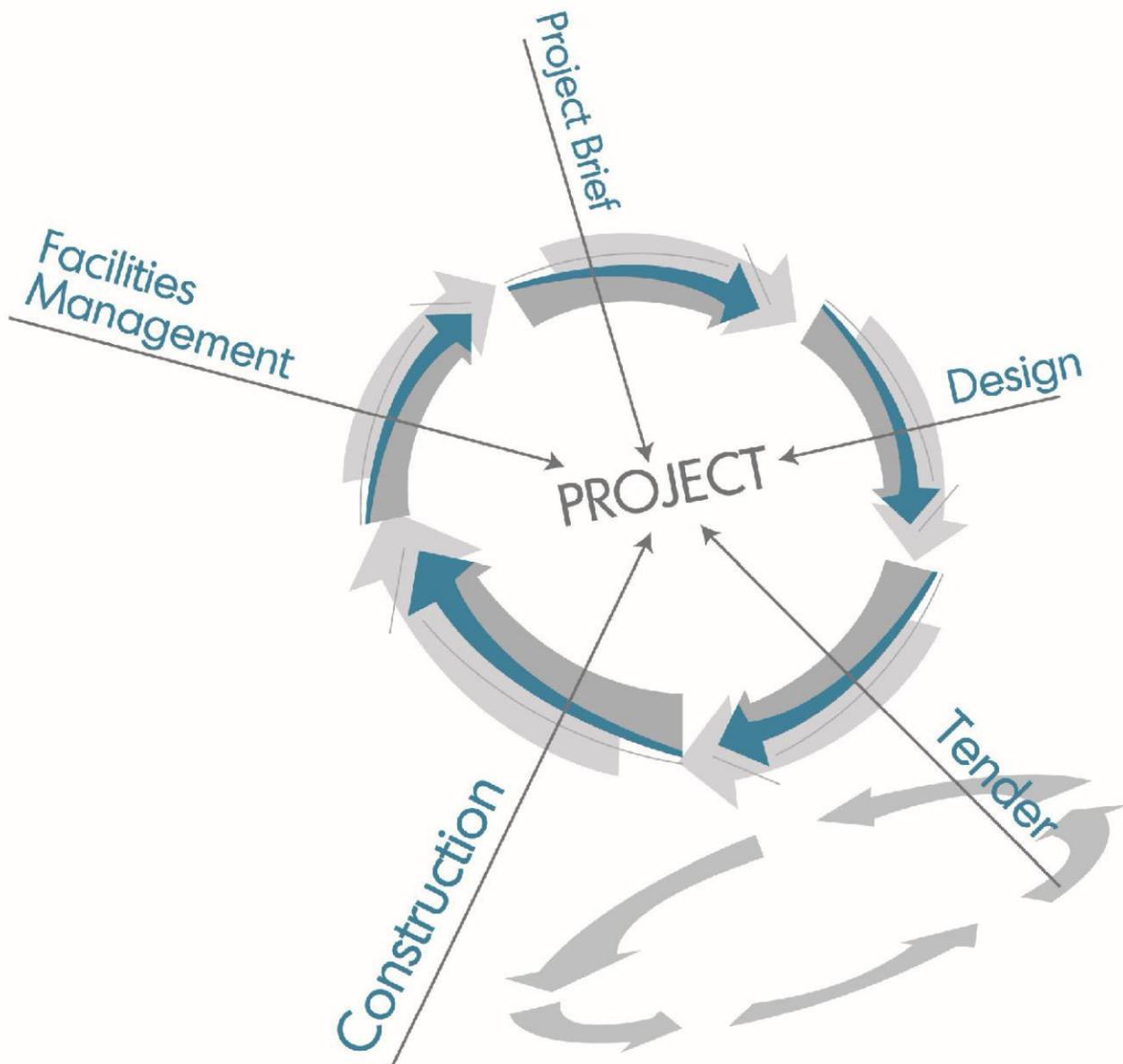


# Malaysian Construction Research Journal





# **MALAYSIAN CONSTRUCTION RESEARCH JOURNAL (MCRJ)**

**Volume 22 | No. 2 | 2017**

The Malaysian Construction Research Journal is indexed in

**Scopus Elsevier**

ISSN No.: 1985 - 3807

Construction Research Institute of Malaysia (CREAM)  
MAKMAL KERJA RAYA MALAYSIA  
1<sup>st</sup> Floor, Block E, Lot 8, Jalan Chan Sow Lin,  
55200 Kuala Lumpur  
MALAYSIA

*This page intentionally left blank*

# Contents

Editorial Advisory Board	ii
Editorial	iv
<b>ADOPTION OF INDUSTRIALISED BUILDING SYSTEM (IBS): EXPLORING COMPETITIVE ADVANTAGES FROM A TECHNOLOGY VALUATION PERSPECTIVE IN NORTHERN MALAYSIA</b> Sharifah Akmam Syed Zakaria, Taksiah A. Majid and Fadzli Mohamed Nazri	1
<b>APPLICATION OF MODIFIED DELPHI IN IDENTIFYING THE PRESENCE OF INCOMPLETE CONTRACT (IC) IN PRIVATE FINANCE INITIATIVE (PFI) PROJECTS</b> Nur Syaimasyaza Mansor, Khairuddin Abdul Rashid, Mohd. Fairullazi Ayob and Sharina Fariyah Hassan	19
<b>COMPETENCY AND COMMITMENT OF FACILITIES MANAGERS: KEYS TO SAFEGUARD MAINTENANCE PERFORMANCE</b> Cheong Peng Au-Yong, Azlan Shah Ali and Faizah Ahmad	35
<b>INFLUENCE OF COIR RANDOM FIBRE LENGTH ON CONCRETE: MECHANICAL PROPERTIES</b> Noor Aina Misnon, Siti Khadijah Che Osmi, Nawawi Chouw and Shahiron Shahidan	47
<b>THE EFFECTIVE PARAMETERS ON THE BEHAVIOR OF CFDST COLUMNS</b> E. Farajpourbonab, S. Kute and V.M. Inamdar	59
<b>SUPPLY CHAIN INTEGRATION ISSUES AND CHALLENGES IN INDUSTRIALISED BUILDING SYSTEM (IBS) CONSTRUCTION PROJECTS IN MALAYSIA</b> Wan Zukri Wan Abdullah and Siti Rashidah Mohd Nasir	73

## Editorial Advisory Board

**Zuhairi Abd. Hamid, Prof., Ir., Dr.,  
Chief Editor**

Construction Research Institute of Malaysia  
(CREAM)

**Mustafa Alshawi, Prof., Dr.**  
University of Salford, UK

**Charles Egbu, Prof., Dr.**  
University of Salford, UK

**C. S. Poon, Prof., Dr.**  
Hong Kong Polytechnic University, Hong Kong

**George Ofori, Prof., Dr.**  
National University of Singapore, Singapore

**Vilas Nitivattananon, Dr.**  
Asian Institute of Technology (AIT), Thailand

**Abu Bakar Mohamad Diah, Datuk Wira, Dr.**  
Deputy Minister of Science, Technology and  
Innovation, Malaysia

**Khairun Azizi Mohd. Azizli, Prof., Dr.**  
Universiti Teknologi PETRONAS

**Roslan Zainal Abidin, Prof., Dr.**  
Infrastructure University Kuala Lumpur

**Taksiah Abdul Majid, Prof., Dr.**  
Universiti Sains Malaysia

**Joy Jacqueline Pereira, Prof., Dr.**  
LESTARI, Universiti Kebangsaan Malaysia

**Muhd Fadhil Nuruddin, Prof., Ir., Dr.**  
Universiti Teknologi PETRONAS

**Mohd. Saleh Jaafar, Prof., Dato', Ir., Dr.**  
Universiti Putra Malaysia

**Norwina Mohd. Nawawi, Assoc. Prof., Ar. Dr.**  
International Islamic University Malaysia

**Chan Toong Khuan, Ir., Dr.**  
University of Melbourne, Australia

**Ahmad Baharuddin Abd. Rahman,  
Assoc. Prof., Dr.**  
Universiti Teknologi Malaysia

**Lee Yee Loon, Prof., Dr.**  
Universiti Tun Hussein Onn Malaysia

**Mohamad Omar Bin Mohamad Khaidzir, Dr.**  
Forest Research Institute of Malaysia (FRIM)

**Kurian V. John, Prof., Dr.**  
Universiti Teknologi PETRONAS

**Paridah Tahir, Prof., Dr.**  
Universiti Putra Malaysia

**Roshana Takim, Assoc. Prof., Dr.**  
Universiti Teknologi MARA

**Siti Hawa Hamzah, Prof., Ir., Dr.**  
Universiti Teknologi MARA

**Mohamad Jamil Sulaiman, Ir., Dr.**  
SIRIM Berhad

**Megat Azmi Megat Johari, Prof., Dr.**  
Universiti Sains Malaysia

**Kamaluddin Abdul Rashid, Mr.**  
Jabatan Kerja Raya Malaysia

**Md. Abdul Mannan, Prof., Dr.**  
Universiti Malaysia Sarawak

**Mahmood Md Tahir, Prof., Ir., Dr.**  
Universiti Teknologi Malaysia

**Nasir Shafiq, Prof., Dr.**  
Universiti Teknologi PETRONAS

**Noraini Bahri, Ir.**  
Construction Industry Development Board (CIDB)  
Malaysia

**Badorul Hisham Abu Bakar, Prof., Dr.**  
Universiti Sains Malaysia

**Zulkifli Mohamed Udin, Assoc. Prof., Dr.**  
Universiti Utara Malaysia

**Abdul Rashid Abdul Aziz,  
Prof., Sr, Dr.**  
Universiti Sains Malaysia

**Sobri Harun, Assoc. Prof., Dr.**  
Universiti Teknologi Malaysia

**Aziz Saim, Assoc. Prof., Dr.**  
Universiti Teknologi Malaysia

**Hamimah Adnan, Assoc. Prof., Datin, Sr, Dr.**  
Universiti Teknologi MARA

**Abdul Karim Mirasa, Prof., Ir., Dr.**  
Universiti Malaysia Sabah

**Wan Hamidon Wan Badaruzzaman,  
Prof., Ir., Dr.**  
Universiti Kebangsaan Malaysia

**Hamidah Mohd. Saman, Assoc. Prof., Dr.**  
Universiti Teknologi MARA

**Azmi Ibrahim, Prof., Dr.**  
Universiti Teknologi MARA

**Mahyuddin Ramli, Prof., Dato', Ir., Dr.**  
Universiti Sains Malaysia

**Hajah Faridah Hj. Ismail, Assoc. Prof., Sr, Dr.**  
Universiti Teknologi MARA

**Mohd. Shahir Liew, Assoc. Prof., Ir., Dr.**  
Universiti Teknologi PETRONAS

**Low Kaw Sai, Assoc. Prof., Ir., Dr.**  
The Institution of Engineers Malaysia

**Narayanan Sambu Potty, Prof., Dr.**  
Mohandas College of Engineering and  
Technology, India

**Padzil Fadzil Hassan, Assoc. Prof., Dr.**  
Universiti Teknologi MARA

**Maria Zura Mohd. Zain, Ms.**  
Construction Research Institute of Malaysia  
(CREAM)

**Sugiura, Kunitomo, Dr.**  
Kyoto University, Japan

**Itaru Nishizaki, Dr.**  
Public Works Research Institute (PWRI), Japan

**Low Sui Pheng, Prof., Dr.**  
National University of Singapore, Singapore

**Zhangping You, Prof., Dr.**  
Michigan Technological University, USA

**Norhayati Abdul Hamid, Assoc. Prof., Dr.**  
Universiti Teknologi MARA

**Ahmad Hazim Abdul Rahim, Mr.**  
Construction Research Institute of Malaysia  
(CREAM)

**Mazlin Mokhtar, Prof., Dr.**  
LESTARI, Universiti Kebangsaan Malaysia

**Hassan Basri, Prof., Dato', Ir., Dr.**  
Universiti Kebangsaan Malaysia

**Khairuddin Abdul Rashid, Prof., Sr. Dr.**  
International Islamic University Malaysia

**Foo Chee Hung, Dr.**  
Construction Research Institute of Malaysia  
(CREAM)

**Dongping Fang, Prof. Dr.**  
Tsinghua University, China

**Francis K.W. Wong, Prof., Dr.**  
Hong Kong Polytechnic University, Hong Kong

**Kobayashi Kiyoshi, Prof., Dr.**  
Kyoto University, Japan

**Sulaiman Abdulkareem, Dr.**  
University of Ilorin, Nigeria

**Aidah Jumahat, Dr.**  
Universiti Teknologi MARA

**Barjoyai Bardai, Dr.,**  
Universiti Tun Abdul Razak

**Siti Akhtar binti Mahayuddin, Dr.**  
Universiti Teknologi MARA

**Abdul Kadir Othman, Dr.**  
Universiti Teknologi MARA

**Sarah Aziz, Dr.**  
LESTARI, Universiti Kebangsaan Malaysia

**Yuen Choon Wah, Dr.**  
Universiti Malaya

Guest Editor:

**Farid Ezanee Mohamed Ghazali, Dr.**  
Universiti Sains Malaysia

**Syuhaida Ismail, Ir. Dr.,**  
Universiti Teknologi Malaysia

Secretariat:

**Tengku Mohd Hafizi Raja Ahmad, Mr.**  
Construction Research Institute of Malaysia  
(CREAM)

**Nurulhuda Mat Kilau, Ms.**  
Construction Research Institute of Malaysia  
(CREAM)

## Editorial

### Welcome from the Editors

Welcome to the twenty-second (22<sup>nd</sup>) issue of Malaysian Construction Research Journal (MCRJ). In this issue, we are pleased to include six papers that cover wide range of research area in construction industry. The editorial team would like to express our sincere gratitude to all contributing authors and reviewers for their contributions, continuous support and comments.

In this issue:

**Sharifah Akmam Syed Zakaria et al.**, explore the valuation of Industrialised Building System (IBS) technology as perceived by the construction players based on competitive advantages aspects at the strategic level with internal, competitor and market analysis. It is demonstrated that the valuation of IBS for competitive advantage is based on various aspects such as human-nature, people-environment and IBS future outlook in the construction environment. Collaboration through partnering and strategic alliance will make it possible for building projects to gain competitive advantages from IBS technology valuation.

Using the two-round modified Delphi, **Nur Syaimasyaza Mansor et al.**, attempted to identify the presence of Incomplete contract (IC) in Private Finance Initiative (PFI) projects in Malaysia. 12 clauses were identified as incomplete, and the findings become the basis of the semi-structured questionnaire for the modified Delphi. While the results show that the 12 identified clauses were deemed incomplete, the findings reported herein are considered significant towards effort in enhancing the effectiveness and efficiency of PFI contracts.

**Cheong Peng Au-Yong et al.**, examine the relationship between the competency of facilities manager and maintenance performance; and investigate the relationship manager's salary and manager's commitment through questionnaire survey and interview. The findings indicate that there are significant relationship between manager's competency and maintenance performance; as well as manager's salary and manager's commitment. The study concludes that actions should be taken in order to improve the competency and commitment of facilities managers constantly, and hence enhance the maintenance performance.

Instead of focusing on the influence of fixed fibre length in the development of Coconut Fibre Reinforced Concrete (CFRC), which has been proven to cause extra production cost, **Noor Aina Misnon et al.**, is considering the random length of fibres in CFRC. Four different fibres contents were added to the concrete; 1%, 2%, 3% and 5% of the cement weight. The cement, sand and aggregate ratio used was 1:2:2, with water cement ratio in the range of 0.48 to 0.65. A number of experiments on CFRC with random fibre length were conducted to identify the static properties of CFRC composite, i.e. compressive strength, splitting tensile strength, modulus of elasticity and flexural strength. The results revealed the mechanical characteristics are similar to that of CFRC with fixed lengths.

**Farajpourbonab E. et al.**, investigate the effects of load application type, material (yield stress of steel tubes, concrete strength), and geometric parameters (thickness and diameter of the steel tubes) on the behaviour of CFDST columns. Findings of the current study clearly indicate the high ductility and strength of CFDST columns under axial loading. The results show the significant impacts of yield stress of steel section, compressive strength of concrete, thickness and diameter variations on the strength and ductility of CFDST columns.

**Wan Zukri Wan Abdullah and Siti Rashidah Mohd Nasir** reviewed the impact of Industrialised Building System (IBS) supply chain on the execution of IBS undertaking progress. The main challenges in Supply Chain Management (SCM) that have been identified are the relationship, communication and contractual. This finding is to help the IBS key persons in handling the situation that they may encounter during the IBS construction progress.

*Editorial Committee*

*This page intentionally left blank*

# ADOPTION OF INDUSTRIALISED BUILDING SYSTEM (IBS): EXPLORING COMPETITIVE ADVANTAGES FROM A TECHNOLOGY VALUATION PERSPECTIVE IN NORTHERN MALAYSIA

**Sharifah Akmam Syed Zakaria, Taksiah A. Majid and Fadzli Mohamed Nazri**

*School of Civil Engineering, Engineering Campus, Universiti Sains Malaysia, 14300 Nibong Tebal, Penang, MALAYSIA*

## **Abstract**

Construction projects have been continuously urged to adapt and adopt construction technologies in supporting the achievement of project management objectives in more efficient and effective ways. However, the shift of construction technology adoptions from conventional methods may require the concurrent adoption of new business strategies due to cost, quality, suitability, culture and other relevant factors. This paper explores the valuation of Industrialised Building System (IBS) technology as perceived by the construction players based on competitive advantages aspects at the strategic level with internal, competitor and market analysis. The rationality of this study is to explore the applicability of a technology valuation model, from the viewpoints of the construction stakeholders and IBS supply chain members. Specifically, this paper presents research evidence using a quantitative method through questionnaire surveys for exploring competitive advantages aspects from a technology valuation perspective, with attention to the importance of each competitive aspect and outcome measures reported. This paper presents the results of quantitative study on a technology valuation matrix within the northern region states of Malaysia and concludes that, there were no significant differences between the construction stakeholders and the IBS supply chain members in terms of the way they comprehend IBS technology valuation for competitiveness. Conclusively, the valuation of IBS for competitive advantage is based on various aspects such as human-nature, people-environment and IBS future outlook in the construction environment. It is recommended that collaboration through partnering and strategic alliance will make it possible for building projects to gain competitive advantages from IBS technology valuation.

**Keywords:** *Industrialised Building System, technology valuation, competitive advantage*

## **INTRODUCTION**

Construction technology adoptions play a vital role in improving individuals', groups' and firms' lives and these are becoming important to societies. There is also an increasing awareness on the value of construction technology to enhance productivity, efficiency, effectiveness and competitiveness. Unfortunately, the concept of construction technology valuation has not been explored scientifically until recently. Given the challenges and complexity of the world's construction technology application, there is a need to respond to the challenges of its revolution.

The need to manage construction technology-based application and enhance project completion of construction projects is not new. The ability to develop and incorporate research advances and technological know-how into new construction practices has been a base of economic growth and industrialization. Malaysia is currently entering into a new era to seek solutions for sustainable infrastructure, particularly in the adoption of Industrialised Building System (IBS). However, the IBS technology adoption from one project to another is not easy as its sound (CIMP, 2010). Many country and project-experience have indicated that the adoption new technology from one country or project to another has not always been

successful (Krawczyk and Serea, 2013). Therefore, technology valuation has been seen as an important decision-making mechanism for high-tech business (Saaty, 2008; Venkatesh, 2006). In this case, leveraging the effective contributions of civil engineering research through project completion is one of the more important areas in the management of technological application.

The diversification, the growth of international alliance, competition, faster rates at which new construction technology are being generated world-wide, the increasing demands of more sophisticated customers and the reduction of lead times for new project application have all placed greater pressure on construction industry to expand both its commitment and its competence in managing technological application and environmental change. Therefore, Jaillon et al. (2009) acknowledge that huge building projects are able to take advantage of large resources by pursuing niche strategies such as new building technology adoption, thus gaining competitive advantages that could not be achieved by small building projects. In addition, changes in the external environment such as the regulatory conditions and competitive advantage have various impacts on IBS adoption (Ndungu et al., 2012).

It is increasingly realized that value constitutes a main obstacle to technology adoption in the construction industry (Becerik-Gerber et al., 2011; Son et al., 2012) and that, at best, the effort to adopt technology ideas tends to encourage the state of formalism producing only the appearance but also the essence of success (Arora and Gambardella, 2010; Selic, 2012). However, the prevalent literature indicates that attempts to understand the perceived values of IBS technology in relation to the performance of IBS technology are relatively scarce. In view of this research gap in comparative studies coupled with the growing interest among the players of the Malaysian industry in the adoption of building technology, there is now a pressing need to undertake the study on the technology values of IBS (Mahbub, 2012; Majid et al., 2011). The present study is exploratory in nature and attempts to systematically analyse and compare the perceived IBS technology values of the construction stakeholders and IBS supply chain members towards competitive advantages.

The merging or combination of construction technology application and project completion is facilitating firm's activities and nations' socio-economic application. Goulding et al. (2012) explain that the effect of conventional building methods on a project's competitive position depends on project sizes. The extent use of construction technology advancement particularly to keep ahead of competition determines application in various sectors of the economy. IBS technology adoption, in turn, can enhance competitive advantage or develop business opportunities in the marketplace (Girmscheid and Rinas, 2012). Based on these scenarios, construction technology need to be assessed and valued so that it can be utilized effectively to generate profits.

## **LITERATURE REVIEW**

Construction technology is often employed as a competitive weapon and players in construction industry must know how to take the advantage of competitive possibilities of construction technology application and how far to go to protect the construction firms from possible aggressive moves by the competition. In this era, researchers are not going to get away with qualitative allegation about productivity, "more ideas from lab to market" and "research thrives and sells", these themes reflected the current dual emphasis at the

construction technology application activities. Internally, it is to increase the freedom and initiative of researchers to come out with more new ideas and do more exploratory research. Externally, it is to increase the emphasis of effective valuation on construction technology application to the construction industry' wealth.

Commercial aspect and the capabilities of researchers to produce unique and strategically important forefront construction technology to meet challenges and problems in the industry are equally important. According to Christensen (2013), one of the most critical decisions that managers make is choosing the type of technology the organization will use to produce its products or deliver its services. The results of research exploration should go beyond the current scope of construction industry' engineering expertise and effort. In today's era of intense global competition, the activities of construction industry should not be restricted to the critical path applications but they should set off a broader spectrum of their activities. Moreover, the rapid accelerating rate of technological and environmental change demands greater construction industry ability.

Construction industry not only has to improve their capacity to progress their ability to assess, coordinate, integrate and strategize engineering applications within their overall construction activities, but they must also be capable of implementing their plans through the leadership of their management and the efforts of their technical and non-technical staffs. In most industries today, a variety of economic, technical and market-driven forces have joined together to make this project completion-related problem even more prominent. The ways in which a construction firm's resources such as money, manpower, machine, materials, intellectual capital and information are allocated, positioned and managed will have a strong manner on the construction firm's ability to compete successfully in tomorrow's more global economy. As a result, construction industry must have those managerial skills and perspective necessary to enhance the application process and bring civil engineering advances successfully to the marketplace.

## **Construction Technology and Competitive Advantage**

The proportion of construction firms engaged in construction technology developments that have developed specific strategies for their application of those technologies and aware of its potential impact on existing business practices in construction industry, is not known. If a construction firm adopts construction-based innovations without a clear understanding of the scope and implications of that adoption, then not enough attention may be paid to realigning business strategy. As a result, business resources needed to achieve competitive advantage from the construction technologies investment may not be made available and the investment in innovation may in the end be wasted, or even be detrimental to the firm's pre-adoption competitive position (Gambardella and McGahan, 2010; Tassef, 2012).

The conventional wisdom is that technology strategy must reinforce the competitive advantage a firm is seeking to achieve and sustain (Porter, 2008). According to Christensen (2013), decisions about the adoption of technology were, therefore, able to be made in the framework of production theory, in which adoption creates benefits in the form of lower production costs for a given level of output as productivity benefits included operational gains (via rationalization, product standardization and such) and economic gains (via lower costs of labour, economies of scale, knowledge acquisition and such). Technology adoption by a firm

led to competitive advantage through productivity based efficiency, provided that access to the technological development was restricted, that is, provided there were effective barriers to entry (Tambe et al., 2012). In the face of wide diffusion of production technology and a market increasingly perceived as global, firms therefore needed to differentiate themselves and/or their products in the consumers' eyes (Poetz and Schreier, 2012), in order to establish or maintain competitive advantage (West et al., 2015).

During the last decade, the source of competitive advantage has increasingly been seen to reside in the supplementary benefits provided to customers, leading to the creation of sustainable perceived value for customers (Blocker et al., 2011; Prahalad and Ramaswamy, 2013). As well as high perceived quality, control over costs, and product innovation, a firm has to have excellent service, a market-driven learning-oriented culture and speed, that is, the ability to deliver quickly and to quickly solve customer problems (Santos-Vijande et al., 2012). In business markets, speed also involves time to market, because being first to the market is usually associated with competitive advantage (West et al., 2015). Prahalad and Ramaswamy (2013); Sashi (2012) claim that in order to be competitive, companies must employ technology to develop low-cost customer-prospecting methods, establish close relationships with customers and develop customer loyalty.

### **Industrialised Building System (IBS)**

The definition as given by Hamid et al. (2008), IBS 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 work. Sarja (2003) defines IBS as “the term given to building technology in which modern systematic methods of design, production planning and control as well as mechanised and automated manufacture are applied”. In essence, the term ‘industrialisation’ generally has three characteristics, first; it has a generic organisation, second; it is based on quantity and third; it offers an individualised finished product (Richard, 2005). In the construction industry, it is important to decide whether to use a conventional building method or to use some degree of modern industrialised construction method, that is, complete or partial modern technology (Kempton, 2010).

According to Gibb (2001), IBS technology is not new, but its application, pragmatism and perception need to be considered in the light of current technology and management practice. In some developed countries like the United States of America, United Kingdom, Japan, Australia and other European countries, IBS technology adoption is already a common building-construction method that is widely accepted and adopted (Thanoon et al., 2003). Although the situation differs from one country to another in terms of types and degree of adoption in building projects, in most developed countries such as the USA and UK, the adoption of IBS technology has increased since the 1990s (Polat, 2010).

IBS technology policy over these years has focused on better understanding the practice behind the scientific and technical aspects of IBS technology itself (CIMP, 2010). In particular, Bonev et al. (2015) discover that in industrialized construction, building projects use different layers of product, process and logistics platforms to form the right cost – value ratio for the target market application, with a focus on systematically balancing cost and value. Japan's prefabrication industry also incorporates the latest product and process technologies

and combines automation, products and services into complex value-capturing systems (Linner and Bock, 2012). Additionally, Li et al. (2014) also include a value-changed variable in the quantitative assessment of the influence of prefabrication on construction waste management and Pan et al. (2012) develop value-based decision criteria and quantifies their relative importance for assessing building technologies systematically.

## **Value Creation**

Value creation is important for business because customers compare the perceived net value associated with each competing business offering and choose the highest value (Prahalad and Ramaswamy, 2013). However, competition based on customer's perceived value has a two-tier consequence for firms. First, it shifts business orientation towards the market (Terho et al., 2012). Secondly, adoption of the marketing concept directs the efforts of the firm as a whole to satisfaction of customers' needs, subject to business objectives and societal interest (Carroll and Buchholtz, 2014).

As the acquisition of new customers is believed to be more expensive than the retention of existing ones, business strategy focuses on customer loyalty and the development of long-term relationships with good customers (Goetsch and Davis, 2014). This focus in turn has the consequence that a firm needs to know its market and more precisely, what actual and potential customers consider in their valuations, in order to position itself as the best provider of satisfaction to its customers, and to closely control and allocate resources. Focusing on supplementary benefits for creating value obviously requires the identification of which supplementary benefits provide competitive advantage, a task made especially difficult once variability across industries and across countries is considered (Arora and Nandkumar, 2012).

Creation of customer perceived value brings a renewed dependence on construction technologies. This is illustrated, for example, by the growth of marketing and management support modules in project management, or by the importance attributed by firms to "customer solution" and customer satisfaction in the end products of construction industry. Better construction methods and systems contribute to competitive advantage because they allow for more efficient use of business resources to meet customers' needs, and support delineation of positioning strategies that can gain customers' preference and loyalty. Hence, if firms perceive construction technologies as cost factor and barriers, the opportunities afforded by better construction techniques or methods may surge as it is seen as necessary for the development and/or maintenance of competitive advantage (Gambatese and Hallowell, 2011).

## **Technology Valuation**

No economic phenomenon is more important to the modern world than the creation of wealth through technological application although this is risky and involves competitive business besides considering the cost of the research and application (R&D) effort itself (Scarborough and Corbett, 2013). According to Belderbos et al. (2015), R&D has strategically impacted the speed of technology application. In recent years, technology valuation has been seen as an important decision-making mechanism for business as it involves not only technical steps of valuation but also strategic management of a technology (Hill and Schilling, 2014). The application and project completion of advanced technologies will depend increasingly on efficient technology transfer and technology trading systems and this requires the application

of technology markets or exchanges and hence a reliable technology valuation methodology (Wang et al., 2013).

Filled with in-depth insight, technology valuation offers a better way to value the profitability and risk of R&D projects (Sköld and Karlsson, 2012). Technology valuation provides a framework to link business to technology as this has been widely used in current research and application strategies that focuses on markets and customers (Davenport, 2013). Policy makers have a responsibility to broaden the analytic horizons to include new technology valuation models where traditional valuation models, conceived long before risk, cost and quality choices became traditionally feasible, cannot “see” the special attributes and values because they are steeped in the vocabulary of a different technological era – one of the active and expense-intensive projection of technology (Bergek et al., 2013). According to Chen (2011), technology evaluation module includes the evaluation of the technological level of the firm and its competitors using a comparative technology valuation process and to establish a detailed application plan based on the valuation results. In addition, the key determinants of the value of the technology-based intangible assets are the technology itself and the economic return the technology creates (Garleanu et al., 2012).

### **IBS, Competitive Advantage and Technology Valuation**

It is argued that IBS improves the productivity of construction and reduces the amount of site labour involved in building operations (Kadir et al., 2005). As the adoption of IBS technology has been relatively slow in Malaysia, it is vital to understand the actions and conduct of construction players in the context of social and economic occurrences. Pan et al. (2008) discover that barriers to the acceptance of off-site production are centred on human perceptions grounded in the historical failure of off-site practices to deliver improved performance, technical difficulties e.g. site specifics, delivery issues, interfacing problems, cost, lack of opportunities for benefiting from economies of scale, and the fragmented structure of the construction supply chain.

Specifically, competition in any industry does not stem only from competitors, but is also influenced by the underlying structures of the industry (Porter, 2008). The future of competition is being shaped by changes in the meaning of value, the roles of the consumer and company, and the nature of their interactions (Prahalad and Ramaswamy, 2013). Therefore, by analysing their industry firms could understand their current position, influence the structure positively or could define a position where they can uniquely have a competitive advantage (Porter et al., 2011). Although setting a technology value perspective, which coordinates the project principles among its team members, it is also vital to recognize the significance of competitive factors as perceived by various team members to achieve certain project activities (Kim and Reinschmidt, 2010). Moreover, discovering the competitive aspects influencing on decision-making in relation to issues associated with the introduction of new technology like IBS, besides, identifying the stakeholders’ biases and personal agendas, is extremely important (Shen et al., 2009).

Technology innovation in building projects is based on a comprehensive project description with the anticipation of competitive pressures (Salunke et al., 2011). If possible, the project decision should provide for a response to competitive threats as the construction unfolds (Tan et al., 2011). The unfolding will often occur over a long time scale, a requirement

that particularly demands the consideration of competitive elements in dealing with the economic and technological context. Thus, consistent evaluation based on relevant criteria is necessary to succeed and this helps in understanding the source of competitiveness that are enablers for sustainable performance (Ajitabh and Momaya, 2004). It is therefore considered important to summarize the latest developments in research on competitiveness in construction through a comprehensive review, and to suggest new directions for further studies (Flanagan et al., 2007).

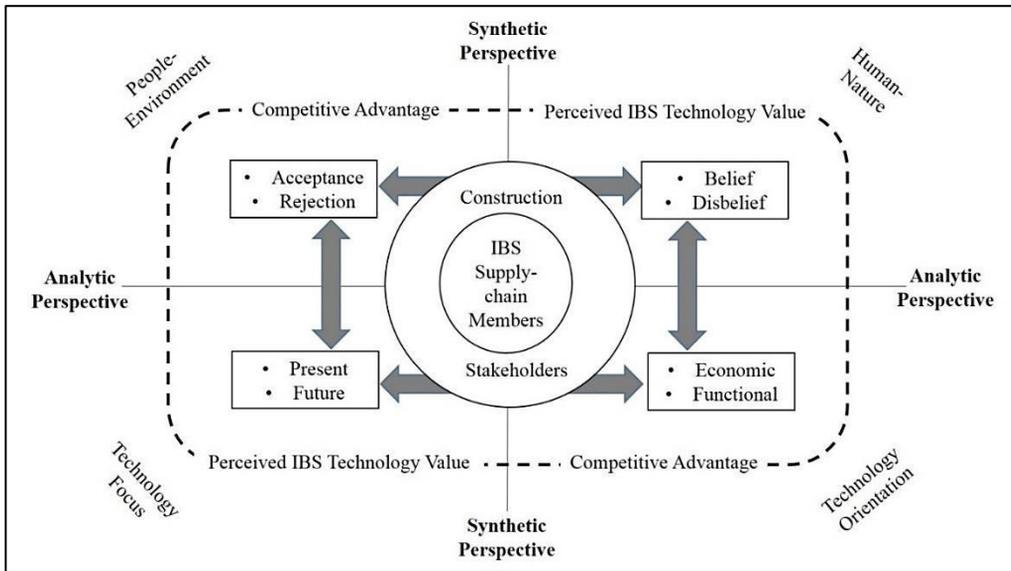
## **THE RESEARCH FRAMEWORK AND METHODOLOGY**

This part contains a combination of theoretical ideas, concepts and generic description on IBS technology adoption from the perspective of decision making, behaviour and environmental forces. Technology adoption in this study involves knowledge-based systems derived from the accessibility and exploitation of technical, managerial and behavioural features. In principle, values are defined in various ways by different researchers and writers. For the purpose of this study the definition by Boer (2006), who is well-known in the study of technology valuation is adopted. Boer comprehends value orientation as complex but technology is about linkages with principles, resulting from the interaction of technology and business issues. Boer (2006) clarifies that people appreciate an effort to change from a qualitative to a quantitative assessment of the financial impact of a new technology.

Based on several works, perceived technology valuation (Thorn et al., 2011) can be classified into analytic and synthetic perspectives (Jonassen and Land, 2012). As perhaps the complex part of exploring IBS technology valuation is also one of the least researched area in the construction industry (MacDougall and Pike, 2003). From the perspective of competitive advantages pertaining IBS, these aspects were based on a dimensional hierarchy model that was developed in the earlier study conducted by Zakaria et al. (2015). It can be used to explore competitive factors relevant to IBS technology valuation.

Therefore, a framework for understanding the technology valuation perception of multiple-perspectives among the construction stakeholders and IBS supply chain members is developed to guide this research based on the adaption and adoption of Boer's (2006), Jonassen and Land (2012), Thorn et al. (2011) and Zakaria et al. (2015) models and frameworks. In addition, origination and development of this framework (Figure 1 and Table 1) with its detail aspects in this study were based on the conceptual synthesis of literature reviews as discussed in this research paper.

As illustrated in Figure 1, the continuous interaction between construction players and their perception towards IBS value provides the means for a dynamic outlook that drives competitive advantage. The perspective of IBS technology valuation focuses primarily on determining prioritised four aspects supported by exploring IBS valuation through the perceptions of the construction stakeholders and IBS supply chain members. The perceptive process addresses and gauges their thoughtfulness on IBS technology valuation to gain competitive advantages.



**Figure 1.** Framework of IBS Technology Valuation with Competitive Aspects

The analytic perspective involves the classic financial mind-set arises from the premise that maximizing net present value of a technology adoption is the best criterion for making investment decisions in technology given limited resources. This is the common capital budgeting decision facing most decision makers in technology adoption. Additionally, the consideration is also on projects that maximizes net present value in terms of shareholder value. Indeed, this analytic perspective often goes one step further: it is pointed out that project proposals often contain the combination of positive outcomes that maximize value.

Meanwhile, the synthetic perspective refers to conditions where technology decision-maker is required to assess technology information and make smart choices as to which technical developments will create promising positions. Additionally, the decisions of technology adoption are based on creativity experience and depth of training. A firm exploits a new and proprietary technology that is linked to the corporation's core technologies. Even greater leverage occurs if a firm develops proprietary technology which enables the technology of other firms to create great future products under conditions where they must pay it for access.

The analytic and synthetic perspectives of technology valuation as they may be noted are done for methodical reasons, and it is not just to suggest that technology perceptions can easily be compartmentalized. In the attempt to develop the profiles of the construction stakeholders and IBS supply chain members, perceived technology valuation is also linked to the character of human nature, the relation between people and their environment; the orientation of technology adoption and the focus of technology adoption. Out of these links, the perception of technology valuation are further subcategorized in the following ways:

- a) The character of human nature; Disbelief (D) vs Belief (B)
- b) The relation between people and their environment; Rejection (R) vs Acceptance (A)
- c) The orientation of technology adoption; Economic Orientation (EO) vs Functional Orientation (FO)

d) The focus of technology adoption; Present Outlook (PO) vs Future Outlook (FO)

A conceptual rubric for visualizing the valuation of IBS for competitive advantage based on various competitive aspects is presented in Table 1 below. Hence, the perception of IBS technology valuation based on multiple-perspectives among the construction stakeholders and IBS supply chain members is related to the analytic and synthetic continuum as follows:

**Table1.** Rubric of IBS Technology Valuation and Competitive Aspects from Multiple Perspectives

Competitive Aspects	Analytic Perspective (AP)		Synthetic Perspective (SP)	
The character of human nature ( <i>Human-Nature</i> ): Minimal labour, Knowledge and experience, Work efficiency	Disbelief (D)	Belief (B)	Disbelief (D)	Belief (B)
The relation between people and their environment ( <i>People-Environment</i> ): Design and resources, Improved productivity, Innovations	Rejection (R)	Acceptance (A)	Rejection (R)	Acceptance (A)
The orientation of IBS technology adoption ( <i>Technology Orientation</i> ): Technology alternatives, Better building quality, Project performance	Economic Orientation (EO)	Functional Orientation (FO)	Economic Orientation (EO)	Functional Orientation (FO)
The focus of IBS technology adoption ( <i>Technology Focus</i> ): Profit margins, Future prospect, Substitute building materials	Present Outlook (PO)	Future Outlook (FO)	Present Outlook (PO)	Future Outlook (FO)

More often than not a study of technology valuation tends to focus on a single perspective and its category. In the analysis of human character pertaining technology valuation, Chang et al. (2006) and Postman (2011) place special emphasis on belief and confidence. Similarly, Bagozzi (2007), Im et al. (2008); Venkatesh and Bala (2008) focus on technology acceptance in their examination of technology adoption for competitiveness. Studies of technology development by Adner and Kapoor (2010), Demirkan et al. (2009) and Weber (2009) also underline the importance of economic orientation in technology valuation. Markard and Truffer (2008); Weber and Rohrer (2012) discover that in the field of technology innovation and transformation are among the few who have their attention to more than a single technology focus. This study however does not confine itself into a single perspective of technology valuation but it highlights analytic and synthetic perspectives as the character of human nature, the relation between people and their environment; and the orientation and focus of technology adoption pertaining competitive advantages.

Methodically, a self-administered questionnaire was developed and administered to construction professionals as the research participants in exploring their perceptions towards the aspects of competitive advantages in IBS adoption from a technology valuation perspective. In order to understand the perceived valuation of IBS technology between the construction stakeholders and the IBS supply chain members, the measurement scales consisting of five (3) items each were used for each competitive advantage aspect in the questionnaire. Each item is presented in the form of a statement. Each statement is rated on a straight 0 – 1 basis (with 1 for agree and 0 for disagree). The structuring of the questionnaire was developed and supported by a review of related literatures on the elements of competitive

advantage, technology valuation and IBS technology adoption. The survey was performed in 2015 for two months.

For the purpose of this study, the sampling of the construction stakeholders and the IBS supply chain members were drawn at random based on a purposive sampling. A purposive sampling or judgment sampling involves selecting elements in the sample for a specific purpose as they represent the target population, but they are not necessarily representative (Ritchie et al., 2013).

In this study, ninety-eight (98) participants were identified within the northern region of Malaysian construction industry in a questionnaire survey. The population distribution of the construction stakeholder's sample, consisting forty-eight (48) professionals. The sample of IBS supply chain members consists of fifty (50) professionals. For each construction stakeholders and the IBS supply chain category, these participants include a/an architect, quantity surveyor, contractor, civil engineer, consultant, developer, project manager, and IBS manufacturer.

## THE FINDINGS AND DISCUSSION

The chi-squared test was used to determine whether there is a significant difference between the expected frequencies and the observed frequencies in one or more categories. Overall, from the results presented in Table 2, it can be described that the construction stakeholders tend to be optimistic in the positioning of IBS technology valuation. They can be described as being more believing, less rejection with future focus as compared to those pessimistic categories. Table 2 also indicates that on every technology valuation perspective, there is a consistently a higher proportion of both analytic and synthetic perspectives on technology valuation as perceived by the construction stakeholders. This analysis suggests that there is no significant difference between analytic perspective and synthetic perspective on each technology valuation category as perceived by the construction stakeholders.

**Table 2.** Perceived Technology Values by the Construction Stakeholders

Competitive Aspects	Analytic Perspective (AP)		Synthetic Perspective (SP)		X <sup>2</sup>
	Disbelief (D)	Belief (B)	Disbelief (D)	Belief (B)	
The character of human nature ( <i>Human-Nature</i> ): Minimal labour, Knowledge and experience, Work efficiency	14	34	17	31	0.51
The relation between people and their environment ( <i>People-Environment</i> ): Design and resources, Improved productivity, Innovations	23	25	16	32	0.15
The orientation of IBS technology adoption ( <i>Technology Orientation</i> ): Technology alternatives, Better building quality, Project performance	33	15	30	18	0.56

Competitive Aspects	Analytic Perspective (AP)		Synthetic Perspective (SP)		X <sup>2</sup>
	Present Outlook (PO)	Future Outlook (FO)	Present Outlook (PO)	Future Outlook (FO)	
The focus of IBS technology adoption ( <i>Technology Focus</i> ): Profit margins, Future prospect, Substitute building materials	7	41	9	39	0.59

An attempt was also made to compare technology valuation as perceived by the IBS supply chain members. From Table 3, from the analytic and synthetic perspective, it is discovered that IBS supply chain members also share similar perception towards technology valuation. However, in terms of the relation between people and their environment, there is a difference between analytic perspective and synthetic perspective, as illustrated by the X<sup>2</sup> of 0.04.

**Table 3.** Perceived Technology Values by the IBS Supply Chain Members

Competitive Aspects	Analytic Perspective (AP)		Synthetic Perspective (SP)		X <sup>2</sup>
	Disbelief (D)	Belief (B)	Disbelief (D)	Belief (B)	
The character of human nature ( <i>Human-Nature</i> ): Minimal labour, Knowledge and experience, Work efficiency	17	33	10	40	0.11
The relation between people and their environment ( <i>People-Environment</i> ): Design and resources, Improved productivity, Innovations	Rejection (R) 18	Acceptance (A) 32	Rejection (R) 6	Acceptance (A) 44	0.04
The orientation of IBS technology adoption ( <i>Technology Orientation</i> ): Technology alternatives, Better building quality, Project performance	Economic Orientation (EO) 20	Functional Orientation (FO) 30	Economic Orientation (EO) 11	Functional Orientation (FO) 39	0.05
The focus of IBS technology adoption ( <i>Technology Focus</i> ): Profit margins, Future prospect, Substitute building materials	Present Outlook (PO) 9	Future Outlook (FO) 41	Present Outlook (PO) 12	Future Outlook (FO) 38	0.46

As presented in Table 2 and 3, the survey results indicate that most of the construction stakeholders and IBS supply chain members were positively responsive to the competitive aspects in the valuation of IBS technology adoption. They also perceived that these aspects such as human-nature, people-environment and technology focus should be highly considered in valuing IBS adoption. The results of the study also clarify the opinion that indicated the major influence of competitive aspects on IBS technology adoption was based on a viable framework of IBS technology valuation.

However, from the aspect of IBS technology orientation that value IBS as a technology alternative, better building quality and project performance, IBS supply chain members perceived these aspects as more optimistic as compared with the construction stakeholders. This result reflects the situation that the construction stakeholders valued IBS as an economic orientation tool, whereas IBS supply chain members valued IBS according to its functional orientation. This finding is indeed in tandem to the findings of Holton et al. (2010) who identify that from the stakeholders' view, the adoption of IBS technology leads to a range of economic benefits. Additionally, from the outlook of IBS supply chain members, Peng and

Pheng (2011) discover that the value of IBS can contribute to improved quality for the sustainable development of an economy.

From the overall results, many participants recognised the fact that the exploration of competitive advantage by the means of IBS valuation requires various interdependent activities between human and nature in addition to people and environment, besides the emphasis on technology orientation and technology focus. Therefore, the aspect of collaboration can be considered as a mechanism to value IBS as a tool of competitive edge. This finding is indeed comparable to the study of Pan et al. (2012) who emphasis on the market value of IBS technology and for competition to facilitate the strategic management of building companies. Accordingly, in gaining competitive from IBS technology valuation, there are needs for the consideration of human nature aspects in IBS adoption such as minimal labour, knowledge and experience, besides work efficiency. Consistent with this finding, the relation between people and their environment with aspects such as design and resources, improved productivity and innovations are also important in gaining competitive from IBS technology valuation. Similarly, Goulding et al. (2012) is instructive in that it provides a clearer understanding of the value of IBS technology adoption, as the authors also suggest that there are other factors, such as people, process and technology, which influence the success of IBS technology adoption for competitiveness.

The findings from the analysis of perceived technology values of the construction stakeholders and the IBS supply-chain members are indeed encouraging. If there were no significant differences between the construction stakeholders and the IBS supply chain members in terms of the way they comprehend IBS technology valuation, it might be possible for the Malaysian construction industry to adopt IBS technology in building projects at ease especially when they have acquired knowledge, understanding and experience in IBS and are doing the same type of work. Additionally, the results reveal that the focus of IBS technology adoption is based on its future outlook and the construction environment. The results of the study also clarify the opinion that alluded that the perception of competitive factors among construction stakeholders and IBS supply chain members on IBS technology adoption through was based on the framework of IBS technology valuation. This reflects that in valuing IBS technology adoption and far as competitive aspects are concern, collaboration through partnering and strategic alliance will make it possible for building projects to adopt IBS technology more effectively.

Collaboration between the construction stakeholders and IBS supply chain members through partnering has received much attention in the construction industry, the way partnering influences decision-making depends on the degree to which it takes place and the make-up of the partners (Crespin-Mazet and Portier, 2010; Skibniewski and Zavadskas, 2013). However, it is rather difficult to undertake that the perception of the construction stakeholders and IBS supply chain members in particular would remain relatively unchanged. Some perception towards technology adoption change with time as suggested by Venkatesh et al. (2007) and by Foster and Rosenzweig (2010) in their investigation into changing concepts of technology adoption value. Therefore, it appears that perception towards technology valuation can and have changed through time in different settings. Hence, the capabilities of players in the Malaysian construction industry appreciate, engage and adopt IBS technology depends on the stability of their perception towards IBS technology values. Furthermore, in view of the exploratory nature of this study and because of the samples used

are relatively small, the findings of this study should be viewed as tentative rather than conclusive. If the results of this study are to be strengthened, there is a need for elaboration and collective effort to understand the mechanism of exploring competitive advantage aspects by the means of IBS technology valuation.

## **CONCLUSION**

This paper concludes that there were no significant differences between the construction stakeholders and the IBS supply chain members in terms of the way they comprehend IBS technology valuation but collaboration between these two groups is important. The need for strategic partnering need to be adjusted interdependently with IBS adoption strategies is then justified. A framework of construction technology valuation that may assist managers in designing a marketing or adoption strategy is also presented, by taking into account informational and market considerations in the construction industry.

Assessment of IBS technology provides a basic approach to advance the appreciation of IBS technology adoption and for guiding improvement efforts when as to steer the competitiveness of the Malaysian construction industry and in the global market. The accomplishment and adoption of IBS technology will require the close interaction between the construction stakeholders and IBS supply chain members with the construction industry. Practically, the valuation of IBS technology application is indeed requires detailed assessment in economical, technical and managerial functions of construction projects and also those who are involve in all stages of the project process in order to obtain appropriate and detailed financial or cost information. Besides this, it is also important to assess the extrinsic and intrinsic value of IBS technology in a holistic way.

## **REFERENCES**

- Bagozzi, R. P. (2007). The Legacy of the Technology Acceptance Model and a Proposal for a Paradigm Shift. *Journal of the association for information systems*, 8(4), 3.
- Adner, R., & Kapoor, R. (2010). Value creation in innovation ecosystems: How the structure of technological interdependence affects firm performance in new technology generations. *Strategic Management Journal*, 31(3), 306-333.
- Ajitabh, A., & Momaya, K. S. (2004). Competitiveness of firms: review of theory, frameworks and models. *Singapore management review*, 26(1), 45-61.
- Arora, A., & Gambardella, A. (2010). Ideas for rent: an overview of markets for technology. *Industrial and corporate change*, 19(3), 775-803.
- Arora, A., & Nandkumar, A. (2012). Insecure advantage? Markets for technology and the value of resources for entrepreneurial ventures. *Strategic Management Journal*, 33(3), 231-251.
- Becerik-Gerber, B., Gerber, D. J., & Ku, K. (2011). The pace of technological innovation in architecture, engineering, and construction education: integrating recent trends into the curricula. *Journal of Information Technology in Construction*, 16, 411-432.
- Belderbos, R., Carree, M., Lokshin, B., & Sastre, J. F. (2015). Inter-temporal patterns of R&D collaboration and innovative performance. *The Journal of Technology Transfer*, 40(1), 123-137.

- Bergek, A., Berggren, C., Magnusson, T., & Hobday, M. (2013). Technological discontinuities and the challenge for incumbent firms: destruction, disruption or creative accumulation?. *Research Policy*, 42(6), 1210-1224.
- Blocker, C. P., Flint, D. J., Myers, M. B., & Slater, S. F. (2011). Proactive customer orientation and its role for creating customer value in global markets. *Journal of the Academy of Marketing Science*, 39(2), 216-233.
- Boer, F.P. (2006). *Technology Valuation Solutions*. Wiley Finance Series, London
- Bonev, M., Wörösch, M., & Hvam, L. (2015). Utilizing platforms in industrialized construction: A case study of a precast manufacturer. *Construction Innovation*, 15(1), 84-106.
- Carroll, A., & Buchholtz, A. (2014). *Business and society: Ethics, sustainability, and stakeholder management*. Cengage Learning.
- Chang, E., Hussain, F., & Dillon, T. (2006). *Trust and reputation for service-oriented environments: technologies for building business intelligence and consumer confidence*. John Wiley & Sons.
- Chen, Y. J. (2011). Structured methodology for supplier selection and evaluation in a supply chain. *Information Sciences*, 181(9), 1651-1670.
- Christensen, C. (2013). *The innovator's dilemma: when new technologies cause great firms to fail*. Harvard Business Review Press.
- Crespin-Mazet, F., & Portier, P. (2010). The reluctance of construction purchasers towards project partnering. *Journal of Purchasing and Supply Management*, 16(4), 230-238.
- CIMP (2010). *Construction Industry Master Plan 2006-2015 (CIMP 2006-2015)*. Kuala Lumpur: Construction Industry Development Board Malaysia (CIDB).
- Davenport, T. H. (2013). *Process innovation: reengineering work through information technology*. Harvard Business Press.
- Demirkan, H., Kauffman, R. J., Vayghan, J. A., Fill, H. G., Karagiannis, D., & Maglio, P. P. (2009). Service-oriented technology and management: Perspectives on research and practice for the coming decade. *Electronic Commerce Research and Applications*, 7(4), 356-376.
- Flanagan, R., Lu, W., Shen, L., & Jewell, C. (2007). Competitiveness in construction: a critical review of research. *Construction Management and Economics*, 25(9), 989-1000.
- Gambardella, A., & McGahan, A. M. (2010). Business-model innovation: General purpose technologies and their implications for industry structure. *Long range planning*, 43(2), 262-271.
- Gambatese, J. A., & Hollowell, M. (2011). Factors that influence the development and diffusion of technical innovations in the construction industry. *Construction Management and Economics*, 29(5), 507-517.
- Garleanu, N., Panageas, S., & Yu, J. (2012). Technological growth and asset pricing. *The Journal of Finance*, 67(4), 1265-1292.
- Gibb, A. G. (2001). Standardization and pre-assembly-distinguishing myth from reality using case study research. *Construction Management & Economics*, 19(3), 307-315.
- Goetsch, D. L., & Davis, S. B. (2014). *Quality management for organizational excellence*. Pearson.
- Goulding, J., Rahimian, F. P., Arif, M., & Sharp, M. (2012). Offsite construction: strategic priorities for shaping the future research agenda. *Architectonica*, 1, 62-73.
- Girmscheid, G., & Rinas, T. (2012). Business Design Modeling for Industrialization in Construction: Cooperative Approach. *Journal of Architectural Engineering*, 18(2), 164-175.

- Hamid, Z., K.A.M. Kamar, M. Zain, K. Ghani and A.H.A. Rahim, (2008). Industrialized Building System (IBS) in Malaysia: The Current State and R&D Initiatives. *Malaysia Construction Research Journal (MCRJ)*, 2(1): 1-13
- Hill, C., Jones, G., & Schilling, M. (2014). *Strategic management: theory: an integrated approach*. Cengage Learning.
- Holton, I., Glass, J., & Price, A. D. (2010). Managing for sustainability: findings from four company case studies in the UK precast concrete industry. *Journal of Cleaner Production*, 18(2), 152-160.
- Im, I., Kim, Y., & Han, H. J. (2008). The effects of perceived risk and technology type on users' acceptance of technologies. *Information & Management*, 45(1), 1-9.
- Jaillon, L., & Poon, C. S. (2009). The evolution of prefabricated residential building systems in Hong Kong: A review of the public and the private sector. *Automation in Construction*, 18(3), 239-248.
- Jonassen, D., & Land, S. (Eds.). (2012). *Theoretical foundations of learning environments*. Routledge.
- Kadir, M. R. A., Lee, W. P., Jaafar, M. S., Sapuan, S. M. & Ali, A. A. A. (2006) Construction performance comparison between conventional and industrialised building systems in Malaysia. *Structural Survey*, 24, 412-424
- Kamar, K. A. M., & Hamid, Z. A. (2011). Supply chain strategy for contractor in adopting industrialized building system (IBS). *Australian Journal of Basic and Applied Sciences*, 5(12), 2552-2557.
- Kempton, J. (2010). Modern methods of construction and RSL asset management: a quantitative study. *Structural Survey*, 28(2), 121-131.
- Kim, H. J., & Reinschmidt, K. F. (2010). Effects of contractors' risk attitude on competition in construction. *Journal of Construction Engineering and Management*, 137(4), 275-283.
- Kozinets, R. V. (2008). Technology/ideology: How ideological fields influence consumers' technology narratives. *Journal of Consumer Research*, 34(6), 865-881.
- Krawczyk, J. B., & Serea, O. S. (2013). When can it be not optimal to adopt a new technology? A viability theory solution to a two-stage optimal control problem of new technology adoption. *Optimal Control Applications and Methods*, 34(2), 127-144.
- Li, Z., Shen, G. Q., & Alshawi, M. (2014). Measuring the impact of prefabrication on construction waste reduction: An empirical study in China. *Resources, Conservation and Recycling*, 91, 27-39.
- Linner, T., & Bock, T. (2012). Evolution of large-scale industrialisation and service innovation in Japanese prefabrication industry. *Construction Innovation*, 12(2), 156-178.
- MacDougall, S. L., & Pike, R. H. (2003). Consider your options: changes to strategic value during implementation of advanced manufacturing technology. *Omega*, 31(1), 1-15.
- Mahbub, R. (2012). Readiness of a developing nation in implementing automation and robotics technologies in construction: a case study of Malaysia. *Journal of Civil Engineering and Architecture*, 6(7), 858.
- Majid, T. A., Azman, M. N. A., Zakaria, S. A. S., Yahya, A. S., Zaini, S. S., Ahamad, M. S. S., & Hanafi, M. H. (2011). Quantitative analysis on the level of IBS acceptance in the Malaysian construction industry. *Journal of Engineering Science and Technology*, 6(2), 179-190.
- Markard, J., & Truffer, B. (2008). Technological innovation systems and the multi-level perspective: Towards an integrated framework. *Research policy*, 37(4), 596-615.
- Ndungu, P., Tsao, C., & Molavi, J. M. (2012). Sustainable Construction: Comparison of Environmental Effects on Two Construction Methods. In ICSDC 2011: Integrating

- Sustainability Practices in the Construction Industry: *Proceedings of the 2011 International Conference on Sustainable Design and Construction*, March 23-25, 2011, Kansas City, Missouri (p. 398). ASCE Publications.
- Pan, W., Gibb, A. G. F. & Dainty, A. R. J. (2008). Leading UK housebuilders' utilization of offsite construction methods. *Building Research and Information*, 36, 56-67.
- Pan, W., Gibb, A. G., & Dainty, A. R. (2012). Strategies for integrating the use of off-site production technologies in house building. *Journal of Construction Engineering and Management*, 138(11), 1331-1340.
- Peng, W., & Pheng, L. S. (2011). Lean production, value chain and sustainability in precast concrete factory—a case study in Singapore. *Lean Construction Journal*, 2010, 92-109.
- Poetz, M. K., & Schreier, M. (2012). The value of crowdsourcing: can users really compete with professionals in generating new product ideas?. *Journal of Product Innovation Management*, 29(2), 245-256.
- Polat, G. (2010). Precast concrete systems in developing vs. industrialized countries. *Journal of Civil Engineering and Management*, 16(1), 85-94.
- Porter, A. L., Cunningham, S. W., Banks, J., Roper, A. T., Mason, T. W., & Rossini, F. A. (2011). *Forecasting and management of technology*. 2nd Edition, Wiley, New Jersey.
- Porter, M. E. (2008). *Competitive advantage: Creating and sustaining superior performance*. Simon and Schuster.
- Postman, N. (2011). *Technopoly: The surrender of culture to technology*. Vintage.
- Prahalad, C. K., & Ramaswamy, V. (2013). *The future of competition: Co-creating unique value with customers*. Harvard Business Press.
- Richard, R. B. (2005). Industrialized building systems: Reproduction before automation and robotics. *Automation in Construction*, 14(4), 442-451.
- Ritchie, J. (2003). The applications of qualitative methods to social research. *Qualitative research practice: in Ritchie, J. and Lewis, J.: A guide for social science students and researchers*, Sage Publication, London, 24-46.
- Saaty, T. L. (2008). Decision making with the analytic hierarchy process. *International journal of services sciences*, 1(1), 83-98.
- Salunke, S., Weerawardena, J., & McColl-Kennedy, J. R. (2011). Towards a model of dynamic capabilities in innovation-based competitive strategy: insights from project-oriented service firms. *Industrial Marketing Management*, 40(8), 1251-1263.
- Santos-Vijande, M. L., López-Sánchez, J. Á., & Trespalacios, J. A. (2012). How organizational learning affects a firm's flexibility, competitive strategy, and performance. *Journal of Business Research*, 65(8), 1079-1089.
- Sarja, A. 2003, *Open and Industrialised Building*, Vol. 222, Taylor & Francis, New York.
- Sashi, C. M. (2012). Customer engagement, buyer-seller relationships, and social media. *Management decision*, 50(2), 253-272.
- Scarborough, H., & Corbett, J. M. (2013). *Technology and Organization (RLE: Organizations): Power, Meaning and Design*. Routledge.
- Selic, B. (2012). What will it take? A view on adoption of model-based methods in practice. *Software & Systems Modeling*, 11(4), 513-526.
- Shen, L. Y., Tam, V. W. Y., & Li, C. Y. (2009). Benefit analysis on replacing in-situ concreting with precast slabs for temporary construction works in pursuing sustainable construction practice. *Resources, Conservation and Recycling*, 53(3), 145-148.
- Skibniewski, M. J., & Zavadskas, E. K. (2013). Technology development in construction: a continuum from distant past into the future. *Journal of Civil Engineering and Management*, 19(1), 136-147.

- Sköld, M., & Karlsson, C. (2012). Technology sharing in manufacturing business groups. *Journal of Product Innovation Management*, 29(1), 113-124.
- Son, H., Park, Y., Kim, C., & Chou, J. S. (2012). Toward an understanding of construction professionals' acceptance of mobile computing devices in South Korea: An extension of the technology acceptance model. *Automation in Construction*, 28, 82-90.
- Tambe, P., Hitt, L. M., & Brynjolfsson, E. (2012). The extroverted firm: How external information practices affect innovation and productivity. *Management Science*, 58(5), 843-859.
- Tan, Y., Shen, L., & Yao, H. (2011). Sustainable construction practice and contractors' competitiveness: A preliminary study. *Habitat International*, 35(2), 225-230.
- Tassey, G. (2012). Technology infrastructure and competitive position. Springer Science & Business Media.
- Terho, H., Haas, A., Eggert, A., & Ulaga, W. (2012). 'It's almost like taking the sales out of selling' - Towards a conceptualization of value-based selling in business markets. *Industrial Marketing Management*, 41(1), 174-185.
- Thanoon, W. A. M., Peng, L. W., Kadir, M. R. A., Jaafar, M. S., & Salit, M. S. (2003). The Experiences of Malaysia and other countries in industrialised building system. In *Proceeding of International Conference on Industrialised Building Systems*, Sep (pp. 10-11). International Conference on Industrialised Building Systems, Kuala Lumpur, Malaysia, 10-11 September, 2003
- Thorn, V., Hunt, F., Mitchell, R., Probert, D., & Phaal, R. (2011). Internal technology valuation: real world issues. *International Journal of Technology Management*, 53(2), 149-160.
- Venkatesh, V. (2006). Where to Go from Here? Thoughts on Future Directions for Research on Individual-Level Technology Adoption with a Focus on Decision Making. *Decision Sciences*, 37(4), 497-518.
- Venkatesh, V., & Bala, H. (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision sciences*, 39(2), 273-315.
- Wang, C. H., Lu, Y. H., Huang, C. W., & Lee, J. Y. (2013). R&D, productivity, and market value: An empirical study from high-technology firms. *Omega*, 41(1), 143-155.
- Weber, K. M., & Rohracher, H. (2012). Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework. *Research Policy*, 41(6), 1037-1047.
- Weber, M. (2009). *The theory of social and economic organization*. Simon and Schuster.
- West, D., Ford, J., & Ibrahim, E. (2015). *Strategic marketing: creating competitive advantage*. Oxford University Press.
- Zakaria, S. A. S., Brewer, G. and Gajendran, T. (2015) A Quantitative Method for Ranking the Influence of Competitive Factors on Industrialised Building System (IBS) Decision-making, *World Journal of Management*, 6 (2), Sep, 172-186.

*This page intentionally left blank*

# APPLICATION OF MODIFIED DELPHI IN IDENTIFYING THE PRESENCE OF INCOMPLETE CONTRACT (IC) IN PRIVATE FINANCE INITIATIVE (PFI) PROJECTS

**Nur Syaimasyaza Mansor, Khairuddin Abdul Rashid, Mohd. Fairullazi Ayob and Sharina Fariyah Hassan**

*Kulliyah of Architecture and Environmental Design (KAED), International Islamic University Malaysia (IIUM), Malaysia.*

## **Abstract**

Incomplete contract (IC) is a contract that fails to state all the parties' rights and obligations, has gaps and ambiguities in its terms and conditions. Past studies had reported that most contracts are incomplete to some degree, and this includes Private Finance Initiative (PFI) contracts. PFI involves the private sector to finance, design, construct, operate and maintain an asset through 20-30 years concession period. Due to its long duration, the contracting parties cannot specify all potential contingencies that might occur throughout the term of the contract and PFI contracts are inevitably incomplete. Sometimes IC is preferable because it provides the necessary flexibility to deal with uncertainty, but it also causes inefficiencies and costs, investment problem, contract amendment and so on. The objective of this paper is to report on a study to identify the presence of IC in PFI projects in Malaysia. The methodology used for the study is a two-round modified Delphi. This study is limited only to analyse PFI concession contracts in Malaysia. Based on extensive literature review and content analysis of eight PFI contracts, 12 clauses were identified as incomplete, and the findings become the basis of the semi-structured questionnaire for the modified Delphi. The aim of the modified Delphi is to achieve a consensus of experts' opinion regarding the presence of IC in PFI projects. Results from the study show that the 12 identified clauses were deemed incomplete. Finding reported herein is considered significant towards effort in enhancing the effectiveness and efficiency of PFI contracts.

**Keywords:** *incomplete contract, Private Finance Initiative, gap, ambiguous, renegotiate, change*

## **INTRODUCTION**

The subject of incomplete contract (IC) has been around since the 1930s. Many scholars have applied the theory of IC for various research i.e. explaining what is firm and why firms have boundaries (Coase, 1937), analysing firms' internal organization, delegation and authority in firm, and the issues of asset specificity (Chung, 1991; Grossman & Hart, 1986). Past studies such as Abdallah et al. (2013), Athias & Soubeyran (2012) and Athias & Saussier (2010) had briefly discussed the theory of IC in the perspective of Public-Private Partnership (PPP) and PFI contract. However, most literature only discusses the incompleteness of the contract as in general and did not specify on which clause in PFI contract that is deemed incomplete.

PFI is an alternative procurement method introduced to help the government overcoming the lack of financial resources and advanced technology in procuring socio-economic infrastructures. In PFI contract, the process of financing, designing, constructing, operating and maintaining the assets is bundled together and to be completed by the concessionaire. The Malaysian government had decided to use PFI in 2006, and the implementation continued until now. However, there have been criticisms about PFI. Among the criticisms that concerns IC include lopsided contractual agreement (Jayaseelan & Tan, 2006), the absence of robust and clear agreement (Abdul-Aziz & Jahn Kassim, 2011), and ambiguity and lack of details

on sustainability element in concession contracts (Mohd Farimi Izudin et al., 2011). Nevertheless, there is lack of literature evidence stating that PFI contracts in Malaysia are incomplete. Hence, this paper aims to identify the presence of IC in PFI projects in Malaysia through a two-round modified Delphi.

This paper is organized as follows: First, it begins with literature review regarding IC, PFI, standard contract and concept of IC in PFI. Next, the methodology used in this study i.e. modified Delphi is explained, followed by the results and discussion of the results. The final part of the paper is the conclusion.

## **LITERATURE REVIEW**

### **Incomplete Contract**

Most economic transaction used contract as an instrument to perform the transaction where every rights and obligation of trading parties is specified *ex-ante*. Contracts are categorized in various way for example according to the method of formation of a contract (Express contract, Implied contract, Quasi contract), the time of performance of contract (Executed contract, Executory contract), and others (Beatson et al., 2010; Judicial Education Center, 2014). One school of thought classify contracts according to the substance of the contract i.e. complete or incomplete (Athias & Saussier, 2010; Walker, 2012).

A complete contract is a contract that specifies the rights and obligations in every future state of the world for each party (Grant et al., 2012; Baker & Krawiec, 2006; Scott & Triantis, 2005; Craswell, 1999). However, complete contract is only an imaginary concept used by people to define one endpoint of completeness (Craswell, 2000). In reality, most contract is incomplete to some degree. On the other hand, incomplete contract (IC) is defined as a contract that fails to clearly spell out *ex-ante* the parties' requirements, duties and obligations for every realised contingency (Fraja, 2002; Yates, 1998) and it has gaps, missing provisions, and ambiguities in its terms (Craswell, 2005; Hart, 1995). Although the contract is considered complete and valid when all requirements to contract (i.e. free consent, competent to contract, lawful consideration and object, legality) is met, the concept of IC concerns on the substance of the contract itself. After the contract has been made, some items are not included in the contract due to exogenous and endogenous factors (see Table 1) and cause the contract to be incomplete. However, this does not mean that the transaction (for example, construction contract) is incomplete or unsuccessful.

The project can be completed but under the existence of IC, the project's success may be affected either positively or negatively due to IC. Positively, IC provides the necessary flexibility to deal with uncertainty (Boukendour, 2007; Miller et al., 2013). Some scholar contended that the use of IC could increase the contracting parties' motivation (Herold, 2010). Negative implications of IC refers to inefficiencies and costs implication (Bajari et al., 2014; Hart, 1995), investment problem (Bi & Wang, 2011; Marques & Berg, 2010), contract amendment (Bajari et al., 2014; Garvin, 2009) and so on. As a result, some contracting parties face with disputes and breach of contract (Abdallah et al., 2013; Chua, 2012). From the literature review, four IC characteristics have been identified (see Table 2).

**Table 1.** Factors of IC

<b>Exogenous factors:</b>	
1	<u>Long-duration project</u> -Long-duration contracts usually involve many uncertainties and future changes (social, economic, political and technological). While it is difficult to predict all possible contingencies, to identify all contingencies will be too expensive (Williamson, 1979).
2	<u>High risk or uncertainty</u> -In a project with high risk or uncertainty, the parties are unable to specify all contingencies ex-ante and caused them to have an IC (Lonsdale, 2005).
3	<u>High transaction cost</u> -High transaction cost include; 1) cost determining all contingencies ex-ante; 2) cost of writing them in the contract; and 3) cost of finding and proving the existence of the contingencies (Guasch, 2004; Tirole, 1999).
<b>Endogenous factor:</b>	
1	<u>Bounded rationality</u> -Individual has limited ability to predict future problem/uncertainty because they are bounded by the information they have, the limitation of their mind (knowledge) and the time to acquire the information.
2	<u>Asymmetric information</u> - The phenomenon when the contracting parties did not possess the same amount of information. The party with more/better information might act opportunistically and lead to IC (Spier, 1992).
3	<u>Signaling trust</u> -By designing a more complete contract, which clearly define the fines, punishments, and incentives, the party gives the impression that they did not trust their counterpart and consequently lower their motivation (Herold, 2010). Thus, some party may choose to trust their counterpart and adopted an IC.

**Table 2.** IC Characteristic

<b>No.</b>	<b>Characteristic</b>	<b>Description</b>	<b>Reference</b>
1	Contract has gap or loophole	The following circumstances explain the gap or loophole in the contract: i. The contract has missing provision or complete absence of certain specification; ii. The contract did not specify who has the right to decide or the decision actions for a certain contingency; or it only specifies who has the right to decide but does not specify the decisions actions to be taken; iii. The parties are aware of certain contingencies, but they are unable to specify it in the contract because the state of nature cannot be verified; iv. Certain contingencies were deliberately left out of contract with the intention to renegotiate later Due to the above circumstances, the parties fail to provide for a term and leave a literal gap or a loophole.	GAP
2	Contract has vague or ambiguous clauses	The clause or term used in the contract is not clear and creates room for different interpretation among the parties.	AMBIGUOUS
3	There is additional work and changes	Certain operation is not included in the original contract or during the course of the contract. The parties, usually the client or public entity wish to add or change certain work. Additional work and changes cause the parties to amend the contract.	CHANGE
4	The contract is renegotiated	i. Contracts are renegotiated when contractual provision happen to be inadequate to deal with certain contingencies. ii. An incomplete contract is a contract specifying the available design, which is renegotiated whenever this design turns out not to be appropriate. iii. Renegotiate in terms of scope of work or compensation. iv. Renegotiate because of changes that are required after contract execution.	NEGOTIATE

(Source: Nur Syaimasyaza & Khairuddin, 2014, 2015)

Hart & Holmstrom (1986) and Hart & Moore (1988) contended that almost every contractual dispute that has been brought to courts concerns a matter of incompleteness. The cases present henceforth associated with IC. Although there is no specific indication that the cases concern IC, on a closer review the disputes that occurred show the presence of IC characteristics.

In *Peak Construction (Liverpool) Ltd v McKinney Foundations Ltd [1970] 1 BLR 111*, the construction contract has a gap where it lacks provision specifying contractor's entitlement to an extension of time when there is delay caused by the client. In this case, the client had caused long delays due to its failure to approve a scheme of remedial works and due to that event, the contractor argued that they were entitled to the extension of time. The court ruled that the contractor was entitled to the extension of time and considered the missing provision as a fatal shortcoming. Another case concern *Weeshoff Constr. Co. v. Los Angeles County Flood Control Dist. [1979] 88 CA3d 579*. The parties in this contract disputed on the term 'temporary resurfacing' because the contract was ambiguous in defining the term. Weeshoff Construction was appointed by Los Angeles Country Flood Control District to construct and install a storm drain. During the work, Weeshoff needed to ensure that three traffic lines were maintained. The contract prohibits the use of temporary resurfacing, which Weeshoff did comply by using hard sand compact, but this material did not satisfy the District. After what the District described 'non-compliance' by Weeshoff, the District, themselves used temporary pavement to maintain the road and claimed the cost from Weeshoff. Weeshoff argued that temporary pavement is considered as temporary resurfacing. The court later ruled that the temporary pavement was indeed considered as temporary resurfacing.

In the example of cases above, both contracts are considered incomplete wherein the first case, the IC characteristic for the construction contract is it has a 'GAP'. While in the second case, the IC characteristic shown in the contract is 'AMBIGUOUS'.

### **Private Finance Initiative (PFI)**

Traditionally, the public sector or the government is the sole entity who is responsible for providing public infrastructures. However, as the demand for a new and better infrastructure and services is increasing, many governments face the challenge to cope with the demand (Abdul Quium, 2011; G. Winch et al., 2012). Therefore, PFI was introduced to help the government overcoming the lack of financial resources and advanced technology. PFI was first developed by the United Kingdom in 1992. Based on the UK model, PFI forms a subset under Public-Private Partnerships (PPP) scheme. In Malaysia, PFI was introduced in 2006 under the Ninth Malaysian Plan (Ninth Malaysia Plan, 2006).

In PFI, the public sector will act as the purchaser of the public services, where they will set the standard of services required and pays the private sector unitary payments for the services provided (Khairuddin, 2009). While the private sector will be responsible for financing, designing, constructing, operating and maintaining the assets until the end of the concession period and the contract could expand for as long as 30 years. The public sector and the special purpose vehicle (SPV) will form the main contract (commonly called concession agreement), and the SPV will form contracts with other entities including the finance provider (i.e. debt provider, construction investor, facilities management investor and other investors), construction contractor and facilities management operator.

## **Standard Contract**

It is common practice in the construction industry to use a standard contract. The purpose of using standard contract is to ensure consistent risk allocation setting between the parties to the contract and provides greater certainty regarding the meaning of the contractual terms (Patterson, 2010). Internationally, among the leading institutions that had established standard contract for construction are The Joint Contracts Tribunal (JCT) and International Federation of Consulting Engineer (FIDIC). In Malaysia, Pertubuhan Arkitek Malaysia (PAM) and Jabatan Kerja Raya Malaysia (JKR) are among the leading institutions that produced standard contract.

A standard contract can also become incomplete. As time goes by, new kind of uncertainty or risk might surface and somehow makes the previous provisions or terms in the contract obsolete. This means that the standard contract needs to be continuously updated and modified. Many standard contracts that have been produced by the institutions were revised to adapt to the current practice and implementation. For example, one type of JKR's standard contract (which is the standard form of contract to be used where bills of quantities form part of the contract) had gone a series of revision, i.e. P.W.D. 203A (Rev. 10/83), P.W.D. 203A (Rev. 2007), P.W.D. 302A (Rev. 1/2010).

In some countries such as the United Kingdom, Australia, India, Netherland, Japan and other, standard contract is designed for PFI. However, in Malaysia, there is no evidence showing that standard PFI contract is available. However, through personal communication with personnel in Unit Kerjasama Awam Swasta (UKAS) (the agency that monitor and assist the implementation of PFI), a standard template for PFI contract had been drafted, but it is not made public.

Similarly, a standard PFI contract is also inevitably incomplete. Hence, improvement and modification are needed to deal with the incompleteness. For example, in the UK, they had gone through four version PFI standard form of contracts with the latest version was issued in March 2007. Even with continuous improvement and modification, the provision in the standard contract might be only relevant at the time the contract was signed, but it can easily become obsolete after some time. This is because, for PFI contracts, future events and variables facing the project over the next 20-30 years of the contract is difficult to predict. Over the contract duration, political, economic, environmental and social changes are bound to happen (Cruz & Marques, 2013) and cause the provision specified ex-ante become outdated.

## **Concept of IC in PFI**

Several researches had been done to discuss the concept of IC in the perspective of PPP/PFI (Abdallah et al., 2013; Bennett & Iossa, n.d.; de Brux & Desrieux, n.d.; Hart, 2003). Some of the literature had mentioned some areas in PFI projects where IC normally presents. Using coding of important terms (relating to areas where IC normally present in PFI projects), categories regarding the areas were established (Fellows & Liu, 2015). The identified areas were further analysed to determine whether they comply with the IC Characteristics. Table 3 presents the summary of areas that are deemed incomplete in PFI contract. The result from the analysis shows that every area identified matches with one or more IC Characteristics.

**Table 3.** A summary of area that is deemed incomplete in PFI contract

Area	Description	IC Characteristics
1 Concession charges	Difficulties in forecasting future demand and future economic condition with confidence	NEGOTIATE
2 Service delivery	<ul style="list-style-type: none"> <li>• Difficulties in specifying all service delivery contingencies during the contract period</li> <li>• Difficulties in specifying soft service delivery in certain area.</li> <li>• Terminology in the output specification is very subjective</li> <li>• Contract changes are needed due to problems related to the interpretation or changes to the output specification</li> </ul>	GAP AMBIGUOUS CHANGE
3 Design of output specification	Changes to design due to change in regulations	CHANGE
4 Variation	Many variations due to change in policy or local need	CHANGE
5 Quality	Inability of the contract to specifically address all quality issues	GAP
6 Contract monitoring	Problems related to monitoring are on supervising service quality, contractual disputes resolution and customers complaints, applying sanctions and performance rewards, participating in potential renegotiation, covering early termination of contracts, supervising asset transfer, and defining terms for the renewal of PPP contracts.	GAP
7 Sustainable element	<p>The contract clauses show lack of details and eventually raise uncertainty in delivering sustainable development</p> <p>Ambiguity on the sustainable and green design element during the designs and implementation stage</p>	GAP AMBIGUOUS

(Source: Nur Syaimasyaza & Khairuddin, 2014, 2015)

## RESEARCH METHOD AND DESIGN

### Modified Delphi method

Delphi method is a widely used method to develop a consensus of opinion from a panel of experts (usually referred to as the panellists, participants or respondents) (Hsu & Sandford, 2007) through a structured group communication process. There is four main features of Delphi approach i.e. (i) anonymity of respondents, (ii) reiteration of questions, (iii) controlled feedback, and (iv) the statistical aggregation of group response (Hsu & Sandford, 2007; Rowe & Wright, 1999). The Delphi method were claimed as a suitable research approaches compared to other typical research approaches (e.g. surveys, case studies, action research) when the nature of the research lack up-to-date and reliable data, insufficient theory, and limited number of respondents to provide adequate response rate (Giannarakis et al., 2011; Hamimah & Morledge, 2003; Mohd Fairullazi & Khairuddin, 2016; Mohd Fairullazi, 2014; Skulmoski & Hartman, 2007; Wiersma & Jurs, 2009). In addition, some scholars contended that this approach is the most suitable approach in procuring data that is affluent and profound because the data is generated from the analysis of opinions, views, and judgments of the combined intelligence of the panellist, i.e. the experts, practitioners, knowledgeable persons and learned spectators in the PFI environment (Mohd Fairullazi, 2014; Wiersma & Jurs, 2009). Moreover, the panellists in the Delphi method can work individually and anonymously. As a result, they can freely express their opinion without being influenced by others and no restriction even to provide any extreme opinions (Mohd Fairullazi, 2014; Parsons et al., 2008; Wiersma & Jurs, 2009).

Many variations were found regarding the technique in implementing the Delphi method (refer Table 4). In this research, a modified Delphi was adopted whereby, a semi-structured questionnaire was used in the first round and face-to-face interview was conducted for both rounds.

**Table 4.** Variation of Delphi method

Variation	Delphi method	Modified Delphi method
The design of the instrument	An open-ended question was used during the first round interview (Hsu & Sandford, 2007)	<ul style="list-style-type: none"> <li>• A structured question was used during the first round interview, which the contents of the questionnaire were developed through other methods, e.g. literature review, content analysis, survey, etc. (Bulger, 2004; Hsu &amp; Sandford, 2007; Rafiza, 2010).</li> <li>• Advantage: 1) the Delphi process can be expedited; 2) the researcher sustain control over the range and scope of the issues that being discussed (Bulger, 2004).</li> </ul>
Mode of interaction	Pen and paper based, using traditional mail (Skulmoski & Hartman, 2007)	<ul style="list-style-type: none"> <li>• The Internet and electronic mail are used. Some scholars used an online survey, e.g. SurveyMonkey (Barry et al., 2008; Joseph-Williams et al., 2014; Parsons et al., 2008), e-mail survey (Griffith et al., 2007; Hamimah &amp; Morledge, 2003) and web-based questionnaire (Brill et al., 2006; Hejblum et al., 2008)</li> <li>• Advantage: accelerate data flow and reduce time delay between the rounds of questionnaires</li> <li>• Scholars such as Mohd Fairullazi (2014), conducted a face-to-face interview in the first round with the objectives: 1) to improve the response rate; 2) to provide the panellists with sufficient information about the scope and objectives of the research; 3) to improve the panellists understanding with regards to the questions; and 4) to provide added explanations on any ambiguity arises.</li> </ul>

### **Selection of expert panel**

The careful selection of the panel members is the key point for the success of the Delphi method (Hamimah & Morledge, 2003). Following Hamimah & Morledge (2003) a purposive approach was used to determine suitable experts that have in-depth knowledge and sound experience about PFI contracts. The following criteria were used in determining the appropriate experts:

- Knowledge wise, the person should possess at least a Degree in the area related to PFI practice, e.g. architect, quantity surveyor, engineer, banker, etc.
- The skill that refers to their ability to make a sound judgment based on knowledge and experience in PFI implementation and contracts through involvement in PFI projects e.g. in the form of policy, planning, implementation, supervision of PFI contract, etc.
- Having worked experience in PFI projects in Malaysia.

Academicians with extensive research on PFI were also invited as the panelist for this study. A list of potential experts was initially identified from the literature searches, pilot study, and web-search. However, due to lack of available and reliable database of people or organization involved in PFI projects in Malaysia, a snowball technique was adopted. From literature, no standard number of experts were assigned in Delphi method (Giannarakis et al., 2011; Hsu & Sandford, 2007). The sample size could be as small as 4 and as many as 100 and more (Skulmoski & Hartman, 2007). However, the researcher needs to ensure that all

members in the focus area of the research are represented and participated in the Delphi study (Skulmoski & Hartman, 2007). Considering the limited number of panelists with relevant expertise in PFI in Malaysia, the specialized nature of information required by this research (i.e. the panelists have knowledge or access to PFI concession contract) and following recommendation from Delphi literature, the researcher aims to get between 10 to 18 participants in each round of the Delphi questionnaire (Mohd Fairullazi, 2014). Invitation letters were sent to 23 selected experts to explain the purpose of the research and the objective of the modified Delphi. From the process, 18 panelists were willing to participate.

### Administrating the modified Delphi study

A two-round modified Delphi was conducted from June 2015 to November 2015. Both rounds of modified Delphi interview were conducted face-to-face. The schematic flow of modified Delphi process is presented in Figure 1 (Appendix).

#### Round 1

The questions in the first round were developed in a semi-structured format. The questionnaire was divided into two (2) sections (i.e. Section A and Section B) where the first section requires the panellists to provide their background information, indicate their expertise and competency in relation to the research subject. Section B presents the research question i.e. the clause that is deemed incomplete. The contents of the question in Section B was developed from the findings of the literature review.

From the literature review, IC characteristics (Table 2) and the area that is deemed incomplete by past studies (Table 3) had been identified. The findings from the literature have then become the basis for determining which clause in PFI contracts that is incomplete. Eight PFI concession contracts were reviewed, and the identification process was done by examining similar clauses in the eight contracts, and the clause is categorized as incomplete if: a) It matches with any one or more area of IC that has been identified by past studies; b) Any one or more clause/sub-clause of the contracts show signs of any one or more IC characteristic. The results of literature review have identified 12 clauses that are deemed incomplete (Table 5).

**Table 5.** List of clauses that is deemed incomplete

No	Clause	Incomplete based on	
		Characteristic	Past study (area)
1.	Condition precedent	AMBIGUOUS	
2.	Concession charges	NEGOTIATE	Concession charges
3.	Design and Construction of the Project	GAP	1) Design of output specification 2) Sustainable element
4.	Delay of the Construction Works	GAP	
5.	Asset Management Services	CHANGE, NEGOTIATE, GAP	Service delivery
6.	Service Levels	NEGOTIATE	Quality
7.	Additional Works	GAP, NEGOTIATE	Variation
8.	The Concession Company	GAP, NEGOTIATE	
9.	Force Majeure	GAP,	

No	Clause	Incomplete based on	
		Characteristic	Past study (area)
		AMBIGUOUS, CHANGE	
10.	Project Monitoring Committee	GAP	Contract monitoring
11.	Dispute Resolution	GAP	
12.	Occupational Safety and Health Requirements	GAP	

The panellists were asked to rate their level of agreement with the clause identified as incomplete, on a 5-point Likert-type scale (i.e. 1. Strongly disagree, 2. Disagree, 3. Neutral/Not sure, 4. Agree, 5. Strongly agree). They were also asked to state any other clause that is deemed incomplete, but no suggestion was received. All responses received were analysed and the outcome is presented in the second round modified Delphi. A total of 18 completed questionnaire were obtained representing 78% of response rate (out of 23 experts).

### Round 2

For the second round modified Delphi, the panelists were provided with feedback of the results obtained in the first round, where their score and descriptive statistic of the group response (mode and standard deviation (SD)) were shown. The mode score was calculated to determine the most frequent score in the data set. While SD score was calculated to measure the variability of response in the data set and the level of consensus achieved. SD score below 1.00 indicates that a ‘high level of consensus’ achieved and SD score below 1.5 to 1.00 indicates that a ‘reasonable level of consensus’ achieved (Mohd Fairullazi, 2014). The panelists were given the opportunity to revise or retain their score. If they decide to revise their score, they were advised to give their reason(s). A total of 13 completed questionnaire were obtained representing 72% of response rate, which achieved the minimum acceptance response of 35% (Mohd Fairullazi, 2014).

## RESULTS AND DISCUSSIONS

In the second round, four out of 13 panellists revised their score and rated 4 (Agree). The revised was due to the misunderstanding of the statement that refers to IC and they agree on the results from literature review and descriptive statistic of the group response. The presentation of results (refer Table 6) herewith constitutes descriptive analysis for each round that was carried out using Microsoft Office Excel 2013.

**Table 6.** Comparative analysis result on round 1 and 2 modified Delphi

No.	Clause/Sub-clause	1 <sup>st</sup> round		2 <sup>nd</sup> round		Changed value	
		Mode Score	SD	Mode Score	SD	Mode Score	SD
1.	<u>A - Condition precedent</u> A1 - Condition to be fulfilled	4	0.79	4	0.76	-	-0.03
2.	<u>B - Concession charges</u> B1 - Review of the Asset Management Service Charges	4	0.99	4	1.05	-	+0.06
	B2 - Effect of Review	4	0.97	4	0.96	-	-0.01

No.	Clause/Sub-clause	1 <sup>st</sup> round		2 <sup>nd</sup> round		Changed value	
		Mode Score	SD	Mode Score	SD	Mode Score	SD
	B3 - Goods and Service Tax	4	0.98	4	1.05	-	+0.07
3.	<u>C - Design and Construction of the Project</u> C1 - Design and Construction of the Project	4	0.86	4	0.96	-	+0.10
4.	<u>D - Delay of the Construction Works</u> D1 - Delay in completion of the Construction Works	4	1.16	4	1.21	-	+0.05
5.	<u>E - Asset Management Services</u> E1 - Supply of Equipment	4	0.77	4	0.75	-	-0.02
	E2 - Variation to the Scope of Asset Management Services	4	0.92	4	0.96	-	+0.04
6.	<u>F - Service Levels</u> F1 - Review of the Key Performance Indicators	4	0.98	4	1.09	-	+0.11
7.	<u>G - Additional Works</u> G1 - Additional Works	4	0.86	4	0.96	-	+0.10
	G2 - Additional Asset Management Services Charges	4	0.86	4	0.95	-	+0.09
8.	<u>H - The Concession Company</u> H1 - Change in Shareholding	4	0.78	4	0.28	-	-0.50
	H2 - Refinancing	4	0.51	4	0.28	-	-0.23
9.	<u>I - Force Majeure</u> I1 - Delay	4	0.86	4	0.88	-	+0.02
	I2 - Restoration	4	0.71	4	0.55	-	-0.16
10.	<u>J - Project Monitoring Committee</u> J1 - Project monitoring committee procedure	4	1.02	4	0.96	-	-0.06
11.	<u>K - Dispute Resolution Committee</u> K1 - Dispute Resolution Committee	4	0.97	4	0.96	-	-0.01
12.	<u>L - Occupational Safety and Health Requirements</u> L1 - Occupational Safety and Health Requirements	4	0.92	4	0.88	-	-0.04

From the analysis, the mode scores for all identified clauses in both rounds were '4', which indicates that the majority of the panellists 'Agree' that the identified clauses are incomplete based on the IC characteristics and the areas that are deemed incomplete identified from past studies. However, due to the reduced number of panellist participated in the second round, there was an increased and decreased convergence of opinion (the SD scores) among the responses in the second round. The changes of SD score involved an increase ranging from 0.02 to 0.11 and a decrease ranging from 0.01 to 0.50. Despite that, four items achieved scores above 1.00 with the highest is 1.21 (Delay of the construction works). These indicate a 'reasonable level of consensus' were achieved (Mohd Fairullazi, 2014). While other items achieved SD scores below 1.00 and indicated a 'high level of consensus' achieved (Mohd Fairullazi, 2014). The results from the two rounds modified Delphi have confirmed the presence of IC in PFI contract where there are 12 clauses that contribute to the incompleteness.

Scholars such as Abdallah et al. (2013), Athias & Soubeyran (2012) and Habets (2010) had discussed the subject of IC in the perspective of PPP or PFI contract as in general and did not specify on which clause in the contract that is deemed incomplete. Thus, the findings from this research provide a clear picture of the presence of IC in PFI contract by identifying the clause that causes PFI contract to be incomplete. On the other hand, studies by Guasch (2004) and Ho & Tsui (2009) contended that PFI contract is inevitably incomplete, and the results found in this study has further strengthened their statement.

## CONCLUSIONS

The study identifies the presence of IC in PFI projects in Malaysia through two rounds modified Delphi. The results from this studies have proved the presence of IC in PFI projects in Malaysia where 12 clauses contribute to the incompleteness. Consequently, the presence of IC will cause implications to the project success either positively or negatively.

Input from this paper is considered to be significant towards the effort in enhancing the effectiveness and efficiency of PFI contract. Although this study focuses on PFI contracts in Malaysia, the findings could also benefit PFI players in other countries as it could provide a guideline for them to avoid most of the downfall caused by IC. This study is on-going whereby the next step is to assess the implications of IC in PFI contract and identify the appropriate strategies to improve the positive implication or maintain its status quo and mitigate the negative implication.

## REFERENCES

- Abdallah, A. A.-N., Darayseh, M., & Waples, E. (2013). Incomplete Contract, Agency Theory and Ethical Performance: A synthesis of the factors affecting owners' and contractors' performance in the bidding construction process. *Journal of General Management*, 38(4), 39–57.
- Abdul Quium. (2011). *A Guidebook on Public-Private Partnership in Infrastructure*. Bangkok: Economic and Social Commission for Asia and the Pacific. Retrieved from <http://ppp.worldbank.org/>
- Abdul-Aziz, A. R., & Jahn Kassim, P. S. (2011). Objectives, success and failure factors of housing public–private partnerships in Malaysia. *Habitat International*, 35(1), 150–157.
- Athias, L., & Saussier, S. (2010). *Contractual Flexibility or Rigidity for Public Private Partnerships? Theory and Evidence from Infrastructure Concession Contracts* (No. EPPP DP No. 2010-3). Retrieved from <http://ssrn.com/abstract=828944> or <http://dx.doi.org/10.2139/ssrn.828944>
- Athias, L., & Soubeyran, R. (2013). Demand Risk Allocation in Incomplete Contracts : The Case of Public Private Partnerships. Unpublished manuscript: University of Lausanne.
- Bajari, P., Tadelis, S., & Houghton, S. (2014). Bidding for Incomplete Contracts: An Empirical Analysis of Adaptation Costs. *The American Economic Review*, 104(4), 1288–1319.
- Baker, S., & Krawiec, K. D. (2006). Incomplete Contracts In A Complete Contract World. *Florida State University Law Review*, 33, 725–755.
- Barry, M.-L., Steyn, H., & Brent, A. (2008). Determining the most important factors for sustainable energy technology selection in Africa: application of the Delphi technique. In *International Association for Management of Technology (IAMOT 2008 Proceedings)*.

- United Arab Emirates.
- Beatson, J., Burrows, A., & Cartwright, J. (2010). *Anson's Law of Contract* (29th ed.). New York: Oxford University Press.
- Bennett, J., & Iossa, E. (n.d.). *Public-Private Partnerships; an Incomplete Contract Approach*. Retrieved from [www.esrc.ac.uk/my-esrc/.../cd6820f9-cda8-4035-b4ded713ce35d67?](http://www.esrc.ac.uk/my-esrc/.../cd6820f9-cda8-4035-b4ded713ce35d67?)
- Bi, X., & Wang, H. (2011). The control of moral hazard in PPP project renegotiation. *2011 IEEE 18th International Conference on Industrial Engineering and Engineering Management*, 232–236. doi:10.1109/ICIEEM.2011.6035147
- Boukendour, S. (2007). Preventing post contractual opportunism by an option to switch from one contract to another. *Construction Management and Economics*, 25(7), 723–727.
- Brill, J. M., Bishop, M. J., & Walker, A. E. (2006). The competencies and characteristics required of an effective project manager: A Web-based Delphi study. *Educational Technology Research and Development*, 54(2), 115–140.
- Bulger, S. M. (2004). *Modified Delphi Investigation of Exercise Science in Physical Education Teacher Education*. West Virginia University.
- Chua, S. cing. (2012). *A Study on the Issues of Construction Disputes in Malaysia and Singapore*. University Tunku Abdul Rahman.
- Chung, T.-Y. (1991). Incomplete Contracts, Specific Investments and Risk Sharing. *Review of Economic Studies*, 58, 1031–1042.
- Coase, R. H. (1937). The Nature of the Firm. *Econometrica*, 4(16), 386–405.
- Craswell, R. (2000). Contract Law : General Theories. *Encyclopedia of Law and Economics*, 3, 1–24.
- Craswell, R. (2005). The “Incomplete Contracts” Literature and Efficient Precautions. *Case Western Reserve Law Review*, 56(1), 151–169.
- Cruz, C. O., & Marques, R. C. (2013). Flexible contracts to cope with uncertainty in public-private partnerships. *International Journal of Project Management*, 31(3), 473–483.
- de Brux, J., & Desrieux, C. (n.d.). Public-Private Partnerships and The Allocation of Demand Risk: An Incomplete Contract Theory Approach, 1–25.
- Fellows, R., & Liu, A. (2015). *Research Methods for Construction* (4th ed.). United Kingdom: Wiley-Blackwell.
- Fraja, G. De. (2002). PPP and Contract Incompleteness : A Theoretical Economist's View. In *Paper presented for workshop "Role of Public Private Partnership for eLearning in Europe", 24th-25th November 2002* (pp. 1–27).
- Garvin, M. J. (2009). Governance of PPP Projects Through Contract Provisions. In *Conference of Leadership and Management of Construction*. Retrieved from <http://www.academicventplanner.com/LEAD2009/papers/Garvin.pdf>
- Giannarakis, G., Litinas, N., & Theotokas, I. (2011). A Delphi Study to Identify Corporate Social Responsibility Indicators: The Case of Greek Telecommunication Sector. *Journal of Sustainable Development*, 4(2).
- Grant, S., Kline, J. J., & Quiggin, J. (2012). Differential awareness, ambiguity, and incomplete contracts: A model of contractual disputes. *Journal of Economic Behavior & Organization*, 82(2-3), 494–504.
- Griffith, L. E., Hogg-Johnson, S., Cole, D. C., Krause, N., Hayden, J., Burdorf, A., ... Shannon, H. S. (2007). Low-back pain definitions in occupational studies were categorized for a meta-analysis using Delphi consensus methods. *Journal of Clinical Epidemiology*, 60(6), 625–33.
- Grossman, S. J., & Hart, O. D. (1986). The Costs and Benefits of Ownership: A Theory of

- Vertical and Lateral Integration. *Journal of Political Economy*, 94(4), 691–719.
- Guasch, J. L. (2004). *Granting and Renegotiating Infrastructure Concessions- Doing It Right*. Washington, D.C.: The World Bank.
- Habets, J. (2010). *Incomplete Contracts and Public-Private Partnership; A case study of the Dutch Infrastructure policy*. Erasmus University Rotterdam.
- Hamimah, A., & Morledge, R. (2003). Application of Delphi Method on Critical Success Factors In Joint Venture Projects In Malaysian Construction Industry. In C. O. Egbu & M. K. L. Tong (Eds.), *Proceedings of The First Scottish Conference for Postgraduate Researchers of The Built And Natural Environment 18-19 November 2003 - Glasgow Caledonian University, Glasgow, United Kingdom* (pp. 41–51). Scotland, United Kingdom: Glasgow Caledonian University.
- Hart, O. (1995). *Firms, Contracts, and Financial Structure*. United States: Oxford University Press.
- Hart, O. (2003). Incomplete Contracts and Public Ownership: Remarks, and an Application to Public-Private Partnerships. *The Economic Journal*, 113(486), C69–C76.
- Hart, O., & Holmstrom, B. (1986). *The Theory of Contracts* (No. 418). (T. Bewley, Ed.) *Advances in Economic Theory*. Cambridge: Cambridge University Press.
- Hart, O., & Moore, J. (1988). Incomplete Contracts and Renegotiation. *Econometrica*, 56(4), 755–785.
- Hejblum, G., Ioos, V., Vibert, J. F., Boelle, P. Y., Chalumeau-Lemoine, L., Chouaid, C., ... Guidet, B. (2008). A Web-Based Delphi Study on the Indications of Chest Radiographs for Patients in ICUs. *CHEST Journal*, 133(5), 1107–1112.
- Herold, F. (2010). Contractual Incompleteness as a Signal of Trust. *Games and Economic Behavior*, 68(1), 180–191.
- Ho, S. P., & Tsui, C. W. (2009). The Transaction Costs of Public-Private Partnerships: Implications on PPP Governance Design. In *Lead 2009 Specialty Conference: Global Governance in Project Organizations, South Lake Tahoe, CA* (pp. 5–7).
- Hsu, C., & Sandford, B. A. (2007). The Delphi Technique: Making Sense of Consensus. *Practical Assessment, Research & Evaluation*, 12(10).
- Jayaseelan, R., & Tan, M. (2006). PFI - cure for all ills? *Master Builders*, pp. 96–100.
- Joseph-Williams, N., Newcombe, R., Politi, M., Durand, M.-A., Sivell, S., Stacey, D., ... Elwyn, G. (2014). Toward Minimum Standards for Certifying Patient Decision Aids: A Modified Delphi Consensus Process. *Medical Decision Making*, 34(6), 699–710.
- Judicial Education Center. (2014). Contract Law. Retrieved from <http://jec.unm.edu/education/online-training/contract-law-tutorial>
- Khairuddin, A. R. (2009). *Understanding Private Finance Initiative (PFI)*. Kuala Lumpur: ScholarMind.
- Lonsdale, C. (2005). Contractual Uncertainty, Power and Public Contracting. *Journal of Public Policy*, 25(2), 219–240.
- Marques, R. C., & Berg, S. (2010). Revisiting the Strengths and Limitations of Regulatory Contracts in Infrastructure Industries. *Journal of Infrastructure Systems*, 16(4), 334–342.
- Miller, F., Denison, C. a., & Matuszewski, L. J. (2013). Modeling the Antecedents of Preferences for Incomplete Contracts in Bilateral Trade: An Experimental Investigation. *Behavioral Research in Accounting*, 25(1), 135–159.
- Mohd Fairullazi, A. (2014). *Development of Life Cycle Cost Strategy and Protocol on Cost Data Input in Malaysia*. International Islamic University Malaysia.
- Mohd Fairullazi, A., & Khairuddin, A. R. (2016). Review of Methodology Designed to Investigate Quality of Cost Data Input in Life Cycle Cost. *Malaysian Construction*

- Research Journal (MCRJ)*, 19(2).
- Mohd Farmi Izudin, C. R., Zulhabri, I., Fadzil, H., & Masnizan, C. M. (2011). Sustainable Private Financing Initiative Contracts. In *IEEE Symposium on Business, Engineering and Industrial Applications (ISBEIA)* (pp. 452–457). Langkawi, Malaysia.
- Ninth Malaysia Plan. (2006). *Chapter 10: Streamlining Privatization*. Kuala Lumpur. Retrieved from <http://www.epu.jpm.my/rm9/html/english.htm>
- Nur Syaimasyaza, M., & Khairuddin, A. R. (2014). Identifying the Presence of Incomplete Contract in PFI Contracts. In *13th Management in Construction Research Association (MiCRA 2014) Conference and Annual General Meeting*. International Islamic University Malaysia.
- Nur Syaimasyaza, M., & Khairuddin, A. R. (2015). Identification of Incomplete Contract Provision in PFI Contract in ASEAN countries : A Case Study on Malaysia. In *The 2nd International Conference on ASEAN Community 2015*.
- Parsons, A. M., Almasude, A., Dunn, S., & Green, K. (2008). *A Delphi Study of Best Practices of Online Instructional Design Practices in Malaysia*. Capella University.
- Patterson, M. R. (2010). Standardization of Standard-Form Contracts: Competition and Contract Implications. *William and Mary Law Review*, 52(2), 327–414.
- Rafiza, A. R. (2010). Shared knowledge among instructional multimedia design experts. *Procedia - Social and Behavioral Sciences*, 9, 353–357.
- Rowe, G., & Wright, G. (1999). The Delphi technique as a forecasting tool: issues and analysis. *International Journal of Forecasting*, 15(4), 353–375.
- Scott, R. E., & Triantis, G. G. (2005). Incomplete Contracts and the Theory of Contract Design. *Case Western Reserve Law Review*, 56(1).
- Skulmoski, G. J., & Hartman, F. T. (2007). The Delphi Method for Graduate Research. *Journal of Information Technology Education*, 6.
- Spier, K. E. (1992). Incomplete Contracts and Signaling. *RAND Journal of Economics*, 23(3), 432–443.
- Tirole, J. (1999). Incomplete Contracts: Where do we stand? *Econometrica*, 67(4), 741–781.
- Walker, P. (2012). Anti-Dismal: When is a contract incomplete? Retrieved from <http://antidismal.blogspot.com/2012/01/when-is-contract-incomplete.html>
- Wiersma, W., & Jurs, S. G. (2009). *Research methods in education: An introduction* (9th Edition.). Bson, USA: Pearson.
- Williamson, O. E. (1979). Transaction-Cost Economics: The Governance of Contractual Relations. *Journal of Law and Economics*, 22(2), 233–261.
- Winch, G., Gunawansa, A., Schmidt, S., & Onishi, M. (2012). Executive Summary: Introduction. In G. M. Winch, M. Onishi, & S. Schmidt (Eds.), *Taking Stock of PPP and PFI Around the World* (pp. 7–10). The Association of Chartered Certified Accountants.
- Yates, D. J. (1998). Conflict and Disputes in the Development Process: A Transaction Cost Economics Perspective, 1–14. Retrieved from <http://www.prrs.net/proceedings/proceedings1998/Papers/Yates3Ai.PDF>

APPENDIX

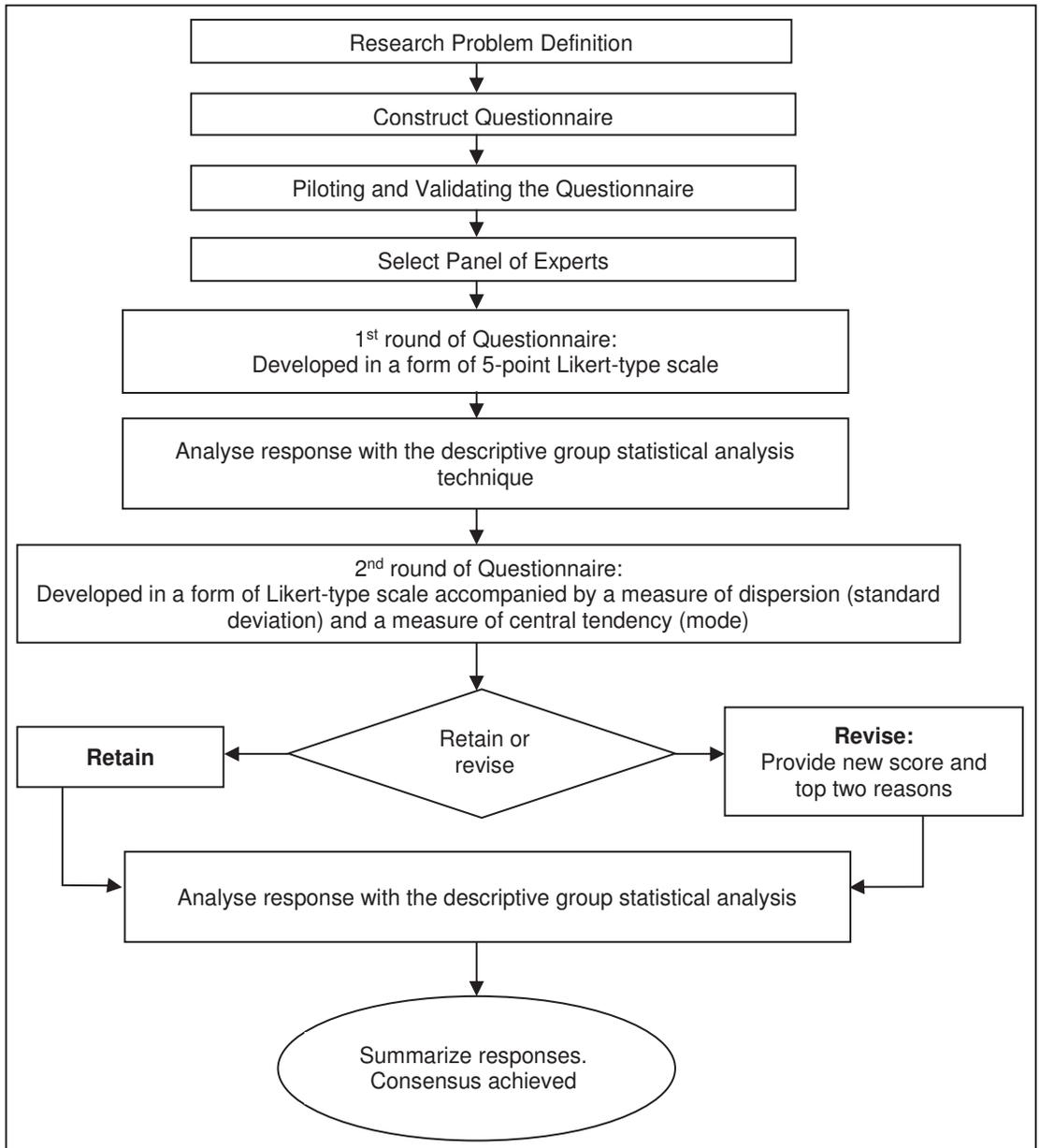


Figure 1. The schematic flow of modified Delphi process

*This page intentionally left blank*

# COMPETENCY AND COMMITMENT OF FACILITIES MANAGERS: KEYS TO SAFEGUARD MAINTENANCE PERFORMANCE

**Cheong Peng Au-Yong, Azlan Shah Ali and Faizah Ahmad**

*Centre for Building, Construction & Tropical Architecture (BuCTA), Faculty of Built Environment, University of Malaya, 50603 Kuala Lumpur, Malaysia*

## **Abstract**

Facilities management is an integrated approach to operate, maintain, improve, and adapt the buildings and facilities of an organisation in order to support the core business operations of that organisation. Due to the lack of knowledge and skill in maintenance-related matters, the organisation and client rely on the facilities manager to take care of their building most of the time. However, the facilities management of the buildings has been unprofessionally applied by the facilities managers, which subsequently triggered negative impacts to the building services and facilities. Lack of manager's commitment is also questioned because of the salary payment. Therefore, this paper seeks to examine the relationship between the competency of facilities manager and maintenance performance; and investigate the relationship manager's salary and manager's commitment through questionnaire survey and interview. The findings indicate that there are significant relationship between manager's competency and maintenance performance; as well as manager's salary and manager's commitment. The study concludes that actions should be taken in order to improve the competency and commitment of facilities managers constantly, and hence enhance the maintenance performance.

**Keywords:** *facilities manager; competency; commitment; maintenance performance; professional development*

## **INTRODUCTION**

Facilities management is an integrated approach to operate, maintain, improve, and adapt the buildings and facilities of an organisation in order to support the core business operations of that organisation (Pathirage et al., 2008). In construction industry, building operation and maintenance take place immediately after the completion of construction. Due to the lack of knowledge and skill in maintenance-related matters, the organisation and client rely on the facilities manager to take care of their building most of the time. Whereby, they deem that the facilities manager is the expertise or profession in these matters. Thus, a facilities manager will lead the operation and maintenance of building upon the establishment of building management team.

Commonly, the facilities managers have wide range scope of works, from administrative to technical tasks. Thus, the role of facilities managers is of vital to the operation and maintenance of building and facilities. Specifically in building maintenance, the facilities managers involve in maintenance planning, implementation, monitoring, and evaluation. They should be able to make decision on selecting appropriate maintenance strategies for the building and systems with optimal resources (Horner et al., 1997). Then, they need to ensure that all the maintenance tasks perform effectively by monitoring the tasks and staffs. Subsequently, they have to evaluate the maintenance outcome and satisfaction of the clients and occupants.

However, Kamaruzzaman et al. (2013) argued that the main problem in maintenance management of the buildings is that it has been unprofessionally applied by the facilities

managers, which subsequently triggered negative impacts to the building services and facilities. The poor performance of building services and facilities potentially harms the building users in the aspects of health, safety, and comfortability (Lai & Yik, 2011). Furthermore, risks of these aspects jeopardise the productivity of workers in office buildings and thus affects the operations or core business activities of the organisations (Kwon et al., 2011).

In fact, the facilities managers should take into account innovation and innovation activities in order to manage the buildings effectively and preserve a competitive advantage (Scupola, 2012). Continuous improvement towards the competency of facilities managers might be essential to guarantee the proper management of building and successful organisation business. Therefore, this paper seeks to examine the relationship between the competency of facilities managers and maintenance performance.

## **COMPETENCY OF FACILITIES MANAGERS**

Williams and Sutrisna (2010) stated that the scopes of work for facilities manager include full responsibility of clients' premises, planning and provision of accommodation and support services to business and occupants, building security and maintenance, management of people, time, cost and building performance. Meanwhile, Meng (2014) claimed that the facilities manager must balance the economic, environmental, and social considerations in building management by linking the strategic level with the operational level.

Building and facilities management is complex as the building and facilities constitute a massive proportion of the fixed asset worth for most of the organisations (Kamarazaly et al., 2013). Taking into cognisance the complexity of the duties, the competency of facilities manager is concerned. Generally, a skilful and experienced facilities manager is able to provide the service as required by the organisation or client, above satisfactory level and ensure all the tasks complete accordingly to provide outstanding building performance (Au-Yong et al., 2014a).

Due to the complexity of buildings, facilities and maintenance managers have evolved from skilled craftsmen to person holding university degree, postgraduate and improvement courses (Amorim et al., 2013). In fact, the development of facilities management has met the criteria that qualify a subject as an academic discipline (Antje & Nils, 2014). Hence, many higher education institutions offer the facilities management program nowadays. Commonly, the institutions gain an accreditation and are required to maintain and regularly improve the program over the accreditation period (Dore et al., 2014). The facilities managers are obliged to participate in this program in order to develop their skill and knowledge in terms of (Facility Management Accreditation Commission, 2014):

- a) Leadership and strategy
- b) Operations and maintenance
- c) Project management
- d) Communication
- e) Finance and business
- f) Human factors
- g) Quality

- h) Real estate and property management
- i) Technology
- j) Emergency preparedness and business continuity
- k) Environmental stewardship and sustainability

Apart from the skill and knowledge, it is vital to have relevant experiences in performing facilities manager's duties. Sharing of knowledge and experience is important. Hebert and Chaney (2011) revealed that communication between experienced facilities managers and their colleagues in younger generations would allow for more efficient transfer of skill between individuals. Apart from that, experienced facilities managers can potentially apply influence upwards to clients, downwards to building users, and sideways through external organisations in the aspects of decision making, awareness, and implementation (Goulden & Spence, 2015).

Undoubtedly, the industry innovates and develops advanced technologies such as Building Information Modelling and Computerised Maintenance Management System to improve the efficiency of facilities management operations (Motamedi et al., 2014). However, the facilities managers have not been motivated to implement them due to the limited knowledge about them (Korpela et al., 2015). There is a need for the facilities managers to improve themselves continuously by attending seminar or workshop. For instance, they learn and familiarise with the new technologies that can apply in their workplace, which they have not exposed to during their study time.

Furthermore, the roles of facilities managers emerge from time to time. Recently, optimising energy efficiency during the building operation phase becomes a factor to improve building sustainability. Thus, facilities managers are liable to adapt the role in optimising energy efficiency (Cao et al., 2015). The professional bodies like IFMA always update the new concepts in the field of facilities management via workshops (IFMA, 2015). Thus, it is important for the facilities manager to attend related seminars, workshops, and training to update their knowledge in facilities management.

Peters (2015) highlighted that a leading facilities manager should be proactive, has vision, promotes growth, and promotes continuous improvement. Thus, it is important for facilities managers to enhance their competencies continuously in order to perform the tasks of facilities management effectively.

## **COMMITMENT OF FACILITIES MANAGERS**

Nowadays, facilities manager is classified as a professional. Fu and Chen (2015) stated that the development of complex expertise requires individuals to be regularly committed to the relevant activities like training workshops. Thus, formation of trainings and professional development programs is compulsory. Unfortunately, the lack of interest and commitment from the facilities managers becomes a main issue. Whereby, they need to participate in such trainings and programs at their own expenses most of the time (Mushchanov et al., 2015). Therefore, the continuous professional development of facilities managers highly depends on their own commitment.

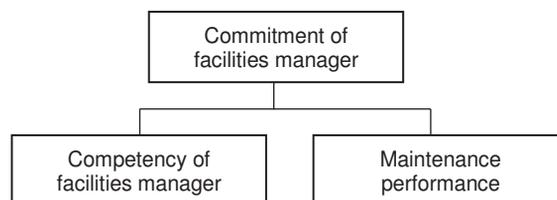
Although the scopes of work for facilities managers are clearly stated and updated from time to time, Meng (2014) mentioned that the efficiency of management is still relying on the commitment of the individual managers. He also noted that the facilities managers should commit themselves in policy making and strategic planning of the management. For example, application of new technologies such as Building Information Modelling in the facilities management requires commitment and involvement of the facilities managers, but the facilities managers are yet hardly committed in the application of the technology (Korpela et al., 2015).

Besides that, manager's commitment in terms of communication is essential. Whereby, there are always some gaps or conflicts between the organisation and facilities management staffs, a middle man should exist to deliver the issues and requirements between the two parties (Lee & Scott, 2009). In this circumstance, the facilities manager is considered as the middle man. Arditi and Nawakorawit (1999) demonstrated that the maintenance performance is likely to improve if the facilities manager commits in communicating within the organisation. Without understanding the needs of all the parties, implementation of facilities management tasks will be in contrast with the organisation objective (Kamaruzzaman & Zawawi, 2010).

Taking into cognisance the importance of manager's commitment, action to stimulate the commitment is required. Maxwell and Steele (2003) revealed that high level of salary pay may encourage the manager's commitment. Furthermore, the amount of salary paid to facilities managers can be a significant factor that influences the maintenance performance, where it would indirectly affect the commitment of facilities managers (Au-Yong et al., 2014b). Thus, this paper also aims to investigate the relationship manager's salary and their commitment.

## RESEARCH DESIGN

In order to achieve the objective of the study, a conceptual model as shown in Figure 1 was developed for accommodating the implementation of research process:



**Figure 1.** Conceptual model

This research adopted the mixed method approach that comprises of literature review, questionnaire survey, and semi-structured interview. This approach allows the researchers to address more complicated research questions and achieve higher reliability and validity of the research (Yin, 2009). Firstly, literature review conducted particularly on the competency and commitment of facilities managers and then followed by a preliminary survey. Secondly, close-ended questionnaires were drafted in five-point Likert scale and multiple choices based

on the findings of literature and preliminary survey. It covered three sections, namely the respondent's particular, facilities manager's characteristics, and maintenance performance.

Subsequently, the simple random sampling method was adopted in distributing the questionnaire. However, the survey targeted the relevant respondents, who are the facilities managers that have been or are currently working on the facilities management of office building. Meanwhile, population criteria included building requirement, which is high-rise office buildings (7-storey and above) located in Klang Valley, Malaysia. The high-rise buildings are usually equipped with more complex systems like HVAC system, lift system, and firefighting system. This would greatly require the competent facilities manager to take care of the facilities. Hoxley (2008) suggested that questionnaire survey requires a minimum response rate of 30 percent to produce reliable and convincing results. In this research, a total of 300 questionnaires were distributed to the facilities managers from different office buildings. 108 returned and valid questionnaires contributed to 36 percent of response rate. Thus, the collected data were reliable.

A correlation test was able to measure the relationship between the manager's competency and maintenance performance through Statistical Package for Social Science (SPSS) (Diamond & Jefferies, 2006). The Spearman rank-order correlation was engaged for the analysis. It is suitable to analyse either or both variables are ordinal (Graziano & Raulin, 2010). Next, this study ran the binary logistic regression analysis to produce the prediction model for maintenance performance. Whereby, the probability of an event can be measured by using logistic regression (Chua, 2009). Basically, logistic regression function is as follow:

$$Z = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k + \varepsilon$$

Where,

Z = latent variable

$X_1, X_2, \dots, X_k$  = independent variables

$\beta_0$  = constant

$\beta_1, \beta_2, \dots, \beta_k$  = change in Y for a change of one unit in  $X_1, X_2, \dots, X_k$  respectively

$\varepsilon$  = error term

Z value is transformed using a link function to obtain the probability of the event occurring. In this research, the link function to obtain the probability of satisfactory maintenance performance is stated below:

**P [satisfactory maintenance performance] =  $e^z / 1 + e^z$** , the value is between 0 and 1.

In order to investigate the relationship manager's salary and their commitment, chi-square test for independence or relatedness was performed to analyse the relationship between two categorical variables (Diamond & Jefferies, 2006), namely manager's salary and manager's commitment.

Lastly, semi-structured interview was carried out with facilities managers with more than five years of experiences in facilities management. The interviewees were selected from the questionnaire respondents who fulfil the requirements. The interview aimed to obtain further

details and understandings about the manager characteristics toward maintenance performance. For example, one of the interview questions was “*Does the degree of manager’s competency significantly influence the maintenance performance? How it influences the maintenance performance?*” The interview allows the researcher to explore and uncover the respondents’ views in detail (Marshall & Rossman, 2006).

## FINDINGS AND DISCUSSION

The correlation analysis result indicated the relationship between manager’s competency and maintenance performance as shown in Table 1. Basically, a correlation coefficient of less than 0.3 points to a weak relationship; a coefficient of 0.3 to 0.5 denotes a moderate relationship; and a correlation coefficient of 0.5 or more points to a strong relationship between two variables (Gray & Kinnear, 2012; Saunders et al., 2009). However, SPSS determines significantly correlated variables with the significance value of 0.05 or below.

**Table 1.** Correlation analysis

		Maintenance Performance
Spearman's rho	Manager Competency	Correlation Coefficient .411**
		Sig. (2-tailed) .000

\*\* Correlation is significant at the 0.01 level (2-tailed).

The result demonstrated that the manager’s competency is significantly correlated with the maintenance performance, with coefficient 0.411 ( $p < 0.05$ ). Sustainability of a building requires planning, implementation, operation and maintenance, evaluation, and improvement activities. In order to ensure its success, it involves advanced skill, knowledge, and technology inputs from the facilities management staff, especially the facilities manager. The result validated that the facilities manager must be able to consider economic, environmental and social aspects from strategic level to the operational level in assuring the optimal performance (Meng, 2014). Moreover, the continuous improvement of the facilities manager is compulsory to update the demands of facilities management that emerge from time to time (IFMA, 2015; Peters, 2015). During the interview session, the interviewees also validated the result by signifying the initiative of facilities managers to perform their tasks with updated technologies and multidisciplinary skills in order to satisfy the clients’ need. For instance, the interviewees’ conversations are quoted as follows:

“... Facilities manager must be able to bring in new technologies to be applied in the facilities management industry in order to improve the service outcome.”

“... Facilities manager is employed to solve the problems that the client cannot solve. So, the manager must be skilful to handle the problem and ensure the functionality of building and facilities.”

“... As a facilities manager, I am expected to be capable in providing service as required by the client to make sure minimal facilities problem occurs with optimal use of resource, manpower, and time.”

In order to validate the correlation analysis result, logistic regression analysis was conducted, where manager’s competency as the independent variable and maintenance

performance as the dependent variable. In the analysis, maintenance performance was coded with the value of 0 and 1. Whereby, “not satisfied” and “satisfied” were labelled as 0 and 1 respectively.

By using forward stepwise method, SPSS produced a logistic regression model (see Table 2) revealing the manager’s competency significantly predicts the odds of satisfactory maintenance performance with  $X^2 = 22.20$ ,  $p < 0.05$ . In this case, the manager’s competency (MC) could predict 27.8% of the variance in maintenance performance. It was a high percentage as the model only included a predictor. Furthermore, the p-value for Hosmer-Lemeshow goodness of fit was 0.09, which was more than 0.05. Thus, the model adequately fit the data. Then, the logistic regression equation was produced as follows (see Table 2):

$$Z = -4.881 + 0.999 MC$$

**Table 2.** Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 1 <sup>a</sup>	ManagerCompetency	.999	.260	14.708	1	.000	2.715	1.629	4.522
	Constant	-4.881	1.094	19.906	1	.000	.008		

a. Variable(s) entered on step 1: ManagerCompetency.

The score of the manager’s competency was quantified from 1 to 5 that represented “very low degree of competency” to “very high degree of competency” respectively. The criteria for the degree of manager’s competency were tabulated in Table 3. Achievement of four criteria would contribute to the score of 5; while none would contribute to the score of 1. Then, the score could be inserted to the equation in order to obtain the probability of satisfactory maintenance performance. Table 4 showed the probability of satisfactory maintenance outcome based on the degree of manager’s competency. Therefore, the manager’s competency is significantly influencing the probability of satisfactory maintenance performance. A high level of manager’s competency is likely to increase the probability of performance satisfaction towards the facilities management. The probability was indeed low because there might be some other predictors or moderating variables that affecting the change of probability.

**Table 3.** Criteria for the degree of manager’s competency

Competency of facilities manager	
Criteria	<ul style="list-style-type: none"> <li>• Possess academic qualification (diploma/degree in relevant field)</li> <li>• Accumulate of working experience</li> <li>• Regularly attending competency development activities</li> <li>• Registered member of relevant professional body</li> </ul>

**Table 4.** Probability of satisfactory maintenance performance based on the degree of manager's competency

Degree of manager's competency	Z	P [satisfactory maintenance performance]
Very low degree	-3.882	0.020
Low degree	-2.883	0.053
Moderate degree	-1.884	0.132
High degree	-0.885	0.292
Very high degree	0.114	0.528

Literature highlighted the commitment of facilities managers could affect the relationship between their competency and maintenance performance (Arditi & Nawakorawit, 1999; Fu & Chen, 2015; Meng, 2014). However, lack of manager's commitment is the issue occurred in facilities management industry (Korpela et al., 2015; Mushchanov et al., 2015). Thus, action to raise the manager's commitment is necessary. The chi-square analysis result summarised that unsatisfactory salary payment contributes to low commitment of facilities manager (See Table 5). Pearson's chi-square has a value of 6.171 with significance of less than 0.05 indicating significant relationship between manager's salary and manager's commitment (see Table 6). The minimum expected cell frequency is 15, which is more than 5. Hence, the main assumptions of chi-square are not violated (Coakes & Ong, 2011). The result confirmed the arguments of Maxwell and Steele (2003) and Au-Yong et al. (2014b) that it is important to allocate satisfactory salary amount for the facilities manager in order to encourage their commitment in professional development and communication in facilities management.

**Table 5.** Manager Salary \* Manager Commitment Crosstabulation

			Manager Commitment		
			No	Yes	Total
Manager Salary	Not Satisfy	Count	48	24	72
		Expected Count	42.0	30.0	72.0
		% within Manager Salary	66.7%	33.3%	100.0%
		% within Manager Commitment	76.2%	53.3%	66.7%
		% of Total	44.4%	22.2%	66.7%
	Satisfy	Count	15	21	36
		Expected Count	21.0	15.0	36.0
		% within Manager Salary	41.7%	58.3%	100.0%
		% within Manager Commitment	23.8%	46.7%	33.3%
		% of Total	13.9%	19.4%	33.3%
Total	Count	63	45	108	
	Expected Count	63.0	45.0	108.0	
	% within Manager Salary	58.3%	41.7%	100.0%	
	% within Manager Commitment	100.0%	100.0%	100.0%	
	% of Total	58.3%	41.7%	100.0%	

**Table 6. Chi-Square Tests**

	Value	df	Asymp. Sig. (2- sided)	Exact Sig. (2- sided)	Exact Sig. (1-sided)
Pearson Chi-Square	6.171 <sup>a</sup>	1	.013		
Continuity Correction <sup>b</sup>	5.186	1	.023		
Likelihood Ratio	6.146	1	.013		
Fisher's Exact Test				.022	.012
Linear-by-Linear Association	6.114	1	.013		
N of Valid Cases	108				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 15.00.

b. Computed only for a 2x2 table

## **Improving the Competency and Commitment of Facilities Managers**

The study proposed that actions should be taken in order to improve the competency and commitment of facilities managers constantly. The research result convinced that appropriate salary paid to the facilities managers would promote the commitment of the managers to develop their competency via training programs or professional practices continuously. Meanwhile, recommendations to improve their competency and commitment were discussed in the interview session. The interviewees were in view that the organisation should encourage the facilities management staffs to achieve specific level of competency by providing financial support. The organisation should also allow the staffs to spend some times for attending courses, workshops, trainings, seminars, and other activities that help to develop their competency. Further study about the actions to enhance competency development is recommended. In addition, study on the effect of manager's commitment towards the relationship between manager's competency and maintenance performance is suggested.

## **CONCLUSION**

This research emphasised the competency and commitment of facilities managers to reach the satisfied maintenance performance level. The findings demonstrated that competency of facilities managers is significantly correlated with maintenance performance. The criteria to be a competent manager includes possess of relevant academic qualification, accumulate of working experience, regularly attending competency development activities, and registered member of relevant professional body. Furthermore, a prediction model generated through SPSS included manager's competency as the significant predictor of the maintenance performance. The model revealed that higher degree of manager's competency is more likely to contribute satisfied maintenance performance. Then, the study determined that the commitment of facilities manager could be influential to the relationship between manager's competency and maintenance performance. However, lack of commitment becomes an issue in the industry. The recommendations to stimulate manager's commitment was identified, they are allocation of appropriate salary and encouragement from the organisation to continuously develop the manager's competency. As a conclusion, the efficiency of facilities management cannot rely solely on the facilities manager; the organisation must support and assist the manager in professional development. Consequently, the competent and committed manager is able to perform the tasks effectively and support the organisation to achieve the organisational goals.

## REFERENCES

- Amorim, G. M., Quintão, E. C. V., Júnior, H. M., & Bonan, P. R. F. (2013). Provision of building maintenance services in healthcare facilities. *Ciência & Saúde Coletiva*, 18(1), 145-158.
- Antje, J., & Nils, O. E. O. (2014). Discussion of facilities management as an academic discipline. *Facilities*, 32(1/2), 67-79.
- Arditi, D., & Nawakorawit, M. (1999). Issues in Building Maintenance: Property Manager's Perspective. *Journal of Architectural Engineering*, 5(4), 117-132.
- Au-Yong, C. P., Ali, A. S., & Ahmad, F. (2014a). Improving occupants' satisfaction with effective maintenance management of HVAC system in office buildings. *Automation in Construction*, 43, 31-37.
- Au-Yong, C. P., Ali, A. S., & Ahmad, F. (2014b). Preventive Maintenance Characteristics towards Optimal Maintenance Performance: A Case Study of Office Buildings. *World Journal of Engineering and Technology*, 2(3B), 1-6.
- Cao, Y., Wang, T., & Song, X. (2015). An energy-aware, agent-based maintenance-scheduling framework to improve occupant satisfaction. *Automation in Construction*, 60, 49-57.
- Chua, Y. P. (2009). *Statistik Penyelidikan Lanjutan: Ujian Regresi, Analisa Faktor dan Analisis SEM Buku 5*. Kuala Lumpur: McGraw-Hill (Malaysia) Sdn. Bhd.
- Coakes, S. J., & Ong, C. (2011). *SPSS: Analysis without Anguish: Version 18.0 for Windows*. Milton: John Wiley & Sons Australia, Ltd.
- Diamond, I., & Jefferies, J. (2006). *Beginning Statistics: An Introduction for Social Scientists*. London: SAGE Publications Ltd.
- Dore, S., Inês, F.-C., & Pedro, R. A. G. B. L. (2014). The road to facility management. *Facilities*, 32(1/2), 46-57.
- Facility Management Accreditation Commission. (2014). Facility Management Accreditation Commission Facility Management Accreditation Commission (FMAC) Standards for Accredited Degree Programs (ADP) *Facility Management Accreditation Commission Standards for Accredited Degree Program's (ADP) Purpose*. Houston, USA: IFMA.
- Fu, J. R., & Chen, J. H. F. (2015). Career commitment of information technology professionals: The investment model perspective. *Information & Management*, 52(5), 537-549.
- Goulden, M., & Spence, A. (2015). Caught in the middle: The role of the Facilities Manager in organisational energy use. *Energy Policy*, 85, 280-287.
- Gray, C. D., & Kinnear, P. R. (2012). *IBM SPSS Statistics 19 Made Simple*. East Sussex: Psychology Press.
- Graziano, A. M., & Raulin, M. L. (2010). *Research Methods: A Process of Inquiry* (7th ed.). Boston: Pearson Education Inc.
- Hebert, P., & Chaney, S. (2011). Enhancing facilities management through generational awareness. *Journal of Facilities Management*, 9(2), 145-152.
- Horner, R. M., El-Haram, M. A., & Munns, A. (1997). Building Maintenance Strategy: A New Management Approach. *International Journal of Quality in Maintenance*, 3(4), 273-280.

- Hoxley, M. (2008). Questionnaire Design and Factor Analysis. In A. Knight & L. Ruddock (Eds.), *Advanced Research Methods in the Built Environment*. Oxford: Blackwell Publishing Ltd.
- IFMA. (2015). Essentials of Facility Management Retrieved 27 November, 2015, from <http://www.ifma.org/professional-development/new-to-facility-management-essentials-of-facility-management>
- Kamarazaly, M. A., Mbachu, J., & Phipps, R. (2013). Challenges faced by facilities managers in the Australasian universities. *Journal of Facilities Management*, 11(2), 136-151.
- Kamaruzzaman, S. N., Myeda, N. E., & Pitt, M. (2013). Performance Levels of High-Rise Private Office Buildings Maintenance Management in Malaysia. *Eksplatacja i Niezawodnosc - Maintenance and Reliability*, 15(2), 111-116.
- Kamaruzzaman, S. N., & Zawawi, E. M. A. (2010). Development of Facilities Management in Malaysia. *Journal of Facilities Management*, 8(1), 75-81.
- Korpela, J., Miettinen, R., Salmikivi, T., & Ihalainen, J. (2015). The challenges and potentials of utilizing building information modelling in facility management: the case of the Center for Properties and Facilities of the University of Helsinki. *Construction Management and Economics*, 33(1), 3-17.
- Kwon, S. H., Chun, C., & Kwak, R. Y. (2011). Relationship between Quality of Building Maintenance Management Services for Indoor Environmental Quality and Occupant Satisfaction. *Building and Environment*, 46(11), 2179-2185.
- Lai, J. H. K., & Yik, F. W. H. (2011). An Analytical Method to Evaluate Facility Management Services for Residential Buildings. *Building and Environment*, 46(1), 165-175.
- Lee, H. H. Y., & Scott, D. (2009). Overview of Maintenance Strategy, Acceptable Maintenance Standard and Resources from a Building Maintenance Operation Perspective. *Journal of Building Appraisal*, 4(4), 269-278.
- Marshall, C., & Rossman, G. B. (2006). *Designing Qualitative Research* (4th ed.). Thousand Oaks, California: Sage Publication, Inc.
- Maxwell, G., & Steele, G. (2003). Organisational commitment: a study of managers in hotels. *International Journal of Contemporary Hospitality Management*, 15(7), 362-369.
- Meng, X. (2014). The role of facilities managers in sustainable practice in the UK and Ireland. *Smart and Sustainable Built Environment*, 3(1), 23-34.
- Motamedi, A., Hammad, A., & Asen, Y. (2014). Knowledge-assisted BIM-based visual analytics for failure root cause detection in facilities management. *Automation in Construction*, 43, 73-83.
- Mushchanov, V., Sievka, V., Veshnevskaya, A., & Nemova, D. (2015). Conception of Development of Staffing of Residential Housing in the Region and Training of Professional Housing Managers. *Procedia Engineering*, 117, 1013-1021.
- Pathirage, C., Haigh, R., Amaratunga, D., & Baldry, D. (2008). Knowledge management practices in facilities organisations: a case study. *Journal of Facilities Management*, 6(1), 5-22.
- Peters, R. W. (2015). Leadership: Creating Maintenance Leaders, Not Just Maintenance Managers. *Reliable Maintenance Planning, Estimating, and Scheduling* (pp. 21-28). Oxford, UK: Gulf Professional Publishing.
- Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research Methods for Business Students* (5th ed.). Harlow, Essex: Pearson Education Limited.

- Scupola, A. (2012). Managerial perception of service innovation in facility management organizations. *Journal of Facilities Management*, 10(3), 198-211.
- Williams, D., & Sutrisna, M. (2010). *An evaluation of the role of facilities managers in managing sustainability and remedial actions in reducing CO2 emissions in the built environment*. Paper presented at the Construction, Building and Real Estate Research Conference, Paris.
- Yin, R. K. (2009). *Case Study Research: Design and Methods* (4th ed. Vol. 5). Thousand Oaks, California: SAGE Publication, Inc.

# INFLUENCE OF COIR RANDOM FIBRE LENGTH ON CONCRETE: MECHANICAL PROPERTIES

Noor Aina Mison<sup>1,2</sup>, Siti Khadijah Che Osmi<sup>1</sup>, Nawawi Chouw<sup>2</sup> and Shahiron Shahidan<sup>3</sup>

<sup>1</sup> Department of Civil Engineering, Universiti Pertahanan Nasional Malaysia, 57000 Kuala Lumpur, Malaysia

<sup>2</sup> Department of Civil and Environmental Engineering, the University of Auckland, Auckland Mail Centre, Private Bag 92019, New Zealand.

<sup>3</sup> Faculty of Civil and Environmental Engineering, Universiti Tun Hussien Onn Malaysia

## Abstract

Incorporating coconut fibre in construction materials is gaining more interest nowadays, mainly due to its toughness and environmental friendliness. Previous studies on the development of Coconut Fibre Reinforced Concrete (CFRC) have revealed that an addition of coconut fibres can significantly enhance both the static and dynamic properties of CFRC composite. However, the studies focused on the influence of fixed fibre length. The fixed length fibres involve additional preparation and thus requires additional cost. To reduce the production cost, random length of fibres is considered. This research paper is mainly emphasized on the influence of random length fibres in CFRC. Four different fibres contents were added to the concrete; 1%, 2%, 3% and 5% of the cement weight. The cement, sand and aggregate ratio used was 1:2:2, with water cement ratio in the range of 0.48 to 0.65. A number of experiments on CFRC with random fibre length were conducted to identify the static properties of CFRC composite, i.e. compressive strength, splitting tensile strength, modulus of elasticity and flexural strength. The results revealed the mechanical characteristics are similar to that of CFRC with fixed lengths.

**Keywords:** *Coconut fibre reinforced concrete, coir, random length fibre, mechanical properties*

## INTRODUCTION

In order to sustain the environment, focusing on sustainable building materials has been given more attention in construction field these days. Adding natural fibre to produce new composite material is one possible way to utilize natural waste as construction materials, thus promotes sustainability. Established research of natural fibres for instance coconut, sisal, jute, hemp, banana, durian peel, bamboo, date palm, hibiscus cannebus, pineapple leaf, abaca leaf, sugarcane fibres, kenaf, flax fibres (Ali et al., 2012; Mahmoudi, 2013; Krishnamoorthy, 1983; Yan and Chouw, 2013; Khedari et al., 2003; Sera et al., 1990; Andiç-Çakir et al., 2014) have shown that fibres exhibit good physical characteristics comparable to synthetic fibre such as steel and glass fibre (Meredith et al., 2012; Wambua et al., 2003; Raftery and Whelan, 2014). Natural fibres enhanced the fibre-concrete composite by holding the matrix together, minimized cracks, enhanced ductility and material damping of structural members (Ali et al., 2012).

Coconut fibre (CF) is one of the potential fibres which can be incorporated in concrete mix due to its high ductility and toughness. It is abundantly available in the tropical countries such as Indonesia, Philippines and India at very low cost. Previously, coconut fibre, which is also commonly known as coir, is only used in limited areas such as shipping rope, laundry brush and landscaping material. Coconut fibre reinforced concrete (CFRC) showed good static and dynamic characteristics for building structural elements. The previous studies proved that incorporating coconut fibres in concrete successfully increase the mechanical properties (compressive, splitting tensile, flexural strength, ductility and damping) of the fibre-concrete composite (see e.g. Ali et al., 2012). Commonly, CF is mixed in concrete either

by replacing the aggregate content (coarse or fine) with coir or as an additional material. Abdullah et al. (2011) found that replacement 9% of sand with coir (by percentage ratio of cement weight) is the optimum value to increase the compressive strength and modulus of rupture (MOR) of CFRC by approximately 6.4% and 7.6%, respectively, compared to plain concrete. However, substituting aggregate with coir gives less significant effect on mechanical properties of CFRC up to a stage where additional fibre content will decrease its performance (Ali et al., 2012). Ramli and Hoe (2010) revealed that an additional 1.8% of coir with very coarse sand in high strength concrete is the optimum value of compressive and flexural strength of 73.41 MPa and 6.15 MPa, respectively. Further investigation on the suitability of CFRC associated with coir rope as vertical reinforcement showed an increment of the ductility of the column (Ali, 2014). Improvement in mechanical properties of lightweight foamed concrete with additional of coconut fibres also reported by Othuman Mydin et al. (2015).

Because of its hydrophobic nature, coir can reduce the mechanical performance of composite materials. Hence, further surface treatment is necessary to improve its fibre-matrix interfacial bonds (Hill and Abdul Khalil, 2000). Fuqua et al. (2012) reported the methods that commonly used to enhance natural fibre surface are physical, chemical and physico-chemical treatments. Chemical treatments are the preferable option in enhancing CFRC because it is easy to handle. Andic-Cakir et al. (2014) reported that alkali treated coconut fibres reduce the amount of superplasticizer and can enhance mechanical properties of fibre-cementitious composites. Soaking coir in water for a few hours is the simplest way to treat the fibre prior to mixing with concrete (Ali et al., 2012; Asasutjarit et al., 2007). Preparing coir fibres with fixed length in CFRC are commonly used in industry but it is not practically for purpose due to the high labour cost. The applications of random length fibres are significant due to the cost reduction and there a lack research area on this matter. Therefore, this research paper is mainly emphasized on the effects of random length coir in CFRC based on mechanical properties. The results of CFRC with fixed fibre length are used for comparison and discussion.

## MATERIAL AND METHODS

### Raw material and mix design

The CFRC contents were ordinary Portland cement (OPC), sand, aggregate, water and brown coconut fibre from Bandung, Indonesia. The maximum size of coarse aggregates used was 13 mm. Design of CFRC was adopted from the work performed by Ali et al. (2012). The mix design ratio was 1:2:2 (cement: sand: aggregate) with water cement ratio (w/c) range of 0.48 – 0.65. More water is needed with increasing CF since the fibres tend to absorb water. The percentages of CF added to CFRC were 1%, 2%, 3% and 5% of the cement weight. The amount of aggregate was reduced according to the amount of fibre content to maintain CFRC density. Table 1 shows the total amount of constituents required to produce 0.01 m<sup>3</sup> CFRC.

**Table 1.** Mix proportion of 0.01 m<sup>3</sup> CFRC.

Specimens	Cement (kg)	Sand (kg)	Aggregate (kg)	Coconut fibre (kg)
Plain concrete (PC)	9.60	19.20	19.20	-
1% CF	9.60	19.20	19.10	0.10
2% CF	9.60	19.20	19.01	0.18
3% CF	9.60	19.20	18.91	0.29
5% CF	9.60	19.20	18.72	0.45

### Preparation of coconut fibre reinforced concrete (CFRC)

In origin, CF was available in a hydraulic pressure form (Fig. 1a) which has random length. The physical properties of the coconut fibres are shown in Table 2 (Malkapuram and Kumar, 2008; Yan et al., 2012; Ali et al., 2013). It was taken out and cut randomly with table cutter (Fig. 1(b)). The length estimation during the cutting process is very important to produce uniform fibres length. Pre-treatment of CF is required to ensure it is free from organic substances. Existing of organic solid may affect the CFRC performance when dust and organic fill up the void in the concrete mix. In this study, CF was treated by soaking in tap water for about 2 – 4 hours to soften the fibre.

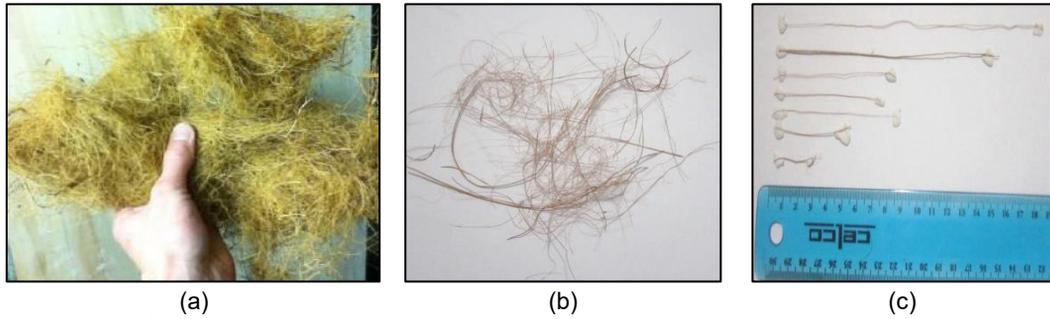
After the immersion, CF was repeated washed until the colour of the water becomes clear to remove the remaining impurities. Subsequently, it was separated and oven dried at the temperature of 50°C for about 10 – 12 hours. Following the drying process, the final length of CF was measured to determine the exact length of fibres that will be used in concrete mix. The length of CF was approximate between 2.5 and 20 cm. Fig. 2 shows the coir in random length before and after the treatment. The method of preparing CFRC mix was slightly different from the conventional procedure for normal concrete. A layer-by-layer method was used as described in detail by Ali et al. (2012) to minimise the ‘fibre balling’ during the mixing process.



Figure 1. (a) Coconut fibre in hydraulic form (b) Table cutter.

Table 2. Mechanical properties of coir

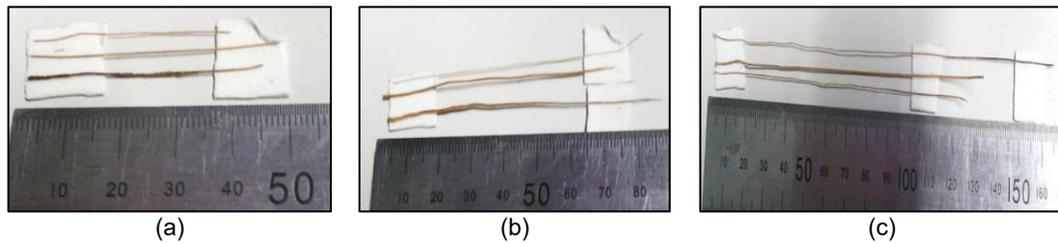
Properties	Malkapuram and Kumar (2008 )	Yan et al.(2012)	Ali et al. (2013)
Density (g/cm <sup>3</sup> )	1.15	1.20	-
Diameter (mm)	0.1– 0.45	0.25	0.15 – 0.20
Tensile strength (MPa)	131 – 175	226	47.3 - 99
Young's modulus (GPa)	4 – 6	2.74	0.58 – 1.24
Elongation at break (%)	15 – 40	17.8	19.5 – 39.3



**Figure 2.** Coconut fibre: (a) before treatment (b) random length after treatment (c) fibre measurement

### Fibre length analysis

The distribution of CF length was analysed statistically to estimate the randomness of the fibres in the concrete mix. A bunch of fibres weight of 10 grams was taken out and was separated according to its length. The fibres were classified into three groups of length which are short (1 – 5 cm), middle (6 – 9 cm) and long (> 10 cm) fibres. The fibres separation was done three times to ensure the consistency of the analysis. Fig. 3 shows the length classification of the coir before the statistical analysis. The fibres were counted according to its length. The result is described in section 3.1.



**Figure 3.** Coconut fibre classification (a) short (b) middle and (c) long fibres.

### Laboratory test

A total of 60 CFRC cylinder samples with diameter 100 mm and 200 mm height were tested to determine the compressive strength, splitting tensile and Young's modulus while third point loading method was conducted on 20 beamlets with cross-section 100 mm x 100 mm and 500 mm length to obtain the flexural strength. The tests were performed in accordance to NZS 3112 Part 2. The displacement of the samples was measured using a Linear Variable Differential Transformers (LVDT) which was located on the side of the samples.

## RESULTS AND DISCUSSIONS

### Random length analysis

The statistical analysis of random fibre length is presented in Fig. 4. The middle length fibres predominate the random fibres lengths with approximately about 54% in CFRC mix. The short and long fibre existences were 28.21% and 21.79% respectively.

## Density

Fig. 5 shows the density of CFRC with different percentages of coir. As predicted, the highest contents of coir (5%) produced the lightest CFRC samples ( $2315.28 \text{ kg/m}^3$ ). The density decrements of CFRC were about 0.7 to 2.2% compared to the plain concrete and similar finding in weight reduction also reported in previous studies (Ali et al., 2012; Abdullah et al., 2011; Aggarwal, 1992). Lightweight concrete is beneficial to the structural elements because it can reduce the structures self-weight and under dynamic loadings, less inertia force will be activated, i.e. the impact of the dynamic loading is less.

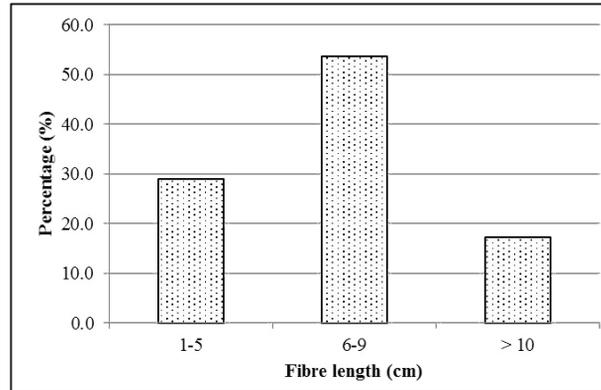


Figure 4. Length analysis of random coconut fibres.

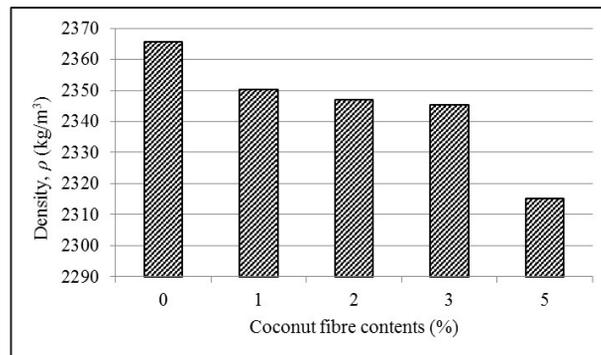


Figure 5. The density of CFRC with different fibre contents after 28 days.

## Compressive strength, $f_c$

The dashed line of Fig. 6 shows the compressive strength of CFRC with random fibres length. Each presented result was the average of the results obtained from experiments on four samples. CFRC with 1% of fibres displays an increment about 7.1% compared to that of the plain concrete. However, higher fibre content was found to reduce the strength of the samples almost linearly to 38.44 MPa, 36.28 MPa and 34.30 MPa, respectively, for 2%, 3% and 5% of coir content. These results support the finding (Ali et al., 2012) that a large amount of fibre content cause air voids in the concrete. Consequently, more fibres and less aggregate may reduce the strength of the concrete.

The compressive strength  $f_c$  of CFRC with random fibre length produces the same trend as compared to that with fixed length whereas the values reduced with increasing coir content. As shown in Fig. 6, the compressive strength of CFRC with random fibre length is slightly lower than that of CFRC with fixed fibre length. Nevertheless, both experimental results agreed that 1% of coir give the highest compressive strength of CFRC while CFRC with random fibre length has a compressive strength of 41.89 MPa, 2.6% smaller than that of CFRC with constant 5 cm fibre length.

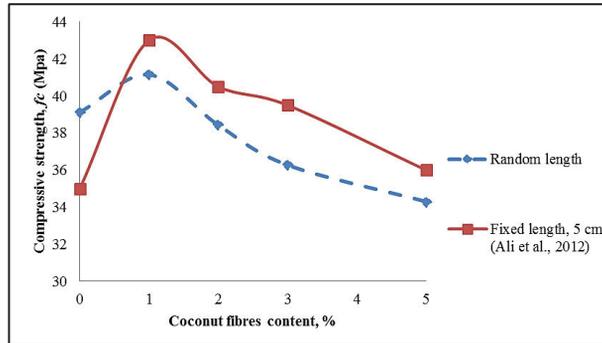


Figure 6. Compressive strength of CFRC with random length relative to that of CFRC with fixed fibre length.

### Splitting tensile strength, $T_s$

From visual observation of the results in Fig. 7(b) more fibre content results in less crack in the concrete. Plain concrete samples were split into two parts at the failure stage whilst the presence of coir held the concrete matrix together. The tensile strength  $T_s$  obtained from the splitting tensile tests are shown in Fig. 8. 1% of coir content gives the maximum  $T_s$  value of 4.57 MPa and decreases as the fibre content increases. The  $T_s$  of CFRC with random fibre length demonstrated a higher tensile strength compared to that of CFRC with fixed fibre length. It might be because the random fibre lengths consist of fibres of various lengths, grouped as short, medium length and long fibres, which can hold the concrete matrix better than only with one particular length.



Figure 7. Broken samples following STS tests: (a) plain concrete (b) CFRC.

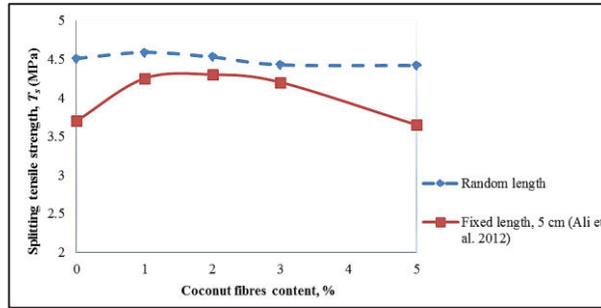


Figure 8. STS of CFRC; comparison between random fibre length and fixed length.

Generally,  $T_s$  of concrete has a close relationship with compressive strength  $f_c$  values (Yan et al., 2013). International standard code of practice, for instance, ASTM developed different equations to predict the  $T_s$  of normal concrete for building design purpose. In this study, the relationship between  $T_s$  and  $f_c$  of CFRC in Fig. 9 with random coir length can be predicted by using the developed empirical Eq. (1).

$$T_s = 0.9(f_c)^{0.41} \tag{1}$$

Table 3 summarizes  $T_s$  obtained from experiments and from Eq. (1) for fixed and random fibre length.

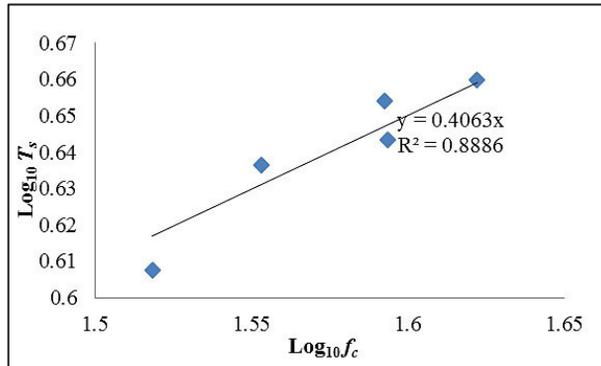


Figure 9. Log-log of  $T_s$  and  $f_c$  value.

Table 3.  $T_s$  value prediction using Eq. (1)

Fibre content (%)	Random length			Fixed length, 5 cm (Ali et al. 2012)		
	STS (MPa)		Diference (%)	STS (MPa)		Diference (%)
	Experimental	Eq. (1)		Experimental	Eq. (1)	
0	4.51	4.05	11.36	3.70	3.82	3.17
1	4.57	4.16	9.86	4.25	4.15	2.27
2	4.40	4.05	8.64	4.30	4.05	5.74
3	4.33	3.90	11.03	4.20	4.01	4.48
5	4.05	3.77	7.43	3.65	3.86	5.80

## Modulus of elasticity, $E_{static}$

Modulus of elasticity, i.e. Young's modulus, is used to characterize materials by relating to the stiffness of the materials. For normal concrete, the  $E_{static}$  values are ranging from 17 GPa – 30 GPa. Fig. 10 shows the influence of different fibre contents on Young's modulus,  $E_{static}$  of CRFC with random and fixed fibre length. It is apparent that additional coir of random length reduces the  $E_{static}$  of CRFC relative to plain concrete (34.79 GPa) where 1% and 2% fibre contents gave 30.12 GPa and 29.10 GPa, respectively. However, for 3% of coir the value was slightly decreased to 30.32 GPa and the lowest was for 5% fibre contents, i.e. 27.54 GPa. These results agree with the findings for CRFC with fixed length (Ali et al., 2012).

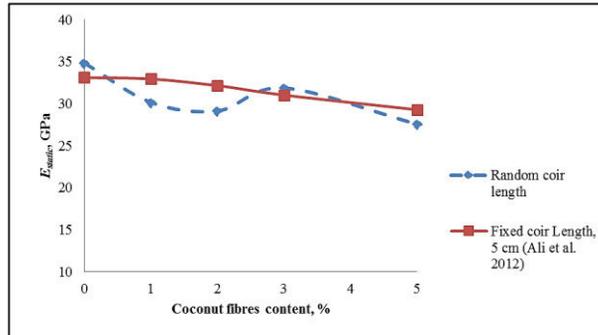


Figure 10.  $E_{static}$  of CRFC with random and fixed length.

It is a challenge to develop a universal equation to predict Young's modulus of CRFC since its behaviour depends on the concrete mix ratio, concrete handling, fibre length and origin of the coir. Ali et al. (2012) established the equation of CRFC with the fixed length to estimate  $E_{static}$  for a different amount of coconut fibre as stated in Eq. (2).

$$E_{stat} = X_s + Y_s c + Z_s c^2 \quad (2)$$

where constant values for  $X_s$ ,  $Y_s$  and  $Z_s$  are 34, -1 and 0 respectively, while  $c$  is the percentage of fibre content; 0,1,2,3 and 5. This equation is limited only to a constant fibre length of 5 cm. However, for random fibre length, the  $E_{static}$  can be estimated using the following Equation.

$$E_{stat} = P_s c^3 + Q_s c^2 + R_s c + S_s \quad (3)$$

where the coefficient for  $P_s$ ,  $Q_s$ ,  $R_s$  and  $S_s$  are -0.6, 4.3, -9 and 35 respectively, while  $c$  is the percentage of the fibre content i.e 0,1,2,3 and 5. The differences of the  $E_{static}$  value obtained from experiment and proposed Eq. (3) is shown in Table 4.

**Table 4.**  $E_{static}$  of experimental and numerical equation.

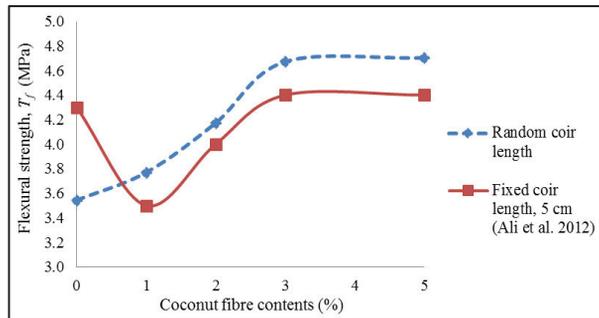
Fibre content (%)	Modulus of elasticity, $E_{static}$ (GPa)		% Difference (A and B)
	Experiment	Eq. (3)	
	A	B	*C
0	34.79	35.00	-0.60
1	30.12	29.70	1.39
2	29.10	29.40	-1.03
3	31.83	30.50	4.18
5	27.54	22.50	18.30

$$* C = \frac{B - A}{B} \times 100$$

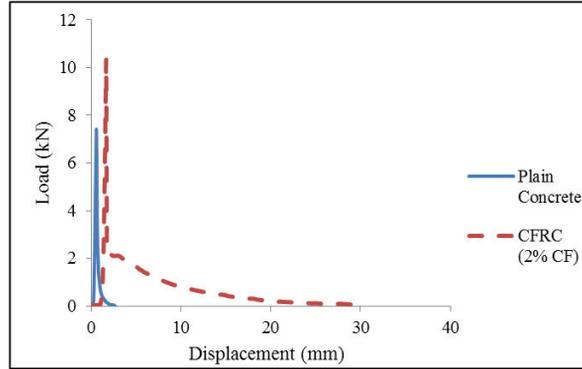
### Flexural tensile strength, $T_f$ and Total Toughness Index, TTI

The flexural tensile strength,  $T_f$  of CFRC with random fibre length is presented by the dashed line in Fig. 11. With growing fibre content  $T_f$  values of the samples increased compared to that of the plain concrete sample. 5% fibre content in the CFRC mix gives the highest  $T_f$  which is 4.70 MPa. A similar finding was reported by Ali et al. (2012) for fixed fibre length which more fibre contents improved the flexural strength. However, the random length posed up to 7% higher flexure strength compared with that of CFRC with fixed fibre length. This might be because CFRC of various length of fibre provides a better bridging effect on the surrounding concrete.

The load – displacement relationships of flexural strength for plain concrete and CFRC is shown in Fig. 12. Unlike the plain concrete samples, which experience sudden failure after the first crack, CFRC samples can still hold the load following the initial crack (Fig. 13(b)). The coir has the ability to absorb the energy, which can be calculated from the area under load – displacement graph. The maximum displacement occurred at the mid-span of the beamlets sample. Fig. 14 shows the condition of CFRC sample after the post cracking and fibre pull out from the concrete. The dashed line in Fig. 15 shows the beam toughness of CFRC. Increasing TTI values with higher fibres contents indicates that more energy will be absorbed. CFRC with random fibres length has higher TTI value compared to CFRC with fixed fibre length.



**Figure 11.** Flexural strength comparison between CFRC random and fixed length.



**Figure 12.** Load-displacement curves of plain concrete and CFRC samples with 2% fibres contents under flexure test.



(a)

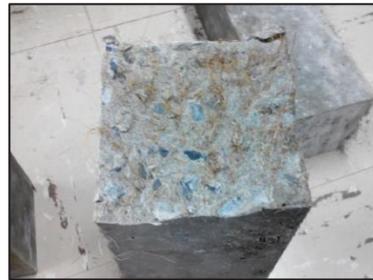


(b)

**Figure 13.** Beam failure under third point loading test (a) plain concrete (b) initial cracking of CFRC

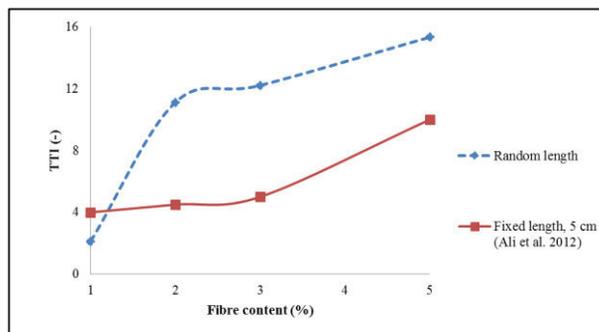


(a)



(b)

**Figure 14.** CFRC beamlets: (a) post cracking (b) fibres pull-out of CFRC after flexure failure



**Figure 15.** Total toughness index TTI of different CF contents

## CONCLUSIONS

In this study, a comparison of the static properties of CFRC with random and fixed fibre length was discussed. The results revealed that:

- (i) The middle length of fibres with length the between 6 to 9 cm was most produced from the random cutting process in the CFRC mix.
- (ii) CFRC with random fibre length has similar static properties compared to CFRC of fixed fibre length of 5 cm.
- (iii) The compressive strength and  $E_{static}$  values of CFRC with random fibre length were slightly lower than that with fixed fibre length. However, it is still acceptable for construction of low-cost building since the values were still higher than 20 MPa. In addition, CFRC with random fibre length is cheaper and more practical to be used in building construction.
- (iv) CFRC of random fibre length has a higher tensile splitting strength and flexural strength than those of CFRC of fixed fibre length.
- (v) CFRC with random length also has more toughness compared with that of CFRC with fixed fibre length.

## ACKNOWLEDGMENTS

The authors are grateful to all colleagues who supported this research, particularly Mark Bryami, Ross, Marie Bourboulou, Victor Llapaset and would like to thank Winstone Aggregates Company for the material support. The first author also would like to thank Ministry of Education, Malaysia for supporting the Ph.D study at the University of Auckland.

## REFERENCES

- Abdullah, A., Jamaludin, S.B., Mazlee, M.N. and Kamarudin, H. (2011), "Composite cement reinforced coconut fiber: physical and mechanical properties and fracture behaviour", *Aust J Basic Appl Sci*; 5(7), 1228–1240.
- Aggarwal, L. (1992), "Studies on cement-bonded coir fibre boards", *Cem Concr Compos*, 14(July 1991), 63–69
- Ali, M. (2014), "Seismic performance of coconut-fibre-reinforced-concrete columns with different reinforcement configurations of coconut-fibre ropes", *Construction and Building Materials*, 70, 226 – 230.
- Ali, M., Li, X. and Chouw, N. (2013), "Experimental investigations on bond strength between coconut fibre and concrete", *Materials and Design*, 44, 596-605
- Ali, M., Liu, A., Sou, H. and Chouw, N. (2012), "Mechanical and dynamic properties of coconut fibre reinforced concrete", *Construction Building and Material*, 30, 814–825.
- Al-Oraimi, S.K. and Seibi, A.C. (1995), "Mechanical characterisation and impact behaviour of concrete reinforced with natural fibres", *Composite Structure*, 32(1–4), 165–171.
- Andiç-Çakir, Ö., Sarikanat, M., Tüfekçi, H.B., Demirci, C. and Erdoğan Ü.H. (2014), "Physical and mechanical properties of randomly oriented coir fiber–cementitious composites", *Composite Part B Eng*, 61, 49–54.
- Asasutjarit, C., Hirunlabh, J., Khedari, J., Charoenvai, S., Zeghmati, B. and Shin, U.C. (2007), "Development of coconut coir-based lightweight cement board", *Constr Build Mater*, 21(2), 277–288.

- Fuqua, M.A., Huo, S. and Ulven, C.A. (2012), "Natural fiber reinforced composites", *Polym Rev*, 52(3), 259–320.
- Hill, C.A.S. and Abdul Khalil, H.P.S. (2000), "Effect of fiber treatments on mechanical properties of coir or oil palm fiber reinforced polyester composites", *J Appl Polym Sci*; 78(9), 1685–1697.
- Khedari, J., Charoenvai, S. and Hirunlabh, J. (2003), "New insulating particleboards from durian peel and coconut coir", *Build Environ*; 38(3), 435–441.
- Krishnamoorthy, S. (1983), "Behaviour of concrete reinforced with jute, coir and bamboo fibres", *Int J Cem Compos Light Concr*, 5(1), 3–13.
- Mahmoudi, N. (2013), "Use of date palm fibers as reinforcement for thermoplastic-based composites", *Mech Ind*, 14(1), 71–77.
- Malkapuram, R. and Kumar, V. (2008), "Recent development in natural fiber reinforced polypropylene composites", *J Reinf Plast Compos*, 28(10), 1169–1189.
- Meredith, J., Ebsworth, R., Coles, S.R., Wood, B.M. and Kirwan, K. (2012), "Natural fibre composite energy absorption structures", *Compos Sci Technol*, 72(2), 211–217.
- New Zealand Standard, Method of test for concrete: Parts 2: Tests Relating to the determination of strength of concrete. NZS 3112.2:1986.
- Othuman Mydin, M.A., Rozlan, N.A. and Ganesan, S (2015), "Experimental study on the mechanical properties of coconut fibre reinforced lightweight foamed concrete", *J. Mater. Environ. Sci.*, 6(2), 407 – 411.
- Raftery, G.M. and Whelan, C. (2014), "Low-grade glued laminated timber beams reinforced using improved arrangements of bonded-in GFRP rods", *Constr Build Mater*, 52, 209–220.
- Ramli, M. and Hoe, K. (2010), "Influences of short discrete fibers in high strength concrete with very coarse sand", *Am J Appl Sci*, 7(12), 1572–1578.
- Sera, E.E., Robles-Austriaco, L. and Pama, R.P. (1990), "Natural fibers as reinforcement", *J Ferrocem*, 20(2), 109–124.
- Wambua, P., Ivens, J. and Verpoest, I. (2003), "Natural fibres: can they replace glass in fibre reinforced plastics?", *Compos Sci Technol*, 63(9), 1259–1264.
- Yan, K., Xu, H., Shen, G. and Liu, P. (2013), "Prediction of splitting tensile strength from cylinder compressive strength of concrete by support vector machine", *Adv Mater Sci Eng*, 2013, 1–13.
- Yan, L., Duchez, A. and Chouw, N. 2012, "Effect of bond on compressive behaviour of flax fibre reinforced polymer tube-confined coir fibre reinforced concrete", *J Reinf Plast Compos*, 32(4), 273–285.
- Yan, L. and Chouw, N. (2013), "Experimental study of flax FRP tube encased coir fibre reinforced concrete composite column", *Constr Build Mater*, 40, 1118–1127.

# THE EFFECTIVE PARAMETERS ON THE BEHAVIOUR OF CFDST COLUMNS

**E. Farajpourbonab, S. Kute and V.M. Inamdar**

*Department of Civil Engineering, K.K.W. Institute of Engineering Education and Research, Nasik (M.S.), University of Pune, India*

## **Abstract**

Concrete Filled Double Skin Steel Tubular (CFDST) columns could be considered as a new type of concrete filled steel tubular (CFT) columns. These columns are composed of two steel tubes in the concentric configurations with concrete between them. In the current study the effects of load application type, material (yield stress of steel tubes, concrete strength), and geometric parameters (thickness and diameter of the steel tubes) have been investigated on the behaviour of CFDST columns. Findings of the current study clearly indicate the high ductility and strength of CFDST columns under axial loading. The results show the significant impacts of yield stress of steel section, compressive strength of concrete, thickness and diameter variations on the strength and ductility of CFDST columns.

**Keywords:** *CFDST column, finite element method, material and geometric parameters, strength and ductility*

## **INTRODUCTION**

Concrete-filled-steel-tube columns have been adopted widely for column construction of tall buildings due to its excellent confining effect. However, the central part of concrete in CFT columns have relatively small contribution towards bending and torsion resistance, which can be effectively replaced by another hollow steel tube with much smaller area without reducing the load carrying capacity due to composite action. This structural form with the in-between annulus of inner and outer steel tubes filled with concrete is called Concrete-Filled Double Skin Tubular (CFDST) columns. According to Han et al. (2011) and Li et al. (2012), this form of column has higher strength (uniaxial, flexural, and torsion). The strength-to-weight ratio is improved significantly by replacing the central part of concrete with a hollow steel tube. The confining pressure builds up more rapidly than CFT column because the inner steel tube would expand outward to increase the confining pressure.

Han et al. (2010) have developed a nonlinear concrete model for the analysis of CFDST columns to understand the effect of confinement on the strength of the concrete. The confined concrete exhibits much higher strength in comparison with unconfined concrete. This is explaining why a CFDST column indicates much strength than the sum of the strengths of outer tube, inner tube, and concrete separately. In addition, the results show that strength and ductility of the concrete in the CFDST column could be controlled by the thickness of the inner and outer tube (Han et al., 2010). Niranjana and Erremma (2012) had conducted experiments on CFT columns having a length of 2.5m and length to diameter ratio, ranging 15, 20, and 25 filled with M20 grade of SCC. The cross section was modified by providing flutes on the steel tube, which increases the moment of inertia by 17 % to 40 % for rectangular flutes and 9 to 23% for triangular flutes. It was observed that the load resistance was better in rectangular fluted columns as compared to the triangular fluted columns (Niranjana and Erremma, 2012). Tao et al. (2004) have conducted a series of experimental tests on CFDST stub columns and beam-columns (CHS outer and CHS inner), for some parameters such as diameter-to thickness ratio and hollow section ratio. The results show the enhanced structural

behaviour of CFDST stub columns and beam-columns because of the ‘composite action’ between steel tube and concrete core. In addition, the tested CFDST samples behaved in a relatively ductile manner and testing proceeded in a smooth and controlled fashion, because of the infill of concrete (Tao et al., 2004). Shah et al. (2014) had performed Finite Element Analysis using ANSYS software on CFT columns under axial loading for circular and square cross sections with varying Grades of concrete. It is concluded that the deformation of the column is decreasing 10% to 15% with the increase in the grade of concrete. It is also found that the circular section leads to better confinement than the square section (Shah et al., 2014). Gupta et al. (2007) conducted an experimental study on circular concentrically loaded concrete filled steel tube columns. Their findings indicated that in the CFT samples, that necessarily fail because of local buckling, with the increase of concrete strength, the confinement effect in the concrete core decreases. In addition, the results showed that the strength of the steel tube decreases as the  $(D/t)$  ratio increases (Gupta et al., 2007). Giakoumelis et al. (2004) investigated the axial capacity of circular concrete-filled tube columns. Their findings showed that in CFT columns with high-strength concrete, the peak load in the sample could be attained for small shortening; on the other hand, for normal concrete, the maximum load could be attained with a large displacement. Furthermore, by the increment of concrete strength, the bond effects between the concrete and the steel tube became more critical. For normal concrete strength, the reduction of the axial capacity in the column, due to bonding, was negligible. With regard to high-strength concrete, variation between non-greased and greased samples was 17% (Giakoumelis et al., 2004).

According to the past studies, there is a need for numerical study to check the parameters, which affect the ultimate strength. Therefore, in the current study the effects of geometric and material parameters have been investigated on the behaviour of CFDST columns under axial loading.

## **FINITE ELEMENT MODELING OF CFDST COLUMNS**

In order to understand the structural behaviour of CFDST columns and carry out comparative investigation under axial and cyclic loadings, geometric and material nonlinear finite element analyses have been undertaken. The models were simulated using ANSYS R 10.0 (2005) finite element software that is a finite element program designed especially for advanced structural analysis.

### **Characteristics of models**

ANSYS R 10.0 (2005) elements and capabilities are as follows:

The concrete was modelled using a special concrete element SOLID 65. This element is an 8-node solid brick element that has crushing (compressive) and cracking (tensile) capabilities. For modelling of steel tube and steel profile, a 3-D solid element SOLID 45 was used. The element has plasticity, creep, swelling, stress stiffening, large deflection and large strain capabilities. For modelling of sliding between interaction surfaces of steel profile and concrete, CONTAC 52 element was used. The CONTAC 52 represents two surfaces, which may maintain or break physical contact and may slide relative to each other.

### Material characteristic

The stress-strain behaviour of in-filled concrete and the steel wall, used for material and geometric static analyses, is given in Figures 1 and 2, respectively (ACI 200, 2005). For the concrete element, the elastic modulus ( $E_c$ ), the Poisson’s ratio ( $\nu_{xy}$ ), the values for the strength of ultimate tensile ( $f_r$ ) and strength of ultimate compressive ( $f_c$ ) are the properties of isotropic material as shown in Figure 1.

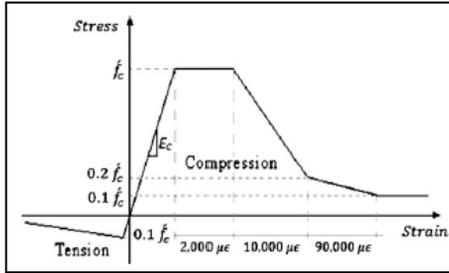


Figure 1. Concrete material

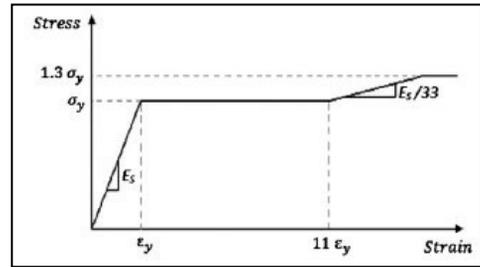


Figure 2. Steel material

Considering Figure 2, the behaviour of steel is characterized with an initial linear elastic portion of stress-strain relationship with a modulus of elasticity, approximately 200 Gpa and up to the yield stress  $f_y$  (ST 37 with  $F_u=370 \text{ N/mm}^2$ ), that is equal to 280 Mpa, followed by a strain plateau of varying length and a following region of strain hardening.

### Verification of finite element modelling

To determine the reliability and validity of the finite element modelling, the findings achieved by conducting material and geometric nonlinear analyses have been compared with the accessible experimental results of Tao et al. (2004) under axial loading. Regarding the axial loading, an experimental CFDST column with circular section (sample cc2a) has been used according to the specifications in Table 1.

Table 1. The specifications of the experimental CFDST columns

Steel Properties			Concrete Properties		x	L (mm)	$D_i \times t_{si}$	$D_i \times t_{so}$	Sp.
$E_s$ (Mpa)	$f_{syi}$ (Mpa)	$f_{syo}$ (Mpa)	$E_c$ (Mpa)	$f'_c$ (Mpa)					
200000	396.1	275.9	33300	47.4	0.47	540	48×3	180×3	cc2a

Figure 3 shows the experimental and numerical load- displacement response of a CFDST sample under axial loading. It is found that the columns behaviour predicted by the finite element analysis closely followed the behaviour shown by the experimental results. Consequently, it was observed that the finite element method has a sufficient degree of reliability to be implemented in undertaking nonlinear analyses of CFDST columns.

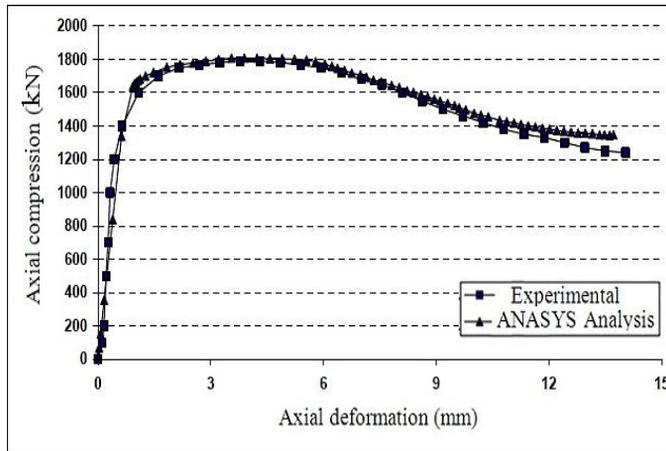


Figure 3. Experimental and numerical responses of a CFDST column (cc1a Specimen)

## NUMERICAL INVESTIGATIONS

For investigation the effective parameters on the behaviour of CFDST columns as shown in Figure 4, various concrete strengths and steel stresses have been considered for the analyses as follows:

### Material specifications

1. Various yield stresses effect of steel
2. Various compressive strengths effect of concrete

### Geometric specifications (slenderness and compactness of steel section)

1. The effect of thickness variations of steel wall
2. The effect of diameter variations of steel wall
3. Load application type (mutual composite action between steel and concrete)

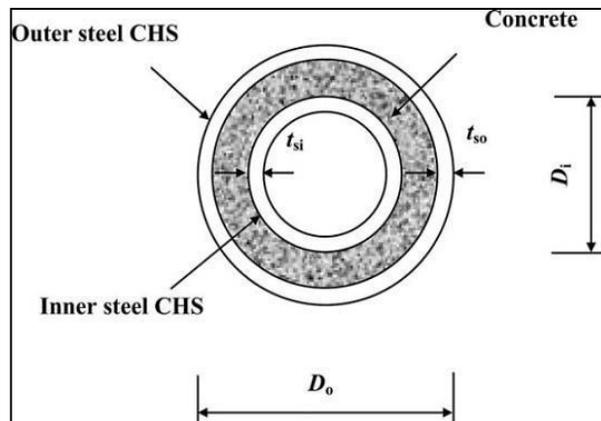


Figure 4. Details and dimensions of CFDST specimen

The following are assumptions that have been taken into considerations for the selection of these sections:

1. CFDST columns have been selected with typical dimensions having a high load bearing capacity (L=3000 mm)
2. Steel wall thickness has been selected according to ACI 318 (1995) and AISC/LRFD (2003) codes, so that the local buckling may not be observed at lower loads.
3. The columns are considered as fixed-end columns
4. Before loading, enough imperfection is applied towards the buckling directions according to the standard codes equal to 1/1000 length of columns (Iranian Code of Practice for Seismic Resistant Design of Buildings, 2007).

### THE IMPACT OF YIELD STRESS OF STEEL WALL

In order to assess the yield stress effects of steel wall, two states have been considered as follows:

1. First, yield stress of inner steel wall has a fixed amount (320 Mpa), and the yield stress of outer steel wall is variable as specified in Table 2.
2. Second, yield stress of outer steel wall has a fixed amount (320 Mpa), and the yield stress of inner steel wall is variable as specified in Table 3.

**Table 2.** The material specifications of specimens (Variations of  $f_{syo}$ )

Steel properties			Concrete properties		$x$	Specimen
$E_s$ (Mpa)	$f_{syi}$ (Mpa)	$f_{syo}$ (Mpa)	$E_c$ (Mpa)	$f'_c$ (Mpa)		
200,000	320	240	35400	50	0.495	MSO 240
200,000	320	280	35400	50	0.495	MSO 280
200,000	320	320	35400	50	0.495	MSO 320
200,000	320	360	35400	50	0.495	MSO 360
200,000	320	400	35400	50	0.495	MSO 400

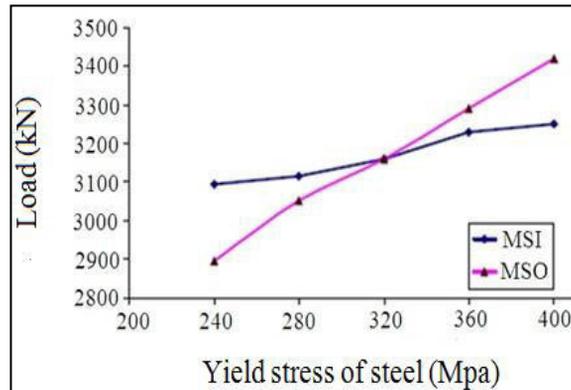
**Table 3.** The material specifications of specimens (Variations of  $f_{syi}$ )

Steel properties			Concrete properties		$x$	Specimen
$E_s$ (Mpa)	$f_{syi}$ (Mpa)	$f_{syo}$ (Mpa)	$E_c$ (Mpa)	$f'_c$ (Mpa)		
200,000	240	320	35400	50	0.495	MSI 240
200,000	280	320	35400	50	0.495	MSI 280
200,000	320	320	35400	50	0.495	MSI 320
200,000	360	320	35400	50	0.495	MSI 360
200,000	400	320	35400	50	0.495	MSI 400

For example, MSO 400 is the sample, which the yield stress in outer steel wall is variable, supposing that the yield stress of inner steel wall is constant (320 Mpa). In addition, MSI 280 is the sample which the yield stress in inner steel wall is variable, supposing that the yield stress of outer steel wall is constant (320 Mpa).

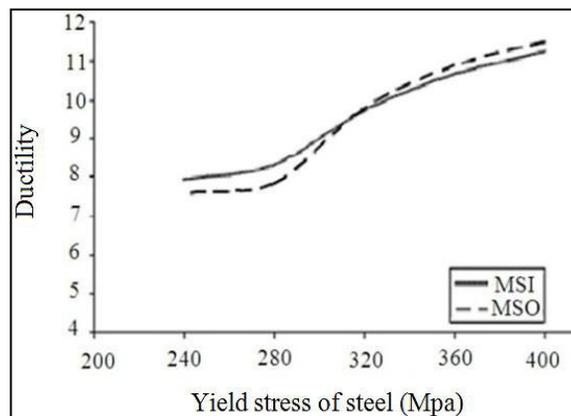
Figures 5 show load-yield stress of steel corresponding response of MSI and MSO samples. It can be seen that load carrying capacity and post yield behaviour of MSI 280, MSO

360, and MSO 400 samples are significantly higher than that of MSO 280, MSI 360, and MSI 400 samples, respectively.



**Figure 5.** The effect of steel walls' yield stress variations on the strength of CFDST columns

Considering Figures 5 and 6, it was defined that when the yield stress of inner steel wall is less than the outer one, maximum load bearing capacity and ductility of the samples MSI 240, MSI 280, MSO 360, and MSO 400 are significantly higher than that of MSO 240, MSO 280, MSI 360 and MSI 400 samples. It means that in case that two kinds of steel with different yield stresses are available, if the steel with more yield stress to be used at outer steel wall, that would have a higher efficiency and a better performance from the viewpoint of ductility and load bearing capacity.



**Figure 6.** The effect of steel walls' yield stress variations on the ductility of CFDST columns

## THE IMPACT OF CONCRETE COMPRESSIVE STRENGTH

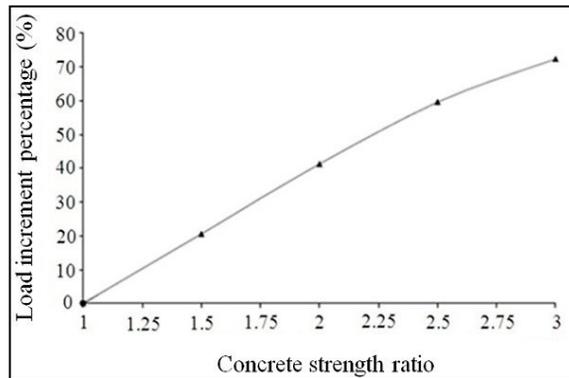
To assess the effect of concrete strength, five samples have been selected having various specified compressive strengths of CFDST samples. For this purpose, the yield stress and geometric specifications of the inner and outer steel wall for all specimens are the same and the strength of the filling concrete is variable.

**Table 4.** The material specifications of component parts of CFDST columns

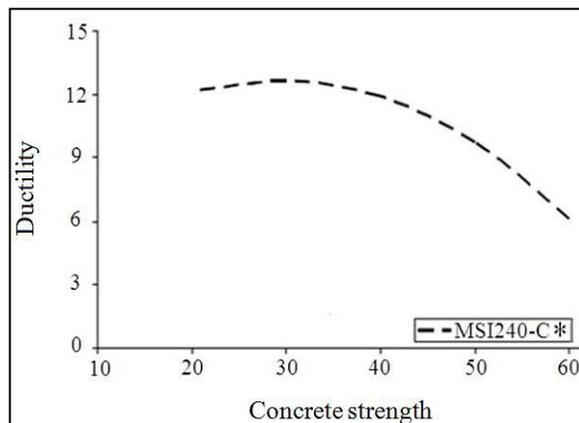
Steel properties			Concrete properties		$x$	Specimen
$E_s$ (Mpa)	$f_{syi}$ (Mpa)	$f_{syo}$ (Mpa)	$E_c$ (Mpa)	$f'_c$ (Mpa)		
200,000	240	320	22400	20	0.495	MSI 240-C20
200,000	240	320	27400	30	0.495	MSI 240-C30
200,000	240	320	31600	40	0.495	MSI 240-C40
200,000	240	320	35400	50	0.495	MSI 240-C50
200,000	240	320	38700	60	0.495	MSI 240-C60

For example, MSI 240 - C20 is the sample for which the concrete strength used in the samples is variable (20 ~ 60 Mpa), supposing that the yield stress of outer and inner steel walls is fixed (320 Mpa outer tube and 240 Mpa inner one). The material specifications of samples are given in Table 4.

Figure 7 shows load increment percentage-concrete strength ratio responses of MSI 240-C\* samples. It can be seen that load-carrying capacity of specimens increases as the strength of the filling concrete increases.



**Figure 7.** The effect of compressive strength of concrete on the strength of CFDST columns



**Figure 8.** The effect of compressive strength of concrete on the ductility of CFDST columns

Considering Figure 8, it is observed that with the increase of concrete strength in specified range, ductility of samples increases, but for more increase of concrete strength, out of specified range, ductility of specimens, decreases. Therefore, this result clearly shows the

considerable effects of concrete strength on the behaviour of CFDST columns such that, for getting an appropriate behaviour of CFDST columns, concrete strength of specimens would be suggested between 30~45Mpa.

## THE EFFECT OF THICKNESS VARIATIONS OF STEEL WALL

To assess the effect of steel wall's thickness variations, eight samples have been selected including the various thicknesses at outer and inner steel walls according to Tables 5 and 6.

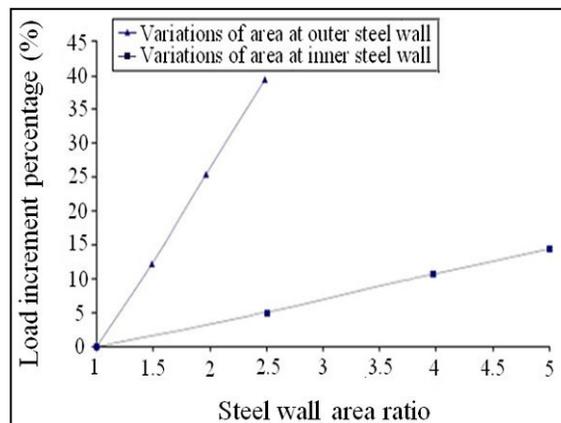
**Table 5.** The specifications of specimens with various thicknesses at outer steel wall

The thickness of outer steel wall is variable (Inner steel wall thickness is constant)					
Sample		ThicOut 4~8(Outer Thickness is variable)			
Wall position	Diameter (mm)	$t_1$ (mm)	$t_2$ (mm)	$t_3$ (mm)	$t_4$ (mm)
OUT	300	4	6	8	10
IN	100	4 (Inner thickness is constant)			

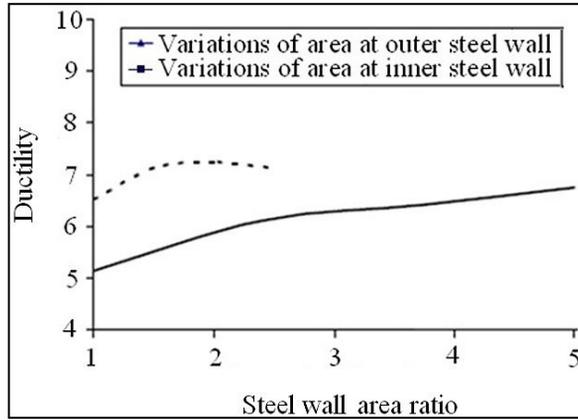
**Table 6.** The specifications of specimens with various thicknesses at inner steel wall

The thickness of inner steel wall is variable (Outer steel wall's thickness is constant)					
Sample		ThicIn 2~10(Inner Thickness is variable)			
Wall position	Diameter (mm)	$t_1$ (mm)	$t_2$ (mm)	$t_3$ (mm)	$t_4$ (mm)
IN	100	2	5	8	10
OUT	300	8 (Outer thickness is constant)			

Figures 9 and 10 shows the effects of increment of steel wall area on the increment of strength and ductility of CFDST samples, respectively.



**Figure 9.** The effect of area of steel wall on the strength of CFDST columns



**Figure 10.** The effect of area of steel wall on the ductility of CFDST columns

It can be seen that axial compression of CFDST samples increases as the thicknesses of the outer and inner steel walls increases. Considering the results in Figure 9, it is defined that with the increase of ratio of inner steel wall area at point 2.5, load carrying capacity of specimens are increased about 5%, while with the increase of ratio of outer steel wall at point 2.5, load capacity of specimens are increased about 40%. That means the achieved load for the samples with outer steel wall thicknesses variations is considerably more than the variations of thicknesses in inner steel wall. The reason is that increment in the thicknesses of outer steel walls considerably affects on the concrete core confinement and that resulted in improvement of ductility and strength of the samples.

**THE EFFECT OF DIAMETER VARIATIONS OF STEEL WALL**

In order to assess the effect of diameter variations of steel wall, eight samples have been selected as shown in Tables 7 and 8 including the various thicknesses at outer and inner steel wall, respectively. It is noticeable that for the selection of these samples,  $D/t$  ratio of specimens have been considered the same amount for all samples ( $D/t = 2.5$ ).

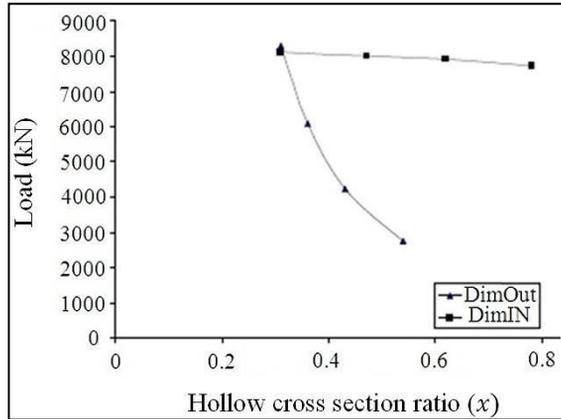
**Table 7.** The specifications of specimens with various diameters of outer steel wall

x variant and outer steel wall variations					
Wall position	Sample	DimOut 200-8	DimOut 250-10	DimOut 300-12	DimOut 350-14
	OUT	200×8(mm)	250×10(mm)	300×12(mm)	350×14(mm)
	IN	100×5 (mm)			
x		0.54	0.43	0.36	0.31

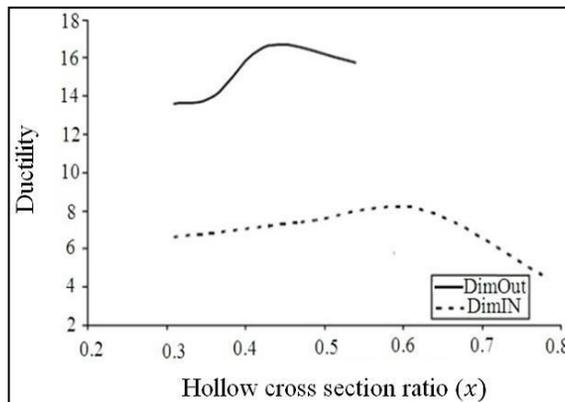
**Table 8.** The specifications of specimens with various diameters of inner steel wall

x variant and inner steel wall variations					
Wall position	Sample	DimIn100-4	DimIn150-6	DimIn200-8	DimIn250-10
	OUT	350×14 (mm)			
	IN	100×4(mm)	150×6(mm)	200×8(mm)	250×10(mm)
x		0.31	0.47	0.62	0.78

Figure 11 shows that by decrease of outer steel wall diameter (increase of  $x$  factor, DimOut state), maximum load capacity of the samples efficiently decreases, while with the decrease of inner steel wall diameter (decrease of  $x$  factor, DimIN state), degradation of strength has got inclined towards increasing slope with negligible increment of load capacity.



**Figure 11.** Effect of hollow cross section ratio on the strength of CFDST columns

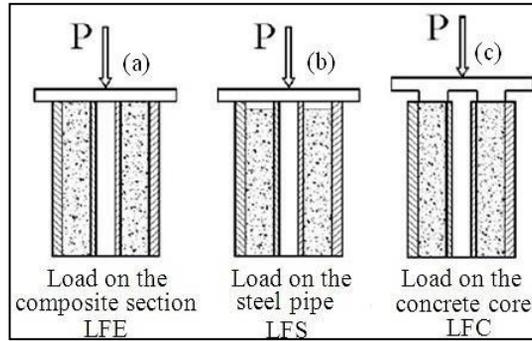


**Figure 12.** Effect of hollow cross section ratio on the ductility of CFDST columns

Considering Figure 12, it is found that with the increase of  $\chi$  factor in specified range, ductility of samples increases, but for more increase of  $\chi$  factor, out of the specified range, ductility of specimens, decreases. So this result clearly shows the considerable effects of diameter variations on the behaviour of CFDST columns such that, in order to increase the ductility and an appropriate behaviour of CFDST columns, the increase of diameter of steel wall must be defined within a specified range.

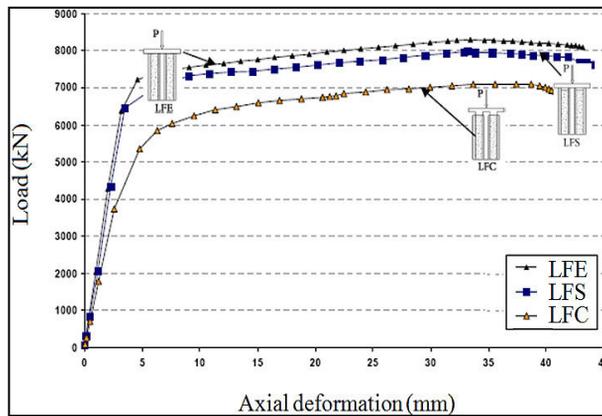
## THE EFFECT OF LOAD APPLICATION TYPE

In order to investigate the behaviour of CFDST samples, under axial loading, three types of load application have been considered as shown in Figure 13. In the case of load application types (b) and (c), the axial load is applied only to the steel section and to the concrete core, respectively. However, in the case of load application type (a), the axial load is applied to the entire section. In each case, two rigid plates, located at the top and bottom of the columns, transfer load.



**Figure 13.** Three load application types

Considering Figure 13, in the case of applying load to the entire section, The results show that the strength of samples in the case of load application type (a) is considerably higher than that of the load application types of (b) and (c). In the case of load application to the entire section, the samples exhibit appropriate strain-hardening characteristics on their post-yield behaviour. In addition, steel walls show the highest ratio in terms of load carrying capacity of columns, not available in load application type of (c).



**Figure 14.** The effect of load application type on the strength of CFDST column

Table 9 shows load application type effects into the load attraction ratio of component parts of CFDST columns. Considering the obtained results in Table 9, the amount of increase in the maximum load when load applied to the entire section is 6 percent and 25 percent more than (LFS) and (LFC) samples, respectively.

**Table 9.** The effect of load application type into the load attraction ratio of component parts

The effect of loading state and the load attraction ration of component parts			
State	In comparison to LFE state	Steel load attraction ration	Concrete load attraction ration
Load on the composite section (LFE)	100	60.3	39.7
Load on the steel pipe (LFS)	94.2	71.6	28.4
Load on the concrete core (LFC)	75.8	43	57

## CONCLUSION

In the present study, some effective parameters into the buckling behaviour of CFDST columns under axial loading have been investigated.

1. To construct the composite CFDST columns, in case that two kinds of steel with different yield stresses are available, the steel with more yield stress is suggesting to be sued at outer steel wall to have a higher efficiency and a better performance from the viewpoint of ductility and load bearing capacity.
2. The findings obviously illustrate the significant impacts of concrete strength including the fact that the use of high strength filling concrete resulted in a reduction of CFDST's ductility. Therefore, for having a desirable behaviour in CFDST columns, compressive strength of concrete should not exceed a specified range
3. In order to have appropriate ductility of CFDST columns, the increase of diameter of steel wall should not be more than a specified range. The results show that the increase of thickness in outer steel wall gives behaviour that is more appropriate rather than the increase of thicknesses in the inner steel wall.
4. In the case of load application to the entire section, the columns exhibits appropriate strain-hardening characteristics on their post-yield behaviour and a better performance from the viewpoint of ductility and load carrying capacity.

## REFERENCES

- ACI 200 Part 1, Materials and General Practice of Concrete, 2005.
- ACI 318, Building Code Requirements for Reinforced Concrete, American Concrete Institute, 1995.
- AISC/LRFD, Manual of Steel Construction, Load and Resistance Factor Design, American Institute of Steel Construction, Part 4, Composite Columns, 2003.
- ANSYS R 10.0, Academic, Structural analysis Guide, 2005.
- Giakoumelis Georgios, Lam Dennis, Axial capacity of circular concrete-filled tube columns, *Journal of Constructional Steel Research*, 2004, 60: 1049–1068.
- Gupta P.K., Sarda S.M., Kumar M.S., Experimental and computational study of concrete filled steel tubular columns under axial loads, *Journal of Constructional Steel Research*, 2007, 63: 182–193.
- Han L.H., Li Y.J., Liao F.Y., Concrete-filled double skin steel tubular (CFDST) columns subjected to long-term sustained loading, *Thin-walled structures*, 2011, 49: 1534-1543.
- Han Taek Hee, Stallings J. Michael, Kang Young Jong, Nonlinear concrete model for double-skinned composite tubular columns, *Construction and Building Materials*, 2010, 24 (12): 2542–2553.
- Iranian Code of Practice for Seismic Resistant Design of Buildings, Chapter 11, Industrial steel buildings Construction, 2007.
- Li W., Ren Q.X., Han L.H., Behaviour of tapered concrete-filled double skin steel tubular stub columns, *Thin-walled structures*, 2012, 57: 37-48.

- Niranjan B.R., Erremma H., Experimental Investigation on Reinforced Concrete Filled Steel Rectangular Fluted Columns, *International Journal of Scientific & Engineering Research*, 2012, 3(11): 645-654.
- Shah K. Darshika, Vakil M.D., Patel M.N., Parametric study of Concrete filled steel tube column, *International Journal of Engineering Development and Research*, 2014, 2(2): 1678-1682.
- Tao Zhong, Han Lin-Hai, Zhao Xiao-Ling, Behaviour of concrete filled double skin (CHS inner and CHS outer) steel tubular stub columns and beam-columns, *Journal of Constructional Steel Research*, 2004, 60: 1129–1158.

*This page intentionally left blank*

# SUPPLY CHAIN INTEGRATION ISSUES AND CHALLENGES IN INDUSTRIALISED BUILDING SYSTEM (IBS) CONSTRUCTION PROJECTS IN MALAYSIA

Wan Zukri Wan Abdullah<sup>1</sup>, Siti Rashidah Mohd Nasir<sup>2</sup>

<sup>1</sup>Faculty of Civil Engineering, Universiti Teknologi MARA (UiTM), 26400 Bandar Tun Abdul Razak Jengka, Pahang, Malaysia.

<sup>2</sup>Faculty of Civil Engineering<sup>2</sup>, Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor, Malaysia.

## Abstract

Malaysian now is as of now driving for executing an advanced development strategy, the Industrialised Building System (IBS), as an option towards improving the construction development execution particularly on site. The IBS development project delivery, includes connections between numerous associations and procedures with the advancement of numerous particular parts and roles with embedded relationships. Nonetheless, the fragmentation and adversarial relationships among the key persons in the IBS supply chain has been distinguished as the primary impediment of the IBS development project conveyance. Hence, this paper attempts to review how far breaking down in IBS supply chain can be impact on the execution of IBS undertakings progress. The main methodology adopted is literature review through articles, journals, proceedings and related research paper, followed by data analysis. From the findings, it shows that integration is the major factor to be discuss in the area of Supply Chain Management (SCM). Furthermore, the relationship, communication and contractual has been identified as the main challenges in SCM. Identifying the factors from this issue will help to increase the IBS key person's understanding to be prepared in handling the situation that they may encounter during the IBS construction progress. It will enables changes in work processes that can streamline the performance in IBS construction projects especially in terms of time and cost of the project. This paper also give the comparison of the findings from the related previous studies. Finally, the reviewed will states the possible new research fields based on the findings.

**Keywords:** *Industrial Building System (IBS), Malaysian Construction Project, Integration, Supply Chain, Project Performance.*

## INTRODUCTION

The Industrialized Building System (IBS) has been presented in Malaysia since 1966 for the projects which include precast houses. From that point forward various development undertakings utilize the IBS framework when fundamental whereby the framework is actualized when the development requires speed precision and work that includes a great deal of repetition.

Up and coming Malaysian government report, Construction Industry Master Plan (CIMP 2006-2015), the requirement for quality and execution upgrade in the Malaysia development industry was examined. CIMP recognized innovative methodologies through Industrialized Building Systems (IBS) and its supply chains as having vital parts in enhancing the profitability and nature of construction development process. Various case studies have demonstrated that dealing with the whole supply chain has turned into a noteworthy achievement component in conveying successful IBS approach (Faizul, 2006; Blismas and Wakefield, 2008), with the procurement system arrangement plan being used as a go between

tool and as the method for controlling integration between players (Gibb & Isack, 2001; Pan et al., 2008). According to Mohammad (2013), using IBS as a platform in pursuing the sustainability agenda can also be immensely rewarding because it can offer organisations and players potential benefits.

As per Faizul (2006) and Kamar et al. (2009), a great supply chain practice will prompt great integration amongst IBS players as "coordination" is the embodiment of Supply Chain Management (SCM). This better approach for working must be identified with the present pattern in the Malaysian construction development to move towards a more creative and aggressive scene. Accordingly, to understand the administration's goal in moving towards a more effective IBS development approach, great routine of supply chain integration ought to be researched and completely settled. In this manner, the point of this paper is to review the approach of supply chain integration in IBS development projects with respect to the current techniques course of action that as of now undertaken.

## **IBS IN MALAYSIAN CONSTRUCTION INDUSTRY**

The importance of IBS was highlighted under Strategic Thrust 5 of CIMP and the IBS Roadmap 2003–2010 (1st phase) and 2011–2015 that were developed to assist Malaysia in capitalizing on new technologies and IBS-related issues. A series of support mechanisms and government initiatives has been designed to educate the construction supply chains in order to improve IBS implementation and performance. The adoption of IBS in Malaysia can be tracked as early as in year 1960's. It is only becoming prominent lately, due to the rapid encouragement efforts made by the Malaysian Government.

The strategy had demonstrated to offer high quality structures, auspicious construction fulfilment and expense reserve funds through standardization, specialization and large scale manufacturing (CIDB, 2003; Thanoon and Peng, 2003). Basically, IBS can be characterized as a procedure of creating building parts in a substantial scale generation either on or off-site, transported or raised into a structure at the site with a minimum site work.

In today's worldwide scenes, the introduction of IBS as one of Malaysian development industry key pushes to the Construction Industry Master Plan (CIMP 2006–2015) ideally assist the vision and in the end add to the execution of development industry. The IBS Roadmap (2003-2010) was intended to help Malaysia advance and profit by new advances for the construction development sector. One of the methodologies taken by the Malaysian government to build the level of IBS use is by requesting more IBS ways to deal with be utilized as a part of the construction industry. These initiatives can be seen through a progression of improvement beginning from the procurement of IBS in yearly National spending plans. In the 2005 financial plan, arrangements were illustrated to give full exclusion of duty forced by CIDB for housing projects undertakings with IBS usage more than 50 percent. In the 2006 financial plan, IBS manufacturers were given Accelerated Capital Expenditure with a development time of three years on moulds. At that point, in the Ninth Malaysian Plan Report and Treasury Circular, public projects undertakings must receive or contain up to 70% of IBS construction approach in its projects. This is further improved by the foundation of National IBS Secretariat as the Coordinator through the Ministry of Works and an IBS Centre as the One Stop Centre.

IBS is a manufacturing process that needs prior and predictable arranging procedure amongst the players involved (Gibb, 2001). Therefore, the significance of enhancing the coordination of the supply chain in IBS execution, its difficulties ought to be broken down and set up keeping in mind the end goal to induce the construction business to take part in a more precise and strategic approach in IBS construction development, particularly in instances of fragmented supply chains. Moreover, as indicated by Mohd Nasrun et al. (2012), the greater part of the IBS projects conveyances still apply the conventional method which is taking into account the fracture approach that was recognized as one of the fundamental boundaries to receiving Industrialized Building System (IBS) in the Malaysian development industry.

## **SUPPLY CHAIN INTEGRATION ISSUES IN MALAYSIA**

Indeed, even with much support and headings in Malaysia, the use of IBS is at present much lower than it could be. These issues show that in spite of the fact that since a long time ago introduced IBS has guaranteed with enhance the present construction process, these practices have typically been confronting a difficult undertaking to set up coordination and participation between parties involved (Faizul, 2006; CIDB, 2007).

Abd Shukor et al. (2009) conducted research to recognize the key issues in the construction business in general and IBS specifically. They ordered conceivable issues into 16 critical topics and revealed that both the business and the IBS players had not been exceptionally effective in their attempts to locate the right answers for the difficulties experienced whilst indicating that the supply chain and procurement to be the base of most issues. The same issues apply to the "Design" stage and among the noticeable issues experienced were the absence of coordination in configuration administration among planners (architects) and engineers, lack of resources and budget limitations. CIMB highlighted poor information and newness to IBS ideas and its advantages as one of the elements obstructing joining among IBS players (CIDB, 2007).

Among the difficulties experienced were correspondence as far as stream of data, traditional outlooks, and issues as far as coordination between different works environment and financing variables which incorporates issues in the process of payments. Abd Shukor et al. (2009) likewise uncovered that there is a scope of procurement stages that shows noticeable issues which make it hard to incorporate individuals.

With the end goal IBS should succeed, construction experts ought to support and comprehend the construction and product conveyance of IBS. Absence of coordination and integration among pertinent players in the design stage has brought about the requirement for arrangement upgrading and extra expenses acquired if IBS is adopted. The disintegration happens in light of the fact that IBS manufacturers are involved strictly when the design stage completed (CIDB, 2007). Accordingly, the difficulties of joining amongst the IBS chain players should be surveyed in connection to the working practices in the present task procurement delivery arrangements approach with a specific end goal to guarantee helpful working connections that will prompt supply chain excellence

## **METHODOLOGY**

There are two main stages to go through in order to produce this paper to gather reliable and relevant data. The approaches are literature review and data analysis.

### **Literature Review**

The first step of getting the information based on the related topic is by reviewing some journals, papers, proceedings and articles from the year 1998 to 2014. This can be done either by electronic or printed copy in proceedings. There are few journals has been reviewed such as Journal in Science and Technology, Journal in Business & Logistics and European Journal of Purchasing & Supply Management. This is the important part and resourceful information that can be obtained to gain understanding of the study. A literature review can be a simple summary of the sources. It might give a new interpretation of old material or combine new with old interpretations. Moreover, it might trace the intellectual progression of the field, including major debates. The literature review may evaluate the sources and advise the reader on the most pertinent or relevant.

### **Data Analysis**

This is the process of systematically applying statistical and/or logical techniques to describe and illustrate, condense and recap, and evaluate data. According to Shamoo and Resnik (2003), various analytic procedures "give a method for drawing inductive derivations from information and recognizing the sign (the phenomenon of interest) from the commotion (statistical fluctuations) present in the data". Result from the findings will be presented in the form of graphs and assume that important to the information data for less demanding comprehension.

## **FINDINGS AND DISCUSSION**

In this part, the findings are divided into two main discussion area which are 'Integration' and 'Supply Chain Management' (SCM). Then, it will be combined together to describe more detail on the challenges factors in SCM.

### **Definition of Supply Chain Management (SCM)**

The term of SCM is the most important to be distinguished to favour that the "integration" is the principle variable for the effective in SCM. The term was created in the 1980s, to express the need to coordinate key business forms, from end-user through the first suppliers. For the most part, the SCM expression mirrors the procedure of arranging, executing, and controlling the operations of the supply chain to be as productively as could reasonably be expected. SCM additionally is the oversight of materials, data, and funds as they move in a procedure from supplier to maker to wholesaler to retailer to customer. It includes organizing and incorporating these streams both inside and among organizations. There are couple of meanings of SCM from the past researchers as given in Table 1.

**Table 1.** Definitions of SCM

Sources	Definition
Koskela & Vrijhoef, 1999	"A concept that has flourished in manufacturing, originating from Just-In-Time (JIT) production and logistics"
Lambert & Cooper, 2000	"Management of multiple relationships, which deals with total business process excellence and represents a new way of managing the business and relationships with other members"
Mentzer et al., 2001	"SCM is defined as the systematic, strategic coordination of the traditional business functions and tactics across these business functions within a particular company and across businesses within the supply chain, for the purpose of improving the long-term performance of the individual companies and the supply chain as a whole"
Nelson, 2003	"complex network or system of interconnected and interdependent individuals, groups, companies, organisations and relationships whose goal is to satisfy and add value to their particular customer."
Udin, Z., Mohammad K.K., 2006	"spans all movement and storage of raw materials, work-in process inventory, and finished goods from point-of-origin to point-of-consumption"
Tarokh & Soroor, 2006	"the integration of key business processes from end user through original suppliers that provides products, services and information that add value for customers and other stakeholders"
Abd Shukor et al., 2009	"an integrated and collaborated supply chains whether upstream or downstream, inter or intra-organization with the same goals and objectives for long term relationship integration"

In light of couple of meanings of SCM in Table 1, it can be reason that supply chains in construction are numerous and varied. A key word and fundamental guideline of SCM is "relationship" which implies that there must be an "integration" which is the most vital between numerous associations and procedures with the advancement of numerous specific parts and embedded relationships. There is a need in dealing with a viable supply chain in conveying successful IBS approach with the acquirement strategy plan being used as a mediator tool and as the method for controlling integration between the IBS key players. A decent supply chain integration practice will prompt great combination amongst the association as "incorporation" is the substance of SCM. This better approach for working must be identified with the present pattern in the Malaysian construction development to move towards a more creative and focused scene.

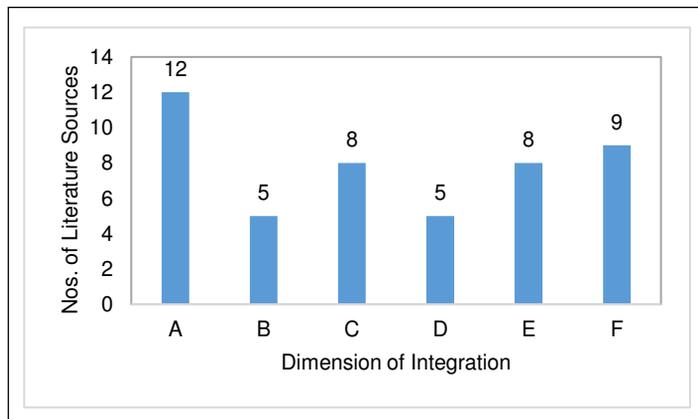
## Integration

From 16 literature sources, the dimensions of integration are summarized in Figure 1 based on the data from Table 2. It obviously demonstrates that the most elevated measurement is 'Single Team Focus, and Objectives' which implies that there must be a compelling of collaboration and coordination of one another to accomplish the execution of IBS construction with the particular time focus by the association itself. This is upheld by Dulaimi et al. (2002) which found that non-coordinated effort and co-appointment between the parties involved in construction likewise can prompt to conflict and has a negative effect on the nature of the design process and design outcome. Moreover, IBS construction empowers early inclusion from contractors, expert subcontractors and manufacturers to accomplish the agreed objective and goal through a collaboration (Wilson et al., 1998).

**Table 2.** Literature Based Analysis of Dimensions of Integration

	Author	Dimensions of Integration					
		A. Single team focus, and objectives	B. Seamless operation with no organizationally defined boundaries	C. Unrestricted cross-sharing of information	D. Creation of a single co-located team	E. Equitable team realtionships, equal opportunities and respect for all	F. 'No blame culture'
<b>Literature Review</b>	Love et al. (2004)		X			X	
	Strategic forum for construction (2003)	X	X		X		X
	Baiden et al. (2003)	X	X	X		X	X
	Bromley et al. (2003)	X	X	X	X		X
	Anumbia et al. (2002)	X			X		
	Dainty et al. (2001)					X	X
	Moore and Dainty (1999)	X		X	X		X
	Vyse (2001)	X	X	X		X	X
	Cornick and Mather (1999)	X		X			
	Evbuomwan and Anumbia (1998)			X			X
	Love and Gunasekaran (1998)	X					
	BuildOffsite (2008)			X			
	Austin et al. (2002)	X			X	X	
	Holland et al. (2002)	X				X	X
	Kim and Kang (2008)	X		X		X	
	Koutsikouri (2008)	X				X	X

(Source: Mohd Nasrun et al., 2012)



**Figure 1.** Analysis of Dimension of Integration Based on Literature Sources

## Challenges in Supply Chain Integration

The difficulties of incorporation between the Client and the main contractor in IBS project procurement delivery should be evaluated in connection to the working practices in the present project procurement delivery arrangements approach to deal with guarantee helpful working connections that will prompt supply chain greatness. The difficulties of integration supply chain found in the literature review are outlined in Table 3.

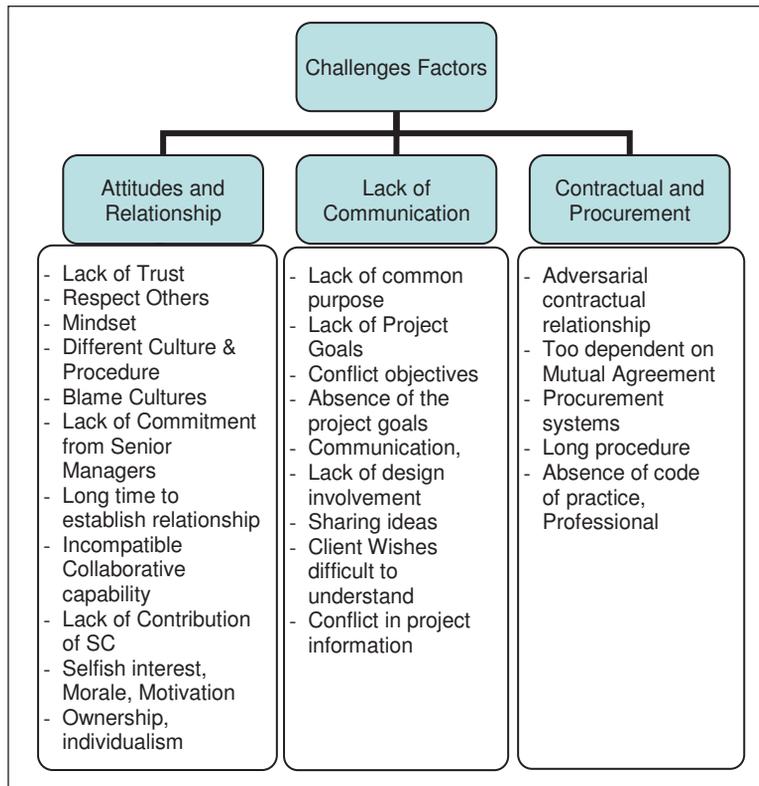
**Table 3. Challenges in Supply Chain Integration**

Challenges	References
Lack of Trust, Mutual Suspicion, Hidden Agenda, Respect Others, Lack of common purpose, Lack of Project Goals, conflict objectives, Absence of the project goals	Wilding & Humpries (2009); Ward & Holti (2006); Olsson (2000); Ahmed et al. (2002); Saad et al. (2002); Jone & Saad (2003); Wong et al. (2004); Benton & Mchenry (2010); Olsson (2000)
Different Culture & Procedure, Mindset, Blame culture, resist Innovation, Resist change, Traditional role thinking	Akintoye et al. (2000); Awad & Nassar (2010); Matipa & Siamuzme (2005); Ahmed et al. (2002); Saad et al. (2002); Jone & Saad (2003); Wong et al. (2004); Benton & Mchenry (2010); Ward & Holti (2006); Olsson (2000); Nicolini et al.(2001); Shelbourn et al.(2007); Ahmed et al (2002)
Lack of Commitment from seniors managers, Project Manager Planning	Akintoye et al (2000); Brown (1999); Suhol & Peter (2004)
Adversarial contractual relationship, Long time to establish relationship, Lack of guidance creating alliances, Incompatible Collaborative capability, Too dependent on Mutual Agreement	Jone & Saad (2003); Wong et al. (2004); Benton & Mchenry (2010); Brown (1999); Matipa & Siamuzme (2005); Wilding & Humpries (2009); Saad et al. (2002)
Power imbalance	Saad et al. (2002)
Communication, Sharing ideas, Lack of openness and opportunistic behaviour, Lack of Open book	Akintoye et al (2000); Wilding & Humpries (2009); Saad et al. (2002); Shelbourn et al.(2007); Saad et al. (2002)
Procurement systems	Jone & Saad (2003); Wong et al. (2004); Benton & Mchenry (2010); Matipa & Siamuzwe (2005); Furgues & Koskela (2009); Dainty et al. (2001); Nicolini et al. (2001)
Lack of Contribution of SC (Ignorance of SC)	Jone & Saad (2003); Wong et al. (2004); Benton & Mchenry (2010)
Client Wishes difficult to understand, Client lack of roles, Long procedure, Client responsibility	Matipa & Siamuzwe (2005)
Conflict in project information	(Li, Guo, Skibniewski, & Skitmore, 2008); Ahmed et al (2002); Suhol & Peter (2004)
Lack of design involvement	(Forgues & Koskela, 2009)
Absence of code of practice, Professional indemnity	Nicolini et al. (2001)
Selfish interest, Morale & Motivation, Ownership, individualism	Furgues & Koskela (2009); (Shelbourn, Bouchlaghem, Anumba, & Carrillo, 2007); Suhol & Peter (2004); Saad et al. (2002); Krisilia et al (2007)

(Source: Mohammad Fadhil et al., 2014)

Based on the literature review and the comparison stated in Table 3 according to the management of supply chain integration in IBS projects, clearly shown that it is difficult and

obliges diligent work and spotlight on both the organizations inside procedures and the relationships that the IBS key persons need to convey one another. In any case, when our IBS projects supply chain is successfully incorporated, the prizes can be great. In the worldwide economy, with supply chain going up against supply chain, integration turns out to be considerably more essential to our construction industry. Mohammad Fadhil et al., 2014 stated eight challenges in Supply Chain Integration in their case study; Attitudes and Relationship, Communication and Information, Contractual and Procurement, Finance, Guidelines and Requirements, Technical and Risk & Conflict Liability. Based on the data from Table 3, three (3) main Challenges Factors and the parameters for each can be summarized as in Figure 2.



**Figure 2.** Three Main Challenges Factors in SCM

### ***Attitude and relationship***

The necessity of attitude and relationship is important due to long-term integration, commitment, respect and responsibility among team members. Generally, attitude of the clients was criticized by the main contractor as one of the factors that challenge the integration between IBS supply chains. In current practice, the customer's pride and presumption taking into account their part as owner of the project undertaking. In this manner, there is no appreciation, understanding and responsibility amongst IBS players. The clients were unwilling to change their old outlooks and declined to change from the traditional procedure. This is supported by Kamar et al., 2010 who uncovered that there is a discriminating need to deal with the design and manufacturing uniquely in contrast to the customary route as IBS is diverse and needs an alternate mindset and attitude alongside the right environment.

### **Lack of Communication**

The findings demonstrated that there were issues in correspondence and data information. A large portion of the findings highlighted that correspondence issues shape an essential piece of the difficulties they confront in the IBS construction supply chain. For instance, miscommunication and question in the middle of clients and contractor under design and execution gave impacts on the nature of correspondence and data and subsequently, influences their integration. Antagonistic vibe between individuals from the projects causes issues emerging from the resistance between the contractor and consultant. This is supported by Briscoe and Dainty, 2005, creating effective correspondence all through the levels of the supply chain will guarantee prevalent and dependable stream of data. This is likewise supported by Hong-Minh et al., 2001 which expressed that the present condition of the supply chain is supported by poor correspondence, unfavourable relationships and lack of trust and commitment.

### **Contractual and Procurement**

According to Mohammad et al., 2014, the principle issue is the clients guaranteed some of them don't generally follow the agreement. This is on the grounds that they think it is excessively muddled and make their work more difficult. Conversely, the main contractors specified the difficulties understanding the client's targets and needs at the early stages. This is supported by Love et al., 1998 who expressed that the client must be clear of their destinations and particular needs as to guarantee the accomplishment of the procurement technique. Moreover, as indicated by them, the remaining utilization of conventional obtainment rehearses that do not encourage incorporation of the parties involved has prompted poor execution.

## **CONCLUSION AND FURTHER RESEARCH**

This paper has briefly reviewed the IBS principles and supply chain practices in our Malaysian construction industry. There are various advantages and drivers in IBS, on the other hand, it likewise raises challenges that should be overcome, for example, the absence of integration and fellowship among parties, early contribution of manufacturers and absence of knowledge and ability. This review findings that more broad observational exploration these regions is required, particularly in the achievement and hindrances variables of coordinating the supply chain players with the fitting courses of action of procurement method and strategy. This better approach for administration and working must be connected and be in line to the Malaysian construction industry current pattern particularly in IBS.

Finally, the study presented in this paper is a preliminary literature and is a part of an ongoing PhD research, which will eventually attempt to further enhance the practices and implementation of the Supply Chain Integration in relation to procurement systems, particularly in the IBS project delivery in Malaysia. The results of the main research will hopefully provide and form the basis of a valuable integration in order to support the Malaysian Construction Industry Master Plan and strengthen the value chain in the Malaysian construction industry. Future empirical studies regarding to this issue should extensively focus on the integration of supply chain, lean construction, just in time principal, readiness of

industry to adopt an effective SCM, and partnering issue in SCM. There are few suggestions or more focussing that can be adopted into further study or research:

1. Each key person/ IBS players role and responsibility in offsite project particularly into the issue of design integration process.
2. Development of an effective method for the client project briefing at the beginning of offsite project to include the issue of lack of integration during design, construction and manufacturing stages.
3. Development of Integration Framework for SCM in IBS construction projects.
4. Development of SCM Monitoring System that can describe the link of each IBS project activities involve within the affecting factor.

## ACKNOWLEDGMENT

The authors would like to thank the Malaysian Construction Research Journal (MCRJ) committee and the reviewers for their suggestions, opinions and invaluable comments on this paper.

## REFERENCES

- Abd Shukor, Saifuza, A. and Mohammad, M. Fadhil, Mahbub, Rohana, Ismail, Faridah, & Halil, F. (2009) 'The implementation of supply chain management in the Malaysian construction industry', in *International Conference on Construction and Real Estate Management (ICCREAM 2009)*.
- Blismas, N. and Wakefield, R. (2008) 'Offsite manufacture in Australia: barriers and opportunities.'
- Briscoe, G. H., & Dainty, A. R. J. (2005) 'Construction supply chain integration: an elusive goal?', *Supply Chain Management: An International Journal*, 10(4), pp. 319–326.
- CIDB (2007) 'Construction Industry Master Plan (CIMP 2006-2010)'.
- CIDB, I. (2003) 'Roadmap 2003–2010', *CIDB Malaysia*.
- Dulaimi, M.F.; Ling, F.Y.Y., Ofori, G.; and Silva, N. D. (2002) 'Enhancing integration and innovation in construction', *Building Research & Information*, 30(4), pp. 237–247.
- Faizul, N. (2006) 'Supply chain management in IBS industry', *Malaysia International IBS Exhibition, Kuala Lumpur*.
- Gibb, A. (2001) 'Standardization and pre-assembly-distinguishing myth from reality using case study research', *Construction Management & Economics*.
- Gibb, A. and Isack, F. (2001) 'Client drivers for construction projects: implications for standardization', *Engineering Construction and Architectural Management*, 8(1), pp. 46–58.
- Hong-Minh, S. ., Barker, R. and Naim, M. . (2001) 'Identifying supply chain solutions in the UK house building sector', *European Journal of Purchasing & Supply Management*, 7(1), pp. 49–59. doi: 10.1016/S0969-7012(00)00009-5.
- Kamar, Kamarul Anuar Mohamad, Hamid, Zuhairi Abd, Ghani, Mohd Khairolden, Zin, M. Z. M., Rahim, Ahmad Hazim, & K. and A., A. Z. (2010) 'The critical success factors for the implementation of industrialised building in Malaysia', *3rd IBS Roundtable Workshop (IRW03)-CIDB/CREAM IBS Survey*.
- Kamar, K., Alshawi, M. and Hamid, Z. (2009) 'Industrialised building system: the critical success factors', *9th International Postgraduate Research Conference (IPGRC 2009)*.

- Koskela, L. and Vrijhoef, R. (1999) 'Roles of supply chain management in construction', *Proc. 7th Annual Int'l Conf. Group for Lean Construction*.
- Lambert, D. and Cooper, M. (2000) 'Issues in supply chain management', *Industrial marketing management*, 29(1), pp. 65–83.
- Love, Peter E. D., Skitmore, M., & Earl, G. (1998) 'Selecting a suitable procurement method for a building project', *Construction Management and Economics*, 16, pp. 221–222.
- Mentzer, J., DeWitt, W. and Keebler, J. (2001) 'Defining supply chain management', *Journal of Business Logistics*, 22(2), pp. 1–25.
- Mohammad, M. (2013) 'Construction Environment: Adopting IBS Construction Approach towards Achieving Sustainable Development', in *AcE-Bs 2013 Hanoi, Hanoi Architectural University, Hanoi, Vietnam*. AcE-Bs 2013 Hanoi, Hanoi Architectural University, Hanoi, Vietnam.
- Mohammad, M. F., Shukor, A. S. A., Mahbub, R. and Halil, F. M. (2014) 'Challenges in the Integration of Supply Chains in IBS Project Environment in Malaysia', *Procedia - Social and Behavioral Sciences*, 153, pp. 44–54. doi: 10.1016/j.sbspro.2014.10.039.
- Mohd Nasrun Mohd Nawi, Angela Lee, K. A. M. K. and Z. A. H. (2012) 'Critical Literature Review on the Concept of Team Integration in Industrialised Building System (IBS)', *Construction Project, Malaysian Construction Research Journal, ISSN 1985 -3807*, 9(1).
- Nelson, M. (2003) 'The Applicability of the Integrate to Innovate (i2i) model in Supply Chain Management (SCM) in Facilities Management (FM)'.
- Pan, W., Gibb, A. and Dainty, A. (2008) 'Leading UK housebuilders' utilization of offsite construction methods', *Building Research & Information*.
- Shamoo, A. and Resnik, D. (2003) *Responsible conduct of research*.
- Tarokh, M. and Soroor, J. (2006) 'Developing the next generation of the web and employing its potentials for coordinating the supply chain processes in a mobile real-time manner', *International Journal of Information Technology*, 12(8).
- Thanoon, W. and Peng, L. (2003) 'The Experiences of Malaysia and other countries in industrialised building system', *International Conference on Industrialised Building Systems, Kuala Lumpur, Malaysia*.
- Udin, Z., Mohammad K.K., and M. Z. (2006) 'A collaborative supply chain Management', *Business Process Management Journal*, 12(3), pp. 361–376.
- Wilson, D., Smith, M. and Deal, J. (1998) 'Prefabrication and preassembly: Applying the techniques to building engineering services'.
- Wilson, D. G., Smith, M.H. and Deal, J. (1998). *Prefabrication and Preassembly: Applying the Techniques to Building Engineering Services*, Building Services Research and Information Association, Bracknell, England.

*This page intentionally left blank*

# GUIDE TO AUTHORS

## Aims and Scope:

The Malaysian Construction Research Journal (MCRJ) is the journal dedicated to the documentation of R&D achievements and technological development relevant to the construction industry within Malaysia and elsewhere in the world. It is a collation of research papers and other academic publications produced by researchers, practitioners, industrialists, academicians, and all those involved in the construction industry. The papers cover a wide spectrum encompassing building technology, materials science, information technology, environment, quality, economics and many relevant disciplines that can contribute to the enhancement of knowledge in the construction field. The MCRJ aspire to become the premier communication media amongst knowledge professionals in the construction industry and shall hopefully, breach the knowledge gap currently prevalent between and amongst the knowledge producers and the construction practitioners.

Articles submitted will be reviewed and accepted on the understanding that they have not been published elsewhere. The authors have to fill the Declaration of the Authors form and return the form via fax to the secretariat. The length of articles should be between 3,500 and 8,000 words or approximately 8 – 15 printed pages (final version). The manuscripts should be written in English. The original manuscript should be typed one sided, single-spacing, single column with font of 11 point (Times New Roman). Paper size should be of Executive (18.42 cm x 26.67 cm) with 2 cm margins on the left, right and bottom and 3 cm for the top. Authors can submit the manuscript:

- By e-mail to maria@cidb.gov.my / hazim@cidb.gov.my / foo@cidb.gov.my
- By hardcopy and softcopy in Microsoft-Word format to MCRJ Secretariat:

**Malaysian Construction Research Journal (MCRJ)**  
Construction Research Institute of Malaysia (CREAM)  
MAKMAL KERJA RAYA MALAYSIA  
1<sup>st</sup> Floor, Block E, Lot 8,  
Jalan Chan Sow Lin, 55200 Kuala Lumpur  
MALAYSIA

Tel. : (6)03 – 9281 0800  
Fax : (6)03 – 9282 4800  
Website : [www.cream.my](http://www.cream.my)

**Type of fonts:** All text, drawing, graph must be written using Times New Roman

**Language:** Follow the spelling of the Oxford English Dictionary.

**Size/Page Setup:** Executive (18.42 cm x 26.67 cm)

**Paper title:** Arial, 16.

## CODIFICATION AND APPLICATION OF SEMI-LOOF ELEMENTS FOR COMPLEX STRUCTURES

**Author's name** (full name): Arial, 9pt. should follow below the title.

**Jamalodin Noorzaei<sup>1</sup>, Mohd. Saleh Jaafar, Abdul Waleed Thanoon, Wong Jern Nee**

**Affiliation** (including post codes): Arial, 9pt. Use numbers to indicate affiliations.

*<sup>1</sup>Department of Civil Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia*

**Abstract:** Arial Bold, 9pt. Left and right indent 0.64 cm.

**Abstract:** it should be single paragraph of about 100 – 250 words.

**Keywords:** Times New Roman Bold, 9pt (Italic). Left and right indent 0.64 cm.

**Keywords:** *Cooling tower; Finite element code; Folded plate; Semiloof shell; Semiloof beam*

Body Text: Times New Roman, 11 pt. All paragraph must be differentiate by 0.64 cm tab.

Heading 1: Arial Bold + Upper Case, 11pt.

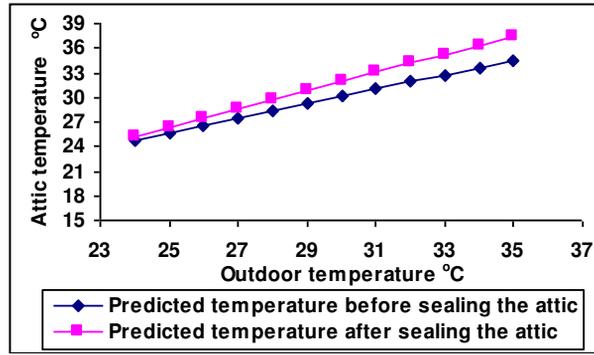
Heading 2: Arial Bold + Lower Case, 11pt.

Heading 3: Arial Italic + Lower Case, 11pt.

**Units:** All units and abbreviations of dimensions should conform to SI standards.

**Figures:** Figures should be in box with line width 0.5pt. All illustrations and photographs must be numbered consecutively as it appears in the text and accompanied with appropriate captions below them.

**Figures caption:** Arial Bold + Arial, 9pt. should be written below the figures.



**Figure 8.** Computed attic temperature with sealed and ventilated attic

**Tables:** Arial, 8pt. Table should be incorporated in the text.

**Table caption:** Arial Bold + Arial, 9pt. Caption should be written above the table.

**Table Line:** 0.5pt.

**Table 1.** Recommended/Acceptable Physical water quality criteria

Parameter	Raw Water Quality	Drinking Water Quality
Total coliform (MPN/100ml)	500	0
Turbidity (NTU)	1000	5
Color (Hazen)	300	15
pH	5.5-9.0	6.5-9.0

(Source: Twort et al. 1985; MWA,1994)

**Reference:** Times New Roman, 11pt. Left indent 0.64 cm, first line left indent – 0.64 cm. Reference should be cited in the text as follows: “Berdahl and Bretz (1997) found...” or “(Bower et al. 1998)”. References should be listed in alphabetical order, on separate sheets from the text. In the list of References, the titles of periodicals should be given in full, while for books should state the title, place of publication, name of publisher, and indication of edition.

**Journal**

Sze, K. Y. (1994) Simple Semi-Loof Element for Analysing Folded-Plate Structures. *Journal of Engineering Mechanics*, 120(1):120-134.

**Books**

Skumatz, L. A. (1993) Variable Rate for Municipal Solid Waste: Implementation, Experience, Economics and Legislation. Los Angeles: Reason Foundation, 157 pp.

**Thesis**

Wong, A. H. H. (1993) *Susceptibility To Soft Rot Decay In Copper-Chrome-Arsenic Treated and Untreated Malaysian Hardwoods*. Ph.D. Thesis, University of Oxford. 341 pp.

**Chapter in book**

Johan, R. (1999) Fire Management Plan For The Peat Swamp Forest Reserve Of North Selangor and Pahang. In Chin T.Y. and Havmoller, P. (eds) *Sustainable Management of Peat Swamp Forests in Peninsular Malaysia* Vol II: Impacts. Kuala Lumpur: Forestry Department Malaysia, 81-147.

**Proceedings**

Siti Hawa, H., Yong, C. B. and Wan Hamidon W. B. (2004) Butt Joint In Dry Board As Crack Arrester. *Proceeding of 22<sup>nd</sup> Conference of ASEAN Federation of Engineering Organisation (CAFEO 22)*. Myanmar, 55-64.



## Contents

Editorial Advisory Board

Editorial

**ADOPTION OF INDUSTRIALISED BUILDING SYSTEM (IBS):  
EXPLORING COMPETITIVE ADVANTAGES FROM A  
TECHNOLOGY VALUATION PERSPECTIVE IN NORTHERN  
MALAYSIA**

Sharifah Akmam Syed Zakaria, Taksiah A. Majid and Fadzli Mohamed Nazri

**APPLICATION OF MODIFIED DELPHI IN IDENTIFYING THE  
PRESENCE OF INCOMPLETE CONTRACT (IC) IN PRIVATE  
FINANCE INITIATIVE (PFI) PROJECTS**

Nur Syaimasyaza Mansor, Khairuddin Abdul Rashid, Mohd. Fairullazi Ayob and  
Sharina Farihah Hassan

**COMPETENCY AND COMMITMENT OF FACILITIES MANAGERS:  
KEYS TO SAFEGUARD MAINTENANCE PERFORMANCE**

Cheong Peng Au-Yong, Azlan Shah Ali and Faizah Ahmad

**INFLUENCE OF COIR RANDOM FIBRE LENGTH ON CONCRETE:  
MECHANICAL PROPERTIES**

Noor Aina Misnon, Siti Khadijah Che Osmi, Nawawi Chouw and Shahiron  
Shahidan

**THE EFFECTIVE PARAMETERS ON THE BEHAVIOR OF CFDST  
COLUMNS**

E. Farajpourbonab, S. Kute and V.M. Inamdar

**SUPPLY CHAIN INTEGRATION ISSUES AND CHALLENGES IN  
INDUSTRIALISED BUILDING SYSTEM (IBS) CONSTRUCTION  
PROJECTS IN MALAYSIA**

Wan Zukri Wan Abdullah and Siti Rashidah Mohd Nasir

ISSN 1985-3807



9 771985 380005