
   - Common usage of this system is with precast concrete slabs, steel columns/beams and steel framing systems. It is widely used in rapid construction of high rise structures.

d. Timber framing system
   - This system involves prefabricated timber truss beams and columns. The usage of these products are popular for simple dwelling units such as chalets because of its attractive designs and high aesthetic values.

e. Blockwork system

  - Interlocking concrete masonry units (CMU) and lightweight concrete blocks are mainly used for non-structural wall as an alternative to conventional brick and plaster.

f. Innovative system

  - This system is the newest IBS type that incorporates various sustainable elements. An example of the innovative mixture of two elements are polystyrene and concrete that is used to produce IBS components that has better heat insulation properties.

2.3 Quality Testing

In the construction industry, quality testing is an important method to ensure the efficiency and effectiveness of a construction process. Hence, it is also a mechanism to achieve the required specification of a project performance. In order to examine the aspects of disaster resilience for IBS implementation in construction projects, quality testing plays an important role in this aspect.

2.3.1 Definition of Quality

Mallawaarachchi and Senaratne (2015) define quality as meeting and conforming to the requirement of the legal, aesthetic and functional requirements of a project. Quality management is to ensure efforts to achieve the required level of quality for the product which is well planned and organized. Quality management in construction projects involves maintaining the quality of construction works at the required standard so as to obtain customers' satisfaction that would bring long term competitiveness and business survival for the companies (O'Brien, 2012).

According to Rumane (2017), quality can be characterized as follows.

- Meeting the requirements of the owner as to functional adequacy; completion on time and within budget; lifecycle costs; and operation and maintenance.
- Meeting the requirements of the design professional as to provision of well-defined scope of work; budget to assemble and use a qualified, trained and experienced staff; budget to obtain adequate field information prior to design; provisions for timely decisions by owner and design professional;

and contract to perform necessary work at a fair fee with adequate time allowance.

- Meeting the requirements of the constructor as to provision of contract plans, specifications, and other documents prepared in sufficient detail to permit the constructor to prepare priced proposal or competitive bid; timely decisions by the owner and design professional on authorization and processing of change orders; fair and timely interpretation of contract requirements from field design and inspection staff; and contract for performance of work on a reasonable schedule which permits a reasonable profit.

2.3.2 Importance of Quality for Construction Projects

Quality is one of the critical factors in the success of construction projects where the quality of construction projects is linked with proper quality management in all the phases of project life cycle (Mallawaarachchi and Senaratne, 2015). According to Mallawaarachchi and Senaratne (2015), quality of construction projects is regarded as the fulfilment of expectations of the project participants by optimizing their satisfaction because quality outcomes of the projects that are not according to required standards will result in faulty construction. Testing and inspection requirements are combined into specifications to emphasize quality control and provide an organized location in which all quality control issues are identified to the bidders in a construction project (O'Brien, 2012).

2.4 Disaster Resilience

Disaster management has received much attention in recent years due to paradigm shift, from managing the disaster itself to ensuring disaster resilience in the construction industry. In this case, IBS implementation should incorporate quality testing elements to ensure the attainment of disaster resilience

2.4.1 Concept of disaster resilience

This concept requires an understanding of not only how people perceive disaster environment and its exposure, but also of the important elements or steps within which knowledge and understanding about disaster resilience are managed, as illustrated in Figure 2.2.

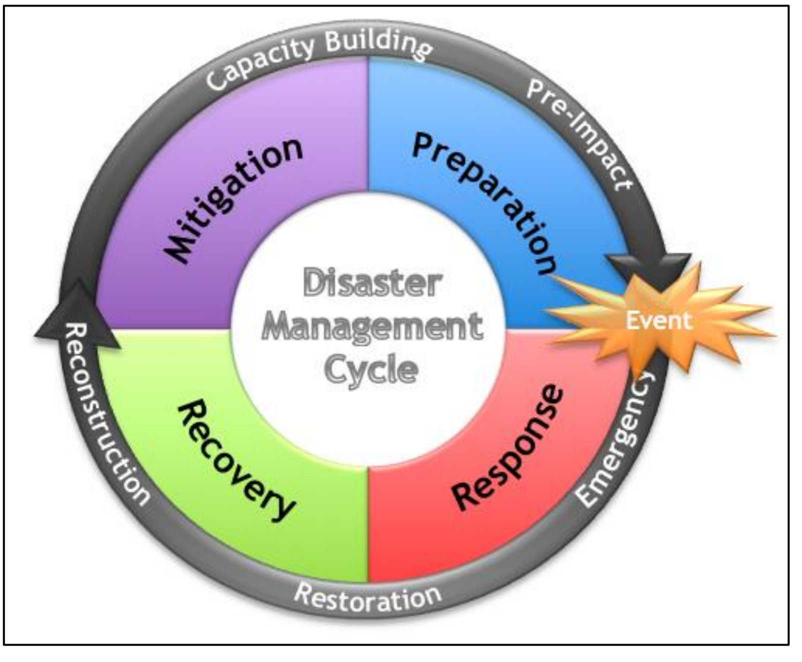

Figure 2.2: Disaster Management Cycle (Carter, 2008)

Figure 2.2 illustrates the four phases of the disaster management cycle which shows the ongoing process by which government, businesses and civil society plan for and reduce the impact of disasters, react during and immediately following a disaster (Carter, 2008). The four phases encompassed in the cycle are:

a. *Mitigation*

- Mitigation efforts are attempts to prevent hazards from developing into disasters or to reduce the effects of disasters. Mitigation measures can be structural or non-structural. Structural mitigation is the strengthening of buildings and infrastructures exposed to hazards while non-structural mitigation are efforts such as directing new development away from known hazards location through land use plans and regulations (Bosher, 2008).

b. *Preparedness*

- Preparedness is a continuous cycle of planning, organizing, training, equipping, evaluation and improvement activities to ensure effective coordination and the enhancement of capabilities to prevent and mitigate the effects of disasters.

c. *Response*

- The response phase includes the mobilization of the necessary emergency services and first responders to the disaster area.

d. *Recovery*

- Recovery aims to restore the affected area to its previous phase where the efforts are concerned with issues and decisions that need to be made after immediate needs are addressed.

According to Bosher (2008), there is now three themes of resilience that are articulated in the concept of disaster risk management which are:

- A shift towards greater mitigation and preparedness than reactive disaster management
- A broadening of the disaster risk management to increase focus on technology and human induced hazards
- Broaden the concept of resilience to also include the resilience of private business and communities.

2.4.2 Definition of disaster resilience

A system can be seen as resilient if its structure couldn't be changed by the disturbance such as adverse events or natural disaster, which would not exceed the upper magnitude of disturbances that will destroy the structure of the system (Wang et al., 2017). The United Nations Office for Disaster Risk Reduction (UNISDR) defines resilience as the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazards in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management (UNISDR, 2017).

2.5 Technical Factors

Technical factors are fundamental part of procedural analysis that also act as an indicator in evaluating a construction project. Many technical indicators have been developed and new variants continue to be developed in construction projects, including IBS implementation with the aim of getting better results. In this study, there are three major factors that are listed as technical factors for IBS quality testing for disaster resilience which are, design criteria, standardization and durability.

2.5.1 Design Criteria

The design criteria are vital for any project and are considered as the back bone for any construction projects. The design for each structural component will determine the strength of the infrastructure. Appropriate selection of materials, the configuration and capacity of, such a frame is vital to the short and long term performance of the building (Chen et al., 2010). Even in the construction industry, stakeholders are trying to exercise quality testing in order to develop strategies that create passionate attachments to a particular building design.

Prefabrication appears to be an advantages solution to tackle major causes of waste during both design and construction stages (Seman et al., 2013). The changes of last minute design especially after the IBS panels are already being installed can influence the quality of the components itself due to the changes to the loads that have been calculated (CIDB, 2016). The design criteria are also affects from the Modern Methods of Construction (MMC) for both IBS and conventional construction.

2.5.2 Standardization

One of the important aspects in planning and monitoring the process of construction projects is standardisation (Shukor et al., 2011). The proposed model merged features related to the sustainable system including economic, social, environmental and organizational criteria with IBS include prefabricated, produced outside the workshop, standard components, repeatability and modulation, and finally, they presented sustainable industrial building systems (Yunus and Yang, 2012). The compelling benefits of standardization in prefabricated components includes shortened time for actual site installation, higher level of quality assurance and safety and fewer backorders (Nawari, 2012).

These standardisation issues pertaining to quality test have also influenced IBS implementation related to disaster resilience. One of the effective means to avoid disharmonies among the entities of the construction industry is the implementation of standardisation of IBS technology requirements and to inculcate this role as a part of its policy on IBS technology adoption in building-project settings.

2.5.3 Materials

Materials are one of the important factors that contribute to the performance for the structures of building projects. According to Lachimpadi (2012), usage of IBS in building construction can results in overall reduction of material usage. This can be observed in the adoption of prefabrication and interlocking block systems where structural framing can be eliminated and this can be deduced to reduce construction material usage such as cement, sand, steel and timber (Bari et al., 2012).

IBS quality tests with new building concepts, materials, manufacturing process and construction techniques would mean that every building project could be different in terms of disaster resilience, with the entities of building projects effectively able to design and construct a customised building project. During the testing process of building components, project members are concerned with new materials and innovation to improve project efficiency.

2.5.4 Durability

It is well known that most high value construction projects prefer to use IBS products because it produces higher quality of components through its careful selection of materials, use of advanced technologies and strict quality assurance (Sashitaran, 2014). For instance, Van Straaten (2016) reports that designers often consider precast concrete to provide a low-maintenance, durable and high-performance solution as requirement for thermal performance, air leakage and rain penetration control in modern buildings.

Precast concrete wall systems are acknowledged to provide increased security during disasters as they provide protection from projectiles (wind borne, thrown, shot, explosion) and require little repair after the disaster (Van Straaten et al., 2016). It has been discovered that IBS quality testing is also influenced by the technical innovations of IBS technology in terms of standardisation, durability and method, particularly of IBS components.

2.6 Non-Technical Factors

Generally, non-technical factors refer to indicators that are not relating to or involving science or technology and not having or requiring specialized or technical knowledge. There are four factors in this study that are listed as non-technical factors for IBS quality testing for disaster resilience which are sustainability, economics, internationalisation and productivity.

2.6.1 Sustainability

Sustainability constructions nowadays are almost recognized in construction industries around the world. Seven principles of sustainable construction; reduce consumption of resources (reduce), reuse resources (reuse), use recyclable resources (recycle), protect nature (nature), eliminate toxics (toxics), apply life cycle costing (economics), and focus on quality (quality). These principles are provided as a benchmark in driving and creating a better world for future generations (Kibert, 2016).

The sustainability factor attributes to the stakeholder like contractors and consultants. The important of sustainability issues has been increased among global community and it is necessary for all parties involved (Kamar et al., 2009). IBS adoption has been identified as a solution to promote sustainability construction (Yunus and Yang, 2011). It can be concluded that the consideration of sustainability aspects in quality testing for IBS implementation has provided greater insight into concerns about the interaction between IBS technology adoption and the physical environment in the construction industry.

2.6.2 Economics

Malaysian construction sector provides many opportunities for building projects to adopt new technology like IBS. Economic aspect is the primary engine of growth that can ensure Malaysia's goal to become a high-income nation. The CITP (2016-2020) has put forward measures to raise the economic levels of the construction industry. One recommendation provided is for the adoption and utilisation of modern construction methods and technologies to address economic challenges, including handling disaster resilience (CIDB, 2016).

Adoption of advanced technologies will be achieved through economic aspects to ensure the workforce is equipped with the skills necessary to adopt technology in a meaningful way. In making economic choices, construction stakeholders are influenced by market and social factors to rationalise and predict a new phenomenon in the market environment (Walls and Hoffman, 2013).

2.6.3 Productivity

A key concern in the Construction Industry Transformation Plan 2016-2020 issued by CIDB is the productivity levels of the construction industry is one of the lowest in Malaysia's economy as compared with developed economies (CIDB, 2016). Besides that, the reality of the construction industry that the uptake on new technology and modern practices is still slow.

Meanwhile, Low (2011) and Zabihi et al. (2013) focus on the key important legislations relating to, not only public health and safety in the usage of IBS components, but also to quality and productivity, workplace safety and environmental sustainability.