

**TITLE**

**BARRIER-DRIVER MODEL FOR ENHANCEMENT OF ICT  
IMPLEMENTATION IN IBS PRODUCTION PROCESS MANAGEMENT IN  
CONSTRUCTION INDUSTRY**

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## **ABSTRACT**

In Malaysia, as a result of the government's initiative and future outlook in advancing the use of innovative technologies, the Industrialised Building System (IBS) approach is actively promoted through several strategies and incentives as an alternative to conventional building methods. Extensive implementations of modern Information Communication Technology (ICT) applications are able to support the different IBS processes for effective production. However, it is argued that ICT uptake at the organisational level is still in its infancy. This raises the importance to explore the extent of effective implementation of ICT usage in the IBS production process management. In the context of Malaysia, there is so far no existing enabling model developed specifically to encourage further implementation of ICT in the IBS supply chain. Hence, this research aims to develop a model to enhance ICT implementation in IBS production process management in Malaysian construction projects through the identification of barriers and drivers in the implementation of ICT. A multi-faceted research approach was adopted using mixed methodology. Initially, a literature review on ICT implementation in IBS production management was conducted. This was followed by an exploratory interview survey involving IBS industry key stakeholders in Malaysia in order to investigate the current industrial practice of ICT implementation in IBS production management. Consequently, critical barriers and drivers to ICT implementation were identified through questionnaire survey with industry stakeholders. The interview data was analysed using the content analysis technique whilst the questionnaire data was analysed using statistical tests such as t-tests, mean indexing and critical t-value with the use of SPSS software. Based on the identified barriers and drivers, a model to enhance ICT implementation which highlights the priority ranked ICT implementation barriers and drivers was developed.

## ABSTRAK

Hasil daripada inisiatif kerajaan Malaysia dan penglihatan masa hadapan dalam memajukan penggunaan teknologi inovatif, pendekatan *Industrialised Building System* (IBS) kian aktif digalakkan melalui beberapa strategi dan insentif sebagai alternatif kepada kaedah pembinaan konvensional. Pelaksanaan aplikasi Informasi Komunikasi Teknologi (ICT) moden yang meluas dapat menyokong proses IBS yang berbeza dan menjadikan pengeluaran berkesan. Walau bagaimanapun, ia diperdebatkan bahawa implementasi ICT di peringkat organisasi masih di peringkat awal. Ini menimbulkan kepentingan untuk mengkaji setakat mana implementasi ICT dalam pengurusan proses pengeluaran IBS. Dalam konteks Malaysia, tiada model yang dihasilkan khusus untuk membantu menggalakkan implementasi ICT dalam rangkaian bekalan IBS. Oleh itu, kajian ini bertujuan untuk menghasilkan satu model untuk meningkatkan pelaksanaan ICT dalam IBS pengurusan proses pengeluaran dalam projek-projek pembinaan di Malaysia. Pendekatan penyelidikan pelbagai aspek telah diguna pakai dalam kajian ini. Pada mulanya, kajian literatur untuk implementasi ICT dalam proses pengurusan IBS telah dijalankan. Ini diikuti dengan temubual yang melibatkan pakar dalam industri IBS di Malaysia. Kajian kes telah menyelidik tentang pelaksanaan ICT dalam proses pengurusan IBS industri semasa. Seterusnya, kekangan dan pemandu kritikal untuk model implementasi ICT telah dikenal pasti melalui kajian soal selidik dengan pakar IBS industri. Data daripada temubual telah di analisa dengan ‘teknik analisis kandungan’ sementara data kajian soal selidik di analisa melalui ujian statistic seperti *t-test*, min index, kritikal t-nilai dengan perisian SPSS. Berdasarkan halangan dan pemandu yang dikenal pasti, model untuk meningkatkan pelaksanaan ICT yang menunjukkan halangan dan pemandu pelaksanaan ICT mengikut keutamaan telah dihasilkan.

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**LIST OF ABBREVIATIONS**

Auto-ID	Automatic Identification
BIM	Building Information Modelling
BIMMI	Building Information Modelling Maturity Index
BOM	Bill of Material
CAD	Computer-Aided Design
CAM	Computer Aided Manufacturing
CIDB	Construction Industry Development Board
CIM	Computer integrated manufacturing
CMU	Concrete masonry units
CREAM	Construction Research Institute of Malaysia
CSF	Critical Success Elements
DSS	Decision Support Systems
EDI	Electronic Data Interchange
GIS	Geographical Information Systems
GPS	Global Positioning Systems
IBS	Industrialised Building System
ICT	Information Communication Technology
IS	Information Systems
IT	Information Technology
JIT	Just in Time
JKR	Public Works Department
KM	Knowledge Management
KPI	Key Performance Indicator

LAN	Local area network
MC	Modular Coordination
NeTI	National e-Tendering Initiatives
OSM	Off-site manufacture
PC	Personal Computer
PDA	Personal Digital Assistants
PDT	Portable Data Terminals
PFI	Public Funding Initiatives
PIS	Precast Internal System
PPP	Public–Private Partnerships
PWD	Public Works Department
R&D	Research and Development
RF	Radio Frequency
RFID	Radio Frequency Identification
RISP	Registered IBS System Providers
RTC	Resistance to change
SME	Small medium Enterprise
SPSS	Statistical Package for Social Sciences
TMS	Top management support
TRI	Technology readiness index
VERDICT	Verify End-User e-Readiness using a Diagnostic Tool
WAN	Wide area networks



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## CHAPTER 1

### INTRODUCTION

#### 1.1 Background of Research

Industrialised Building System (IBS) is defined as a construction technique in which components are manufactured in a controlled environment (on or off site), transported, positioned and assembled into a structure with minimal additional site works (IBS Roadmap, 2003). The benefits of IBS, also called offsite construction have been widely studied and include reductions in time, defects, health and safety risks, environmental impact, and whole-life cost with a consequent increase in predictability, productivity, whole-life performance and profitability (Gibb and Isack, 2003; Venables and Courtney 2004; Pan *et al.*, 2007; Tam *et al.*, 2007; Eastman and Sacks, 2008). There are different IBS systems such as formwork systems, pre-cast concrete framing systems, panel and box systems, steel framing systems, prefabricated timber framing systems and blockwork systems. This research focuses on pre-cast concrete systems.

The government of Malaysia considers the usage of IBS as being low despite its potential advantages. According to Kamar and Hamid (2009), although the administration infrastructure of the IBS Roadmap is well in place, the market still has yet to fully embrace the IBS technology. In order to allow continuous IBS uptake, a number of barriers were identified as being potential hurdles to the IBS implementation. IT is identified as one of the Critical Success Elements (CSF) or enablers for IBS adoption (Kamar, 2011). Hamid *et al.* (2008) also pointed out that observed lack of

Research and Development (R&D), low Information Technology (IT) adoption and limited technology availability have generally discouraged IBS take up in Malaysia.

Accordingly, appropriate implementation of Information Communication Technology (ICT) could in fact facilitate more effective and productive materials management processes. Extensive use of modern IT tools supports the different IBS processes by enabling more accurate documents and hence good conditions for an effective production where errors are discovered early and problems in the manufacturing and assembly phases can be avoided (Lessing, Ekholm and Stehn, 2005). More sophisticated solutions of ICT based technologies in IBS processes are emerging, such as wireless communication, bar-coding and Radio Frequency Identification (RFID) for tagging technologies. Besides that, findings showed that Building Information Modelling (BIM), a 3D modelling software is able to resolve many technical difficulties in the precast construction processes. For instance, design errors caused by inconsistent 2D drawings are able to be eliminated with the adoption of BIM in the precast concrete industry (Eastman *et al.*, 2008). As a result, there is a drastic reduction in engineering lead time and greater support for automation in production.

However, it is argued that ICT uptake at the organisational level is still in its infancy. Recent studies in the area of 'IT failure' have shown that 75% of IT investments did not meet their performance objectives (Alshawi, 2007). There is ample evidence that ICT has not been proficient to bring about a competitive advantage to organisations in spite of the large investments over the past decade, and a large percentage of systems have failed to achieve their intended business objectives. Past similar researches to improve ICT implementation in the construction industry have been conducted. For instance, studies carried out by Peansupap (2004) on elements influencing ICT diffusion; Miozzo *et al.* (1998) derived an IT-enabled process strategy for construction; Santos and Sussman (2000) on improving the return on IT investment for greater productivity; Ruikar *et al.*, (2006) developed VERDICT, an e-readiness assessment application for construction companies; Kasim (2008) on improving construction materials management with RFID adoption and Al-Bazi *et al.* (2010) on improving performance and the reliability of off-site pre-cast concrete production

operations using simulation optimisation. In Malaysia, Aziz and Salleh (2011) developed a readiness model for IT investment in the construction industry; Jaafar *et al.* (2007) studied in the technology readiness assessment of Malaysian contractors. However, no notable research or industry initiatives had been undertaken in Malaysia, specifically in terms of ICT implementation in the IBS process management.

Hence, this study is significant in recognising the existing ICT implementation and identifying key current elements that are affecting the ICT implementation in the IBS process management. The findings will then be significant to be the basis for developing a model to improve the ICT implementation amongst the IBS construction players in Malaysia. The proposed model is expected to enhance IBS process management and accordingly quicken the momentum en route to construction mechanisation in Malaysia.

## **1.2 Problem statement**

Opting for a highly manual-oriented approach in IBS component manufacture can result in low quality in processing data and too much time and effort required, subsequently resulting in infrequent and incomplete project control. Current practice shows that manual data collection at construction sites is not an approach which satisfies the information requirements for today's projects (Ergen, Akinci and Sacks, 2007). Implementation of ICT holds a potential key to improve the overall process management of IBS and hence encourage greater uptake of IBS usage. Lessing *et al.* (2005), Eichert and Kazi (2007), CIDB (2003), and Hervas (2007) suggested the utilisation of IT in IBS projects to support integration, provide accurate data, help customers in the selection process, distribution logistics and cost comparison.

With regards to this, the current practice of ICT implementation in the tracking of IBS components in Malaysia is also rather uncommon. Kamar, Hamid & Alshawi (2010) pointed out the lack of effective logistics management in the Malaysian construction industry, where technology intervention plays a very critical role. IBS production process needs a sustained improvement and management in order to

eradicate waste and to guarantee proper components are developed and handed over at the right time, in the proper order and without damages.

However, despite the potential benefit of ICT, convincing construction organisations to embrace its use and implementation has proved a difficult task. Even developed countries such as the UK is periodically criticised for being too slow to adopt ICT in their construction industry (Moore and Abadi, 2005). From a wider perspective, there is a moderate level of willingness among industry and government to take things forward. There is averseness among companies to take risks, which is mainly related to the unstable market and hence a lack of ICT investment. This raises the importance to obtain answers for the lack of effective implementation of ICT usage in the IBS production process management. In the context of Malaysia, there is so far no existing enabling model developed specifically to help encourage further implementation of ICT whether in IBS supply chain as a whole or specifically within the IBS production process management.

A search of literature revealed no rigorous effort to tackle the ICT implementation issues in IBS process management. Interesting frameworks for IT implementation were developed to provide a strategic view of ICT success in construction (Peña-Mora & Tanaka 2002 and Stewart, Mohamed & Daet 2002). These studies seek to identify key drivers and barriers of IT implementation at the construction industry level (Love *et al.*, 2001; Stewart & Mohamed 2002; Tucker, Mohamed & Ambrose 1999). However, few of these empirical studies focus on ICT barrier and driver elements influencing ICT implementation during IBS process management. Therefore, the finding of this research helps raise an interesting and essential avenue for understanding the issues involved in ICT uptake as well as to provide solutions to tackle the concerns involved in ICT uptake in IBS supply chain management, specifically in the production process.

### **1.3 Research Questions**

Established along the background of the research, the following research questions are presented:

- (i) How does the employment of ICT influence the IBS production process management in the current practices of the Malaysian construction industry?
- (ii) What are the barriers to the implementation of ICT in IBS production process management?
- (iii) What are the solutions to the shortcomings of ICT implementation in IBS production process management?
- (iv) How to develop a model to encourage ICT uptake amongst the construction players in the IBS production process management in Malaysia?

### **1.4 Aim and Objectives**

The aim of this research project is to develop a model to enhance ICT implementation in IBS production process management in the construction industry. The specific objectives of the research include:

- (i) To explore current industrial practice of ICT implementation in IBS production process management in the Malaysian construction industry.
- (ii) To identify critical barriers to the implementation of ICT in IBS production process management in the Malaysian construction industry.
- (iii) To identify critical drivers to enhance ICT implementation in IBS production process management in the Malaysian construction industry.
- (iv) To develop a model for the enhancement of ICT implementation in the IBS production process management.

## 1.5 Scope of Research

This research is focused on the development of a conceptual model which will contribute specifically in enhancing ICT implementation in the IBS production process management. The result can be exploited to develop a conceptual model to increase the ICT implementation amongst the IBS construction players in Malaysia. The research is restricted to IBS precast concrete projects in Malaysia. Some of the relevant aspects of the scope of this study are:

- a) *Research type:* An exploratory interview and a questionnaire survey
- b) *Unit of analysis:* Industry and Government
- c) *Respondents:* IBS manufacturers, Government policy makers and Government technical agency
- d) *Target population size of IBS manufacturers:* Registered IBS manufacturers with CIDB Malaysia [Source: List of Malaysian IBS manufacturers and Registered IBS System Providers (RISP) 2012-2013, CIDB]
- e) *IBS classification:* IBS precast concrete (Refer 2.2.2 for IBS classification)
- f) *IBS process management:* Production of IBS precast components

The scope of this study is the entire total population of precast manufacturers listed under CIDB which was obtained from the list of Malaysian IBS manufacturers and Registered IBS System Providers (RISP), 2012-2013). Apart from that, this study also involves a few main government representatives involved in IBS policy making and IBS technical implementation. They are selected to study on their perception towards ICT implementation in the IBS process management.

## 1.6 Significance of Study

This research seeks to develop a conceptual model for improving the ICT uptake in IBS production process management. The development of the conceptual model of this kind is vital for the fact that it can be used as an enabler for the enhancement of ICT with the

ultimate aim to enhance local technological capabilities in construction organisations. Some other contributions of this research include:

- a) Assessing the impact of ICT applications in the management of IBS processes.
- b) Appending to the consistency of knowledge pertaining to information and communication technology definitions in construction.
- c) Assessing the readiness of IBS players to effectively use ICT in IBS process management.
- d) Identifying the hindrances to greater technology uptake in the IBS process management and the construction industry in general.
- e) Identifying drivers for higher ICT implementation for IBS process management in the Malaysia construction industry.
- f) Mapping out the responsibilities played by the IBS players and the government in enhancing ICT implementation for improving the processes of IBS management.
- g) Creating ICT integration to motivate the government and IBS project stakeholders to maintain relationships, improve communication, and enhance project performance.
- h) Providing and supporting additional knowledge through mixed method studies in the field of construction; specifically construction technology, and use of advanced technology in the IBS field.
- i) Conceptual model will be a strategic implementation of ICT in IBS Roadmap Plan.
- j) A platform for mass production of IBS components and increased adoption of IBS industry, thus encouraging potential for mechanisation.
- k) Improve efficiency and effectiveness of IBS supply chain management.
- l) Reduce dependency on foreign workers.
- m) Enabling other IBS key participants such as IBS consultants and contractors to use and customise the new conceptual model as a checklist and action plans to ensure higher levels of ICT implementation.



## **1.7 Research Methodology**

A combination of research methods was adopted to achieve the research objectives. The research methods adopted comprised of literature review, exploratory interview, questionnaire survey, model development and validation. The following sections briefly illustrates the research methods adopted, and in Chapter 3 provides full details of the research methods selected with the justification for their use.

### **(a) Literature Review**

The literature review was started by gathering information on IBS in the construction industry. It also reviewed the involvement of ICT in the IBS process management in the construction industry. The literature review was based on academic and industry literature e.g. books, refereed journals, conference proceedings, and on-line search of internet websites in the research area. Apart from that, the literature review also assists in the formulation of the research questions; aims and objectives; structuring the research design and methodology; and in selecting the research instruments for a more efficient data collection and analysis. This process was on-going where it was carried out concurrently with all stages in the research project.

### **(b) Exploratory Study**

The exploratory study stage consists of semi-structured interviews which are able to allow some probing and therefore gather more in-depth information on the subject. The vast information gathered will highlight on some strong issues and create a larger supply of data for the development of the questionnaire survey. The interview questions were established to determine the extent of usage and related barrier elements that hinders ICT implementation and driving elements for the enhancement of ICT implementation.

### **(c) Questionnaire Survey**

A questionnaire survey was developed based on the findings from the exploratory survey interviews and within the variable elements identified in the literature review.

The survey questions were established to determine the barriers and drivers to ICT implementation in the IBS production process management. The findings from the questionnaire survey will contribute in identifying the elements to improving ICT implementation in the IBS process management.

**(d) Model Development**

The elements to greater uptake of ICT implementation were identified from the findings of literature review and both the exploratory interview and questionnaire survey. The barrier and driver elements were then used to develop a model for the enhancement of ICT implementation in IBS process management.

**(e) Model Validation**

The ICT implementation model was evaluated by five established IBS manufacturers. The relevant feedbacks on the model practicality and potential improvements were gathered from the validators. Lastly, conclusions and recommendations were then drawn from the research.

This research therefore employs mixed methods approach. Apart from the literature review, the data is collected sequentially, with the exploratory study providing a detailed information base, whilst the questionnaire survey provides the specific focus on the requirements for the development of the model, specifically the barriers and drivers to ICT implementation elements. The summary of the research process is as depicted in Figure 1.1.

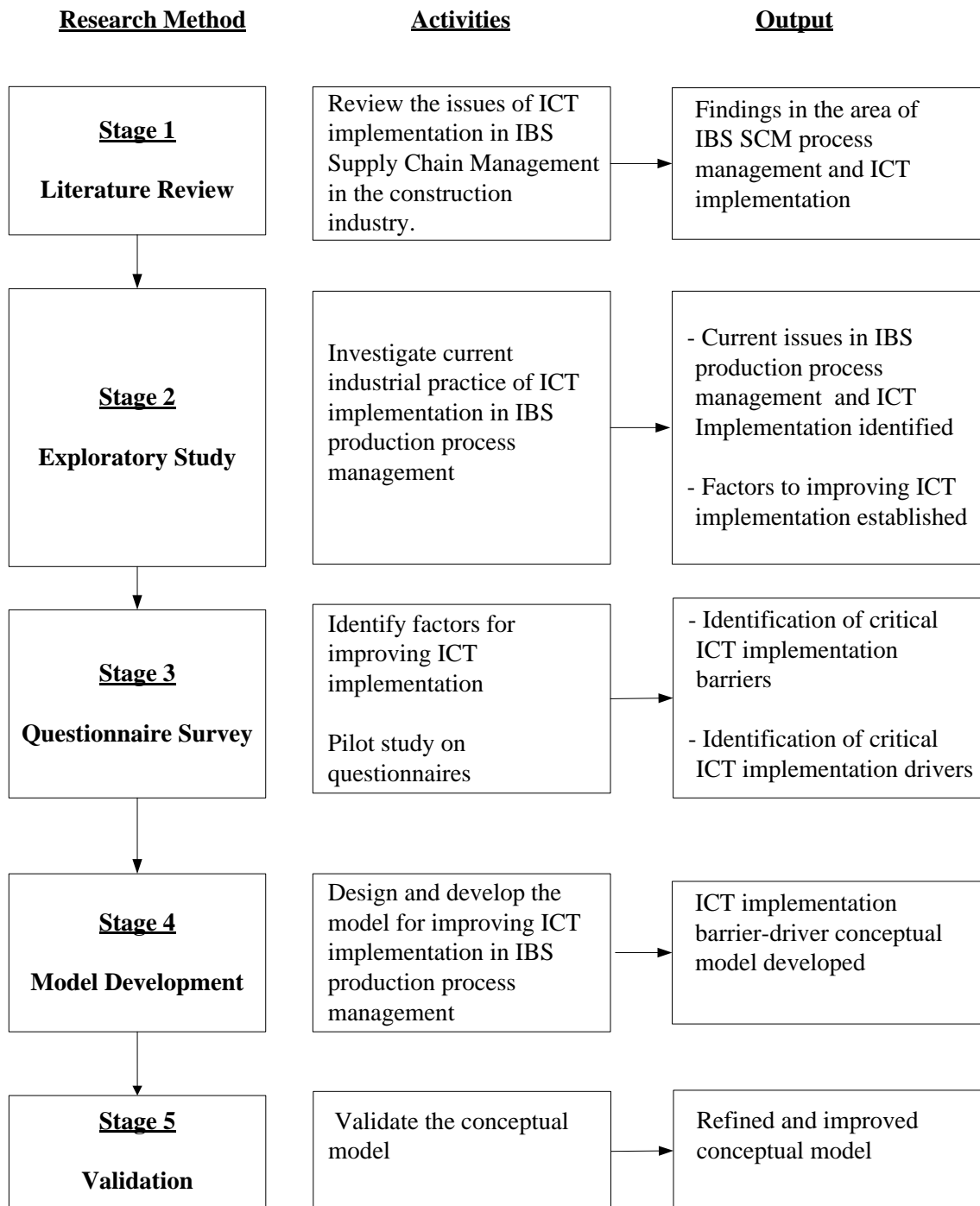


Figure 1.1: Overview of Research Process

## **1.8 Organisation of Thesis**

This thesis is structured into eight chapters. The contents of the chapters are briefed as follows.

### **Chapter 1: Introduction**

This chapter lays the basis of the research; discussing the research background and problem statement, including the aims and objectives of the research, and outlining the research scope, methodology and significance of the research.

### **Chapter 2: ICT Implementation in IBS**

This chapter presents the literature findings through review and discussions of literature pertaining to the precast process management issues. General information about IBS and the processes for IBS precast management are discussed. This chapter also reviews past researches on solutions to overcome IBS issues. ICT implementation is discussed with regards to the ICT applications incorporated in the IBS process management, the benefits of implementing ICT and the shortcomings of ICT implementation in IBS implementation. Besides that, relevant models on ICT implementation are discussed, along with the elements to ICT implementation. Lastly, a theoretical model is developed.

### **Chapter 3: Research Methodology**

This chapter outlines the research design process; including the data collection, data analysis and validation of results. Also addressed in this chapter is the selection of the methods (quantitative and qualitative) and data instrument (exploratory interview and questionnaire survey), with justifications for selection.

### **Chapter 4: Exploratory Study Analysis and Findings**

This chapter describes the data collection phase of the research; emphasising on the primary data collection methods of the semi-structured interview that were conducted

for the purpose of discovering current perception on ICT implementation in IBS process management. The qualitative data from the interviews are organised and categorised with the use of Matrix table; which are then exploited for contents analysis.

### **Chapter 5: Questionnaire Analysis and Findings**

This chapter presents the data collection phase of structured questionnaire survey that were purposed to identify the barriers and drivers to ICT implementation in IBS process management. The pilot study with its preliminary analysis of results is also described in this chapter. The validity of data collected and presentation of data were also discussed in this chapter. The quantitative data obtained from the questionnaire survey is organised, coded and categorised using the SPSS software; which facilitates analysis and testing; and the presentation of the statistical outcomes.

### **Chapter 6: Model Development and Validation**

This chapter presents the layout and detailing of the ICT implementation model, drawn from all the ICT implementation barrier and driver variables identified from the findings from the exploratory study and questionnaire survey, incorporated with the reviews from past literature. A guideline to employ the model was presented. In addition, this chapter puts forth the validation of the model developed. The validation was conducted with five IBS manufacturers. The model was refined after receiving relevant feedbacks from the validation process.

### **Chapter 7: Conclusion and Recommendation**

This chapter imparts the conclusions, contributions and recommendations drawn from the study with reference to the research questions and objectives; as well as elaborating on the research contributions. It also discusses the implications previously identified in the research with regard to literature, methodology and limitations. In that context, it summarises and binds the contents of the thesis together.

## **CHAPTER 2**

### **ICT IMPLEMENTATION IN IBS**

#### **2.1 Introduction**

This chapter reviews the general view on IBS and the issues on IBS supply chain management in the construction industry. Next, this chapter reviews literature on the ICT uptake in the IBS supply chain management. It is then followed by reviewing the shortcomings of ICT implementation and the discussion of current ICT implementation models that have been developed. Elements for improving ICT implementation are derived from the models and finally, a theoretical model is proposed.

#### **2.2 IBS in the Construction Industry**

The construction industry has started to embrace IBS as a method of attaining better construction quality and productivity, reducing risks related to occupational safety and health, alleviating issues for skilled workers and dependency on manual foreign labour, and achieving the ultimate goal of reducing the overall cost of construction. However, the construction industry, like manufacturing and several other industries, is confronting a crisis of restructuring which is founded on rethinking and focusing on reforming current production processes and workflows. In view of that, IBS implementation is deemed a wise solution and has become the trend of many construction industries in

various countries with the aim of adding value to the production process and the product.

### **2.2.1 Terminology and Definition of IBS**

It is important to first introduce the terminologies of IBS used in different parts of the world and its definitions.

#### **Differing uses of the IBS terminology**

IBS has been termed in different ways by different construction industry practitioners in various countries. Some reported examples include the reference to IBS with respect to the development of prefabricated house building in Japan (Barlow and Ozaki, 2005); off-site manufacturing housing in Germany (Venables and Courtney, 2004); off-site manufacture in Australia (Blismas and Wakefield, 2009); prefabricated residential building in Hong Kong (Jaillon and Poon, 2009); timber-framed multistory buildings in Sweden (Mahapatra and Gustavsson, 2008); off-site modern methods of construction in UK house building (Pan *et al.*, 2007); and prefabrication, preassembly, modularization, and off-site fabrication (PPMOF), collectively termed prework, in the United States (Song *et al.*, 2005).

#### **Definitions of IBS**

The term IBS is defined by Abdullah and Egbu (2009) 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 industrialisation. Apart from that, IBS is also referred to the “part of the construction process that is carried out away from the building site, such as in elementy or sometimes in specially created temporary production facilities close to the construction site” (Gibb and Pendlebury, 2005). Whilst IBS is also seen as “a construction process that is carried out away from the building site in which would normally be carried out on site” (Buildoffsite, 2007). Furthermore, Hassim *et al.* (2009) define IBS as an organisational-process continuity of production, implying a steady flow of demand, standardisation, integration of the different stages of

the whole production process, a high degree of organisation of work, and mechanisation to replace human labour wherever possible. Rahman and Omar (2006) defined IBS as construction system that is built using pre-fabricated components. In UK, IBS is defined as “the manufacture and preassembly of components, elements or modules before installation into their final location” (Goodier and Gibb, 2007). Meanwhile, a popular definition of IBS in Malaysia is a construction technique in which components are manufactured in a controlled environment (on or off site), transported, positioned and assembled into a structure with minimal additional site works (CIDB, 2003). Thus, a working definition for IBS in the context of this research is in terms of the processes involved from the components manufactured in a controlled environment right to the assembly of the components, with great amount of technologies replacing the human labour.

### **2.2.2 IBS Classifications**

IBS Survey (2003) listed out five categories of IBS classifications and they are listed as follows:

#### **(i) Formwork Systems**

Considered as one of the “low-level” or the “least prefabricated” IBS, as they generally involve site casting and are therefore subject to structural quality control, the products offer high quality finishes, and fast construction with less site labour and material requirement. These include tunnel forms, tilt-up systems, beams and columns moulding forms, and permanent steel formworks (metal decks).

#### **(ii) Pre-cast Concrete Framing, Panel and Box Systems**

The most common group of IBS products is the pre-cast concrete elements – pre-cast concrete columns, beams, slabs, walls, “3-D” components (e.g. balconies, staircases, toilets, lift chambers, refuse chambers), lightweight pre-cast concrete, as well as permanent concrete formworks.



**(iii) Steel Framing Systems**

Commonly used with pre-cast concrete slabs, steel columns and beams, steel framing systems have always been the popular choice and used extensively in the fast-track construction of skyscrapers. Recent development in this type of IBS includes the increased usage of light steel trusses consisting of cost-effective profiled cold-formed channels and steel portal frame systems as alternatives to the heavier traditional hot-rolled sections.

**(iv) Prefabricated Timber Framing Systems**

Among the products listed in this category are timber building frames and timber roof trusses. While the latter are more popular, timber building frame systems also have its own niche market; offering interesting designs from simple dwelling units to buildings requiring high aesthetical values such as chalets for resorts.

**(v) Blockwork Systems**

The construction method of using conventional bricks has been revolutionised by the development and usage of interlocking concrete masonry units (CMU) and lightweight concrete blocks. The tedious and time-consuming traditional brick-laying tasks are greatly simplified by the usage of these effective alternative solutions.

**2.2.3 IBS Advantages**

The advantages of using offsite are many and numerous. IBS offers benefits to adopters in term of cost and time certainty, attaining better construction quality and productivity, reducing risks related to occupational safety and health, alleviating issue on skilled workers and dependency on manual foreign labour and achieving ultimate goal of reducing overall cost of construction (Alshawi and Kamar, 2009). This is affirmed by other researches which mentioned that offsite construction, another term for IBS offers significant save in labour and material cost, as the number of labour forces required in

offsite is far lower than those required in traditional method (Na and Liska, 2008; Marsono *et al.*, 2006; Badir, Kadir and Hashim, 2002).

In terms of relative productivity, Eastman and Sacks (2008) conducted a study which reveals that off-site production of building components not only has a higher current level of labour productivity, but their overall productivity growth rate is greater than comparable on-site sectors. Results shows off-site productivity grew faster by 2.32% annually, while on-site productivity grew by only 1.43%. In addition, IBS cuts down the duration of work and simplifies the processes by reducing onsite activities and number of trades (Blismas and Wakefield, 2008; Blismas, 2007; Mann, 2006). Besides that fewer tradesmen visiting construction site in offsite projects has reduced local disturbance (BRE, 2002).

Meanwhile, results from the exploratory study conducted in Australia shows that IBS has been seen to reduce construction time; simplify construction processes; provide higher quality, better control and more consistency; produce products that are ‘elementy tried and tested’; reduce costs when resources are scarce, or in remote areas; result in improved working conditions and reduced on-site risks; alleviate skills shortages in certain areas; revitalise ‘traditional’ manufacturing regions; provide fewer trades and interfaces to manage and co-ordinate on site; facilitate the incorporation of sustainable solutions, and achieve better energy performance (Blismas, 2007).

The adoption of prefabrication in Hong Kong compared with traditional construction demonstrated significant advantages, such as improved quality control, reduction of construction time (20%), construction waste (56%), dust and noise on-site, and labour requirement on-site (9.5%). In the public sector, prefabrication has evolved towards the use of non-standard design approach with modular elements optimising site opportunities and constraints, and embracing wider sustainability objectives (Jaillon and Poon, 2009). These findings are consistent with the research conducted by Tam *et al.* (2007) where IBS implementation was able to reduce up to 100% after adopting prefabrication, in which up to 84.7% can be saved on wastage reduction.

Besides that, Ho (2001) and Ting (1997) have identified several benefits of applying prefabrication which is listed below and shown in Figure 2.1:

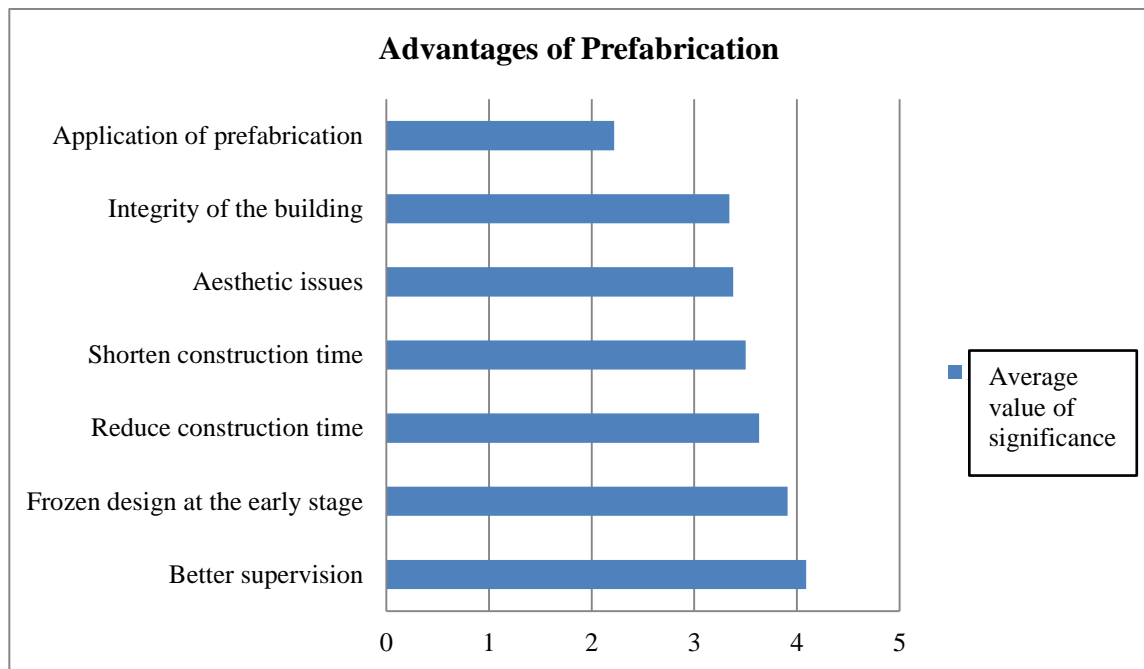


Figure 2.1: Advantages of applying prefabrication (Tam *et al.*, 2007)

The benefits, as illustrated in Figure 2.1 in applying prefabrication are considered as having different levels of significance to construction businesses. “Better supervision on improving the quality of prefabricated products” ranked as first with an average value of 4.09, as the prefabricated products are tested and inspected before site installation. “Frozen design at the early stage for better adoption of prefabrication” and “reduce overall construction costs” are ranked as second and third with the average values of 3.91 and 3.63, respectively. The findings indicate that if the standardised design layouts are used at the early stage similar as the previous projects, the achievement on the performance in cost reduction will be much better. Adopting prefabrication and mass production of building components can reduce construction cost effectively. In addition, the study showed that other than the cost that can be saved from the early standardized design layout, time can also be reduced as the prefabrication can increase the productivity and efficiency of building construction.

In addition, the quality, speed of construction, and cost saving are the main emphases given in the building construction industry in Malaysia. The savings in labour cost and in material cost are also the major advantages of the Malaysian IBSs. The

control in using materials, such as steel, sand, and timber, will result in substantial savings on the overall cost of the project. Almost all the IBSs in Malaysia are suitable for all number of stories, especially for three to five-storey buildings. According to Badir *et al.* (2002), at the same time, all the IBSs in Malaysia are very much suitable for all classes of construction from the unit cost point of view, which are arranged from low-cost house class to high-cost house class.

It is apparent that prefabrication technology brings with it a host of benefits: improved quality with better quality controls, reduction in wastage, less labour-intensive operations, faster production of building components and economies of large scale production (Low and Chan, 1996).

#### **2.2.4 Overview of IBS Supply Chain Management**

The processes of IBS supply chain management can be categorised to the preliminary stage, production stage, delivery of components and the installation stage. The general process is shown in the following:

##### **(i) Preliminary**

The preliminary IBS supply chain management process begins with design and production of shop drawings for the components. The lead-time for both the design and shop drawings is determined. Arif, Goulding and Rahimian (2012) mentioned that given the involvement of more parties in manufactured construction compared to traditional construction, it was therefore perceived to be important that all the stakeholders be involved in the project right from the design phase itself. BIM has been gaining popularity in the last decade as an effective tool for making design stage effective. However, there was an acknowledgment that to effectively implement BIM, it was also important to establish appropriate processes, communication links, hardware and software structures, and suitably train people to use these new technologies (Arif *et al.*, 2012). After the design stage, the specific moulds are produced according to the

drawings. This is followed by procurement of the components, in which the sales department receives orders. The production process will then be planned and scheduled.

### **(ii) Production of IBS Components**

Pre-cast units are produced at ground or bench level, and after hardening are lifted into place to form part of the structure. Pre-casting may be done on the same site as the finished structure, but is usually done away at a pre-cast elementry. Some firms specialise entirely in the manufacture of precast units, while others continue on by doing the erection work on site as well (Collabland, 2011).

The concrete mixer brings concrete onsite to pour into the container which moves with the aid of a crane to pour concrete into the steel moulds controlling solidification. The choice of process depends on the details of the component being produced such as the size, the shape, and the quantity to be made. Smaller casts with detail are suited to a rubber mould, while steel moulds are most often used for larger works such as a floor slabs, and timber is also suitable for the larger moulds, and is often used when the same mould needs to be used many times but each slightly different. The concrete is then mixed and poured into the mould which is lined with a thin oil to make it easier to remove the cast when set. The cast can be removed from the mould after 24hours and left to stand until the curing process has taken effect (usually 28 days).

In relation to manufacturing technology, Arif *et al.* (2012) argues that although a high level of automation seemed infeasible for manufactured construction; however, a justifiable level of automation or mechanisation could be implemented. It is therefore imperative that the manufacturing processes start providing inputs right at the beginning of the design process e.g. by including BIM as the centre for design integration. Conversely however, the manufacturing processes need to be more flexible in order to accommodate design changes.

### **(iii) Delivery of IBS components**

The pre-cast concrete can then be transported by special transportation equipment to the site (Collabland, 2011). A lot of time due to space limitation, the fabricated members

cannot be immediately shipped to the construction site, but they are stored in the storage yard according to erection sequence. The panels are transported to the site in special transportation racks that are lifted and placed onto the trucks. Upon delivery to the jobsite, receiving and unloading of materials should take place as near as possible to the place of erection. The lay-down area should be clean and levelled. After unloading, shakeout of the steel member takes place.

#### **(iv) Installation of IBS Components**

Once on site, IBS components are erected by cranes to either form a building or be placed where it is needed (Collabland, 2011). All materials for the first bay erection are prepared. The rafter sections required are identified by part number, and then assembled as near as possible to their lifting positions. Then the components are erected at the braced bay, meanwhile the part number and orientation, and position over anchor bolts were verified. Finally, the last step is to position the crane for lifting the assembled rafter sections. Construction technology is an important element in the erection of IBS components. Arif *et al.* (2012) pointed out that it is pivotal for the technologies to facilitate effective interaction with manufacturing and design along with providing deeper insights into the implications of design. To achieve this, it is important to incorporate BIM where a streamlined value-based manufacturing process is able to derive the maximum benefits out of manufactured construction. However, it is important to note that processes in design, manufacturing, and construction have to be completely reengineered in order to harness maximum benefits from the manufactured construction Arif *et al.* (2012).

#### **(v) Example of IBS Pre-Cast Concrete Management Process**

In an example of a generic high-level business process mapping for the precast industry, Dawood and Al-Bazi (2009) mapped out a diagram to illustrate the processes involved (refer Figure 2.2). The first process plan addressed order receiving, (in which the sales department receives orders), which involved specifying the required product details and providing the sleeper batch size (quantity of sleepers to be produced).

The second process covered the planning and scheduling of the production plan using Microsoft Excel. Confirmation was given to the sales department indicating any technical difficulties, and Bill of Material (BOM) checks were undertaken to ensure sufficient quantities of materials were available for manufacturing to take place.

The third process, the manufacturing, forms the focus of the research presented here. The production supervisors received the production plan and they were responsible for carrying out the production operations according to the specified production plan. Feedback to the scheduling department was given for confirmation purposes. In the fourth process, finishing activities were undertaken to finalise the sleepers before dispatch: forklifts were used to move finished sleepers from the shop floor to the open stockyard area with lorries and trains being used to transport the product to its final destination. Dispatch confirmation was sent back to update the sales department on the status of the order.

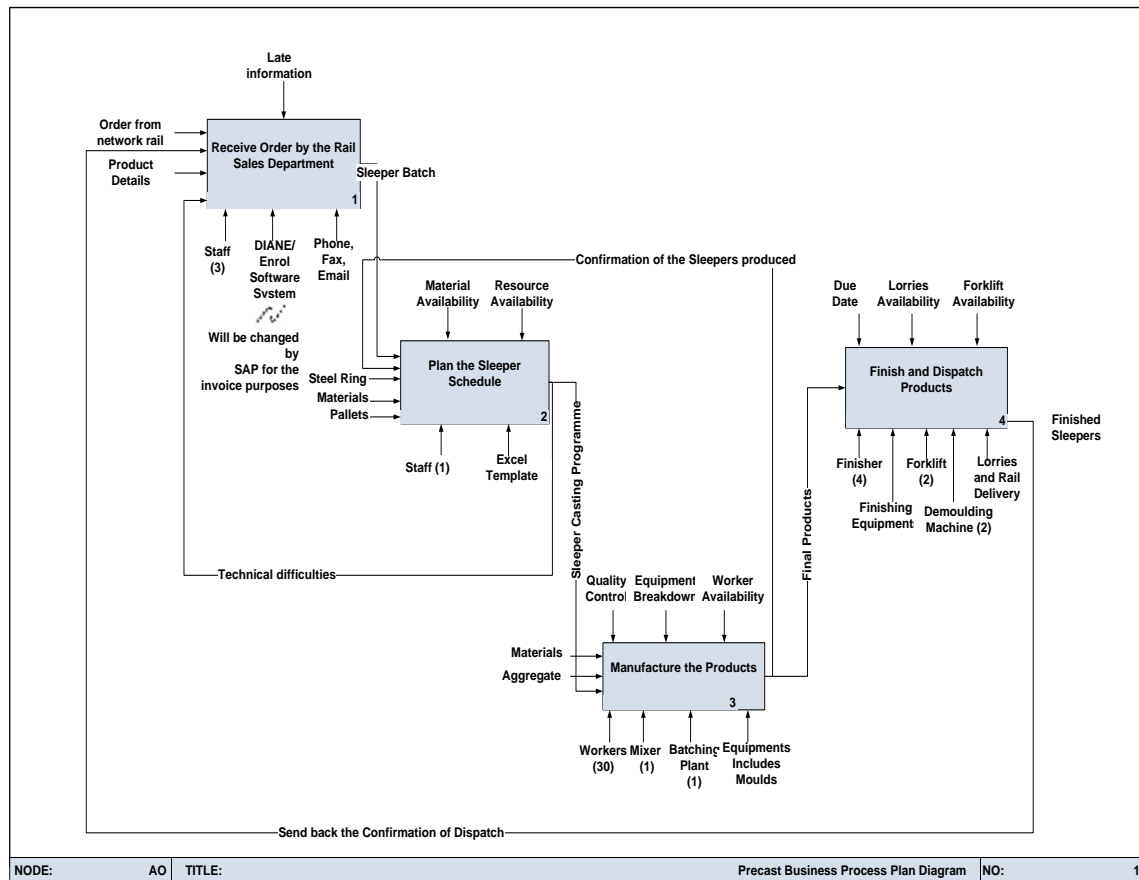


Figure 2.2: Business process mapping diagram for the precast concrete (Dawood and Al-Bazi, 2009)

### 2.2.5 IBS Supply Chain Management Issues

In the precast concrete production as illustrated in Figure 2.2, the study identified a number of elements which affected the progress of the manufacturing system. One of the elements included machine breakdown. Hence, effective ICT input will be a platform to ensure a better progress of the manufacturing system.

The study of Al-Bazi (2010) informs of various research done on the different aspects of the precast and construction systems to improve the performance of the precast in construction industry. The six field applications that was classified to improve the performance and efficiency the precast processes are: (1) production planning and scheduling, (2) supply chain management, (3) stockyard management, (4) resource



allocation, (5) productivity, and (6) process re-engineering. It was concluded that the process re-engineering aspect had not received enough attention in terms of detailed modelling considering different levels of worker skills. Therefore, process re-engineering is a potential key focus area for in depth research, especially on the re-engineering of technology involved in the IBS components process management.

The Australian construction industry has identified off-site manufacture (OSM) as a key vision for improving the industry over the next decade (Hampson & Brandon, 2004). In year 2007, a study was conducted to identify significant constraints that are preventing the wider adoption of OSM, or IBS, as termed in Malaysia. Some of the constraints and actions to overcome them are listed in Table 2.1.

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