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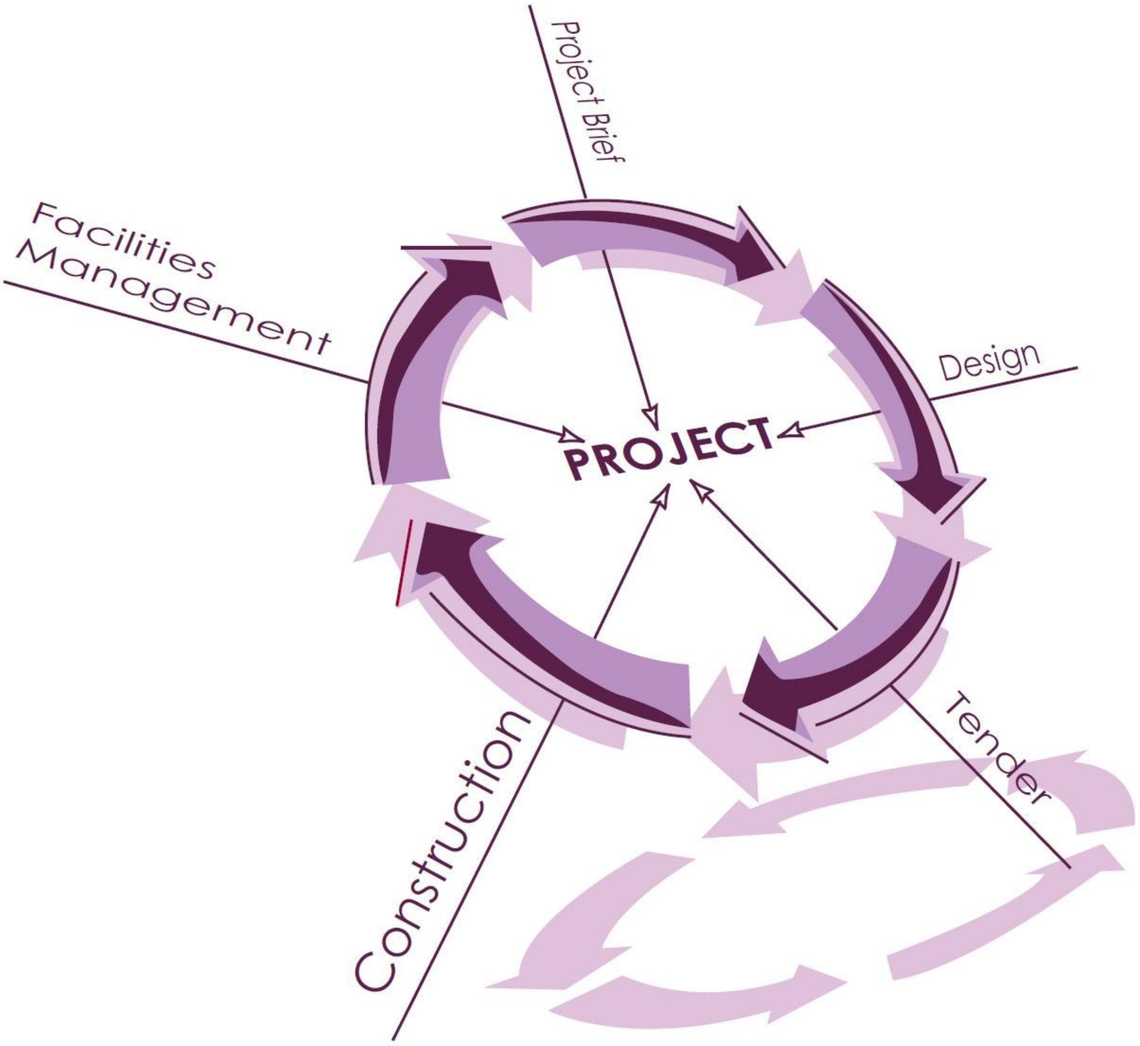

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Editorial Advisory Board

Editorial

Welcome from the Editors

Welcome to the fifteenth issue of Malaysian Construction Research Journal (MCRJ). The editorial team would like to extend our sincere gratitude to all contributing authors and reviewers for their contributions and continuous support to MCRJ. It is hope that the readers will find beneficial information from this edition of this journal. A total of 6 papers published in this issue which mostly will discuss on the Building Information Modelling (BIM) in construction.

The first paper by ***Mohd Harris, et.al.*** proposes the way forward for BIM for contractors in Malaysia. They investigate the barriers, potential solutions and benefits of implementing BIM for contractors in Malaysia. The study revealed that some organisations resist change or are still not ready to adopt BIM as a tool in their projects. This paper offers practical recommendations on the two main issues; i.e. people and technology needed to be addressed, besides the continuous government support programs and serious enforcement policies and regulations which are inevitable.

The next paper by ***Mohd Faizal Omar, et. al.*** looks into the requirement of decision support system for BIM software selection. With a number of BIM related software available in the market today, the authors presented ways to aid the decision making in choosing the appropriate software. The paper also demonstrates on how to improve the development of Decision Support System (DSS) for BIM software selection as it is vital to increase productivity, construction project throughout building lifecycle.

In their paper, ***Mohd Nasrun Mohd Nawi, et.al.*** explore the way to improve integrated practice through Building Information Modelling-Integrated Project Delivery (BIM-IPD) for Malaysian Industrialized Building System (IBS) construction project. Current studies shows that most of IBS project procurement or delivery methods in Malaysia are still based on the traditional approach which is fragmented and its failure to form effective teams thus creating issues such as reworks, time delay, rising costs, lack of communication and coordination, and wastages. This paper aims to explore this fragmentation issue and suggests an integrated approach such as BIM and IPD to contribute for design and construction process in order to minimise the fragmentation issue.

Mohd Khairolden Ghani, et. al. presents a case study on enhancing service delivery in Facility Management for Malaysian healthcare facilities directorate. The paper investigates hospital operational FM activities and proposes the Directorate Activity Hierarchy Diagram in Malaysian healthcare as a strategic system planning framework for FM.

Norsuzailina Mohamed Sutan, et. al. investigate the pozzolanic reaction of nanosilica binder composites (nSBC) through the characterization of the morphology of Calcium Silicate Hydrate (C-S-H) and Calcium Hydroxide (CH) using Fourier Transform Infrared Spectroscopy (FT-IR), X-Ray Diffraction Technique (XRD), Scanning Electron Microscopy

(SEM) and Energy Dispersive X-ray Spectroscopy (EDS). The characterization techniques used in their studies were able to give satisfactory qualitative indication of pozzolanic reactivity of nSBC by the presence and absence of C-S-H and CH.

Nor Hayati Abdul Hamid, et.al. presents their experimental results on seismic behavious of precast shear key wall under in-plane lateral cyclic loading. A full-scale of single bay double-storey house was constructed using precast shear key wall panel and cast-in-situ concrete for column, floor slab and foundation beam. This building is designed using British Standard (BS8110) which did not have any provision for seismic loading and no specific detailing connections at its joint. The aim of this study is to determine the global seismic behaviour of non-ductile double-storey house under quasi-static lateral cyclic loading.

Editorial Committee

THE WAY FORWARD FOR BUILDING INFORMATION MODELLING (BIM) FOR CONTRACTORS IN MALAYSIA

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Abstract
Implementation of Building Information Modelling (BIM) in the Malaysian Architectural, Engineering, and Construction (AEC) industry is a methodology of practice that aims at shifting ways of thinking and working processes. This paper seeks to investigate the barriers, potential solutions and benefits of implementing BIM for contractors in Malaysia. The data to support this research was gathered from through a collaborative workshop between the Construction Industry Development Board (CIDB), Malaysia and Universiti Teknologi MARA (UiTM), conducted in June 2013 to assess the barriers, potential solutions and benefits of BIM implementation in Malaysia, specifically among contractors. The findings of this research highlighted 61 issues raised by the participants during the workshop. Additionally, the study revealed that some organisations resist change or are still not ready to adopt BIM as a tool in their projects. This paper offers practical recommendations on the two main issues; i.e. people and technology needed to be addressed, besides the continuous government support programs and serious enforcement policies and regulations which are inevitable.

Keywords: *Building Information Modelling; BIM; Barriers, Solutions, Benefits; Contractor; Malaysia*

INTRODUCTION

The construction industry in Malaysia contributes approximately 3-5% to the Gross Domestic Product (GDP) annually. This in turn provides employment for about 10% of the total labour force (CIDB, 2009). Despite having strong support from the government, the construction industry is facing serious difficulty particularly in its excessive dependence on foreign workers who are said to be unskilled and lacking in innovation (ibid). As such, the industry has suffered a 20 per cent decline in performance as compared to other industries. This could be attributed to the lack of information sharing, inefficiency in adopting new techniques for project implementation and loss of process continuity (JBIM, 2007). For that matter, the deployment of computer-based technology in construction, particularly Building Information Modelling (BIM), is described by many researchers and practitioners as a new IT tool that could serve as a solution to a number of inefficiencies in the construction environment (Muafi et.al. 2012).

BIM is the methodology of practice which carries the philosophical stand based on the availability of information. It is now increasingly used as an emerging technology to assist in conceiving, designing, construction and operating buildings in many countries (Wong et.al. 2009). BIM is an information-rich, model-centric process that provides an integrated solution to transform project delivery and add value across the project life cycle. Despite the industry's awareness of the potential of BIM, AEC industries in Malaysia are yet to utilise it, particularly the contractors. Similarly, the UK construction sector is also facing slow progressive changes in BIM implementation (Khosrowshahi and Arayici, 2012). This is an exploratory study that attempts to provide preliminary evidence on the implementation of BIM in Malaysia. The core contribution of this research is to investigate the barriers, potential solutions and benefits of implementing BIM for contractors in Malaysia. The paper begins with a review of previous studies on the implementation of BIM. The remainder of the paper discusses the problem statement, methodology, findings and conclusion.

IMPLEMENTATION OF BUILDING INFORMATION MODELLING

Building Information Modelling (BIM) represents the process of development and use of a computer generated model to simulate the planning, design, construction and operation of a facility (Azhar, et al. 2008). According to them BIM is a data-rich, object oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analysed to generate information for the decision making process.

BIM is a technology that allows users to create visual simulation of a project and to provide a digital prototype of a building prior to construction (Weygand, 2011). Indeed, it is a system developed to integrate all aspects of construction processes to serve business requirements. This is in contrast with the traditional 2D CAD which comprises graphical entities (i.e., lines, arcs and circles) that causes poor documentation. According to Kymmell (2008) and Taylor and Bernstein (2008), visualization is one of the benefits to be gained through BIM. The visualization process could assist the project stakeholders in gaining better understanding of the intended construction through a detailed 3D view. For instance, through the 3D parametric modelling of BIM, architects and structural engineers could resolve the 'clash detection' disputes more accurately compared to the traditional method. Conversely, the traditional clash detection in 2D drawings will require resources and excessive time to visualise and resolve. In addition, BIM could assist quantity surveyors to generate efficient cost estimates with up to a 80% reduction in time taken, cost estimation accuracy within 3% and a saving of 10% of the contract value through clash detection (Azhar et. al. 2008). Besides, BIM can also be utilised to analyse and configure site planning and logistics such as location of machineries and temporary access points (Khanzode et. al. 2008). BIM is capable to simulate and analyze the sequence of construction activities to reduce project time up to 7% (Azhar et.al. 2008). In fact, the most contribution of BIM is during the maintenance and operation phase wherein all information gained across project phases (i.e., drawings, procurement, construction and completion phases) are used as input factors to as-built information which will facilitate owners to maintain their assets accurately. Besides, according to Howard and Bo-Christer (2008) and Lee (2013), almost 2% benefits of BIMs are achievable during the construction phase. Although this seems low, the monetary quantum could be substantial for multi-million projects (Lee, 2013).

While more benefits of BIM would accrue over the lifetime of a building, there is presumption that BIM will result in higher initial costs and does not appear to be serving the needs of the construction industry, particularly contractors in Malaysia. Hence, the objectives of this paper are: to investigate the barriers, potential solutions and benefits of implementing BIM for such contractors.

PROBLEM STATEMENT

Despite the many advantages that could be gained from utilizing BIM, the local architectural, engineering and construction (AEC) industry is yet to deploy the technology aggressively in its service delivery (Shuratman, 2012; Khosrowshahi and Arayici, 2012; Howell and Batcheler, 2005). This may be attributed to the complexity of the system and the lack of technical expertise (O'Brien, 2000 and Bjork 2002). Meanwhile, Davis & Songer (2008) and Hartman & Fischer (2008) stated that performance of projects will suffer when implementing BIM because the technology is difficult to learn and the established workflow will be disturbed. Hence, solving technical issues is paramount to minimize resistance to change, in particular technological innovation among contractors.

According to Suebin and Gerdsri (2008), barriers in implementing new technology in construction result from two issues: people and technology itself. The people issue represents the acceptance (or rejection) of the individual which may impact at organisational level. The technology issue however, is related to the stability and maturity of the BIM system and its application. The second segment of the people issue constitutes the organisational barrier (Alshawi, 2010). This refers to the influence of people inner factors (i.e. belief, fear and behaviour) towards the organisation's decision in implementing BIM, specifically related to the top management and decision makers in the organisations. If an organisation decides to invest in BIM, enforcement could be materialised to the respective employees. Nonetheless, the actual implementation is contingent on prior decisions made by top management of an organisation. Without these official decisions, employees would not have the opportunity to utilize BIM and gain any benefits (Suebin and Gerdsri, 2009). To reduce the resistance to change in the organisation, sufficient support from top management is crucial (Gilligan and Kunz, 2007; Khosrowshahi and Arayici, 2012). The support will demonstrate the organisational commitment that in dur course will influence employees to adopt BIM. Motivation by the organisation is another strategy for reducing resistance. O'Brien (2000) revealed that low self-confidence and fear on the implementation of BIM are due to lack of knowledge of the new technology; hence motivation, awareness and sufficient training programs could be the factors to build up the required self-confidence. On the other hand, many local and international organisations decide to implement BIM through push factors such as organisational regulations and policies (Abukhzam and Lee, 2010).

Moreover, according to Regan & O'Connor (2000), implementing BIM in construction projects could affect project performance due to the transition process from fragmented to collaborative in nature (Taylor & Levitt, 2007). The fear factors among construction owners and workers centre on how to adopt and use BIM in their projects. This could be seen from the application (software) risk and financial risk factors. Application risk includes the adoption of BIM, compatibility and interoperability of the system, the complexity, and the security. Compatibility and interoperability refer to the capability of BIM application passing data between different BIM applications without affecting the integrity of the data (Eastman et.al. 2011). The capabilities of the BIM technology to provide a stable sharing information platform are also being questioned. Hartmann & Fisher (2008) identified that the main hurdle is the integration of BIM across different project phases due to the involvement of different stakeholders. Another factor is recognised as cost or financial risk (Marsh & Flanagan, 2000; Bjork, 2002; Gyampoh-Vidogah et.al 2003). The cost refers to the implementation cost which includes the initial purchase of software, cost and time spent for training staff and the maintenance of the software. To a certain extent, BIM trained staff will demand a higher salary and upon failing to fulfil their salary's expectations, could be pinched by other giant organisations. The pinching staff syndrome is a fear factor of most contractor organisations. Nevertheless, technology barriers could be overcome through aggressive research and development to develop higher compatibility and user friendliness to make it easier for people to accept BIM while reducing the training time (Ramamurthy, 1994 and Lederer et.al., 2000). The ease-of-use of BIM will be able to influence the acceptance of BIM by many construction organisations.

Meanwhile, the financial issue is more subjective because the pace of BIM adoption could be increased through the external factors such as regulations and policies imposed by the government (Zainordin et.al., 2012). However, it will be difficult for the Malaysian government to immediately set standards as mandatory, since the use of BIM in Malaysia is still at its infancy stage. Nonetheless, the development of standards and policy will certainly improve the adoption of BIM in the Malaysian AEC industry.

METHODOLOGY

The study starts with a literature search to review the barriers, solutions and benefits of BIM implementation in Malaysia and across the globe. Further research is carried out through a workshop held by the Construction Industry Development Board (CIDB) to investigate the issues (i.e., barriers, solutions and benefits) in implementing BIM in Malaysia. The data collected from the discussion of the workshop is analysed using a content analysis technique.

FINDINGS

Table 1 shows the results of the one-day workshop conducted through collaboration between the Construction Industry Development Board (CIDB), Malaysia and Universiti Teknologi MARA (UiTM), in June 2013. The purpose is to discover the barriers, potential solutions and benefits of BIM implementation in Malaysia, specifically among the contractors. The workshop brought together four industry stakeholders which consist of: contractors, consultants, government agencies and academia representing a total of 90 participants. Among others, the largest group (51 numbers of participants) was from contractors grade G3 to G6, registered with CIDB. The consultants (13 participants) were represented by members of the BIM committee appointed by CIDB. The Government agencies (8 participants) were from CIDB and the Public Works Department (PWD). The 18 academics however, were from four public Universities in Malaysia (i.e., Universiti Teknologi MARA (UiTM), University of Malaya, Universiti Malaysia Pahang, and Universiti Teknologi Malaysia).

Table 1. Barriers, Potential Solution and Benefits of Implementing BIM in Malaysia

Organisation	No. of Participant	Barriers	Potential Solution	Benefits
Contractors	51	• The initial upfront expenditure such as purchase of software, conduct BIM training; to appreciate and use of BIM are time consuming prior to being familiar with BIM • Not ready with BIM (hardware and software) • Staff resistance to change • Lack of expertise and knowledge in BIM	• Government incentives • Enforcement and policy on BIM • Accreditation and recognition	• Competitive advantage • Proposals are better understood through accurate visualisation
Consultants	13	• The cost of initial investment of BIM is high • Stability of the system	• Government to provide incentives • Sufficient training	• Improve design errors • Detailed understanding of the design • Avoid clashes on drawings
Government Agencies	8	• Software capability, compatibility and interoperability are questionable	• Awareness program • Affordable training and software cost • Rolling out National policy on BIM • Carry out further R&D on user-friendliness of the software and systems • CIDB affordable BIM program	• Improve project performance • Early detection of problem • As a database for operation and maintenance phase.
Academician	18	• Insufficient pool of BIM experts in the industry	• To include a BIM course in IPTA teaching syllabi • Relevant Government agencies to provide support in terms of trainings and awareness program.	• Adopt BIM in construction as a new paradigm shift • Lifecycle data can be used in the maintenance and operation of facility
Total	**90**			

There are 61 issues raised by the participants during the workshop as stipulated in Table 2, with 26% revolving on the ‘cost factors’. Most of the cost issues are raised by the contractors and agreed by the consultants. Technology financial risk of BIM is seen to be the main barrier in which contractors and consultants are burdened to purchase the hardware, software, appointment of capable professionals and to conduct staff training of BIM in their organisations. According to the contractors, there is no assurance to secure future projects for those who have invested BIM applications for their projects. To a certain extent, they claimed that the possibility of recovering Return on Investment (ROI) is uncertain despite the high initial capital outlay to implement BIM. As a result, this dilemma could affect project cash flow, particularly for small scale projects. In order to overcome the barrier, contractors insist that the Government provide some incentives to the organisations in utilising BIM for their projects. The incentives are in the form of accreditation and certification programs to recognise the qualified organisations for the incentives. On the other hand, the government agencies (CIDB and PWD) proposing the potential solution for this issue can be facilitated by force factors such as regulations and policies by the government and project clients. The benefit may result in giving the contractors a competitive advantage during tendering process in which proposals are better understood through visualisation. Meanwhile, CIDB explained that the government incentive could be either through a monetary support or non-monetary incentive such as providing an affordable BIM for contractors at the final stages of development.

Table 2. Barriers, Potential Solution and Benefits of Implementing BIM in Malaysia

Key variables	Issues Raised	Percentage%
Cost	16	26.2
Time	10	16.4
IT (software, hardware, computer)	14	23.0
Readiness	9	14.8
Knowledge	5	8.2
Technology	5	8.2
Information	2	3.3

Meanwhile, CIDB and consultants raised on the system or application requirement, which relates to the hardware and software required to implement BIM. One of the consultant's representatives agreed that the compatibility of the BIM software that enables communication and data interoperability between contractors, sub-contractors and other parties is crucial.

For that matter, CIDB recommended that aggressive R&D and technology transfer programs could be one of the potential solutions. Further, contractors stated problems of not having expertise and knowledge to implement BIM. To a certain extent, there is a shortage of competent BIM modellers in the Malaysian AEC industry. The consultants suggested conducting sufficient training and awareness programs could embed the benefits of BIM that may outweigh the hurdles. Unanimously, the academia agreed to incorporate BIM courses in the universities syllabus for the students both at Degree and Master's levels in order to have a sufficient supply of BIM experts in the industry.

In addition, contractors highlighted that some organisations resistance to change or are still not ready to adopt BIM as a tool in their projects. This predicament requires full commitment and buy-in from the top management of the organisations in order to overcome the 'people' problem. The staff behaviour of resisting change from normal working procedures to BIM technology could be another barrier. Despite the usefulness and economic benefits of BIM, the in-house technical staff may not be ready to be trained and not be IT savvy. Hence, the industry is facing a shortage of reliable work force in BIM technology. It is a difficult task to convince the construction companies to embrace and implement BIM for the fact that they are unable to appreciate its benefits within a short period of time. As such, sufficient awareness programs, affordable BIM software for their projects and accreditation requirements could be potential solutions.

CONCLUSION

Building Information Modelling (BIM) is not only a technology; it's a methodology of practice that relates to shifting the way of thinking and working process. Despite the benefits gained through the utilisation of BIM, efforts at BIM implementation in Malaysia are still lagging behind. Barriers to its implementation are identified as two critical issues: people and technology. The technology regards the application requirements, technology system risks and technology financial risks within the perspective of individual and organisations. The technology system risks and financial risks relate to six (6) factors: compatibility; interoperability; security; complexity of the system; the cost of software; and cost and time for training. The potential solutions are the intensive R&D on the user-friendly; and interoperability of the system itself. While the requirements, regulations or policy imposed by the government or project clients could also increase the pace of BIM adoption in the industry. Meanwhile, BIM adoption is also viewed within the perspective of individual and organisational levels which relate to five (4) factors: behaviour; belief; fear in using BIM; and culture of the organisations. The possible approaches to address this issue include sufficient awareness; training and motivation programs; government incentives; enforcement regulations and policies to utilise BIM in projects.

In conclusion, the participants suggested that it is the role of CIDB and other related Government agencies such as the Public Works Department (PWD) to provide valuable support in the form of seminars, workshops and hands-on training frequently and sufficiently until the industry is conversant with BIM.

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A PRELIMINARY REQUIREMENT OF DECISION SUPPORT SYSTEM FOR BUILDING INFORMATION MODELLING SOFTWARE SELECTION

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Abstract

The innovation of Building Information Modelling (BIM) has gained much attention among construction players around the world. The adoption of BIM software has proven to be beneficial to the construction organisation in term of design, analysis, construction, operation and data management. The utilization of BIM software would lead to an effective planning and scheduling; encourage collaboration among technical team member and increase overall quality of the project. In recent years, rapid development of Information Communication Technology (ICT) in construction have witness numerous BIM software available in market where each tools offer wide variety of functionality, features and cost. Thus, it is identified that there is a needs to aid decision making for construction organization in order to select appropriate BIM software to a particular project needs. This paper discusses the some aspect of BIM, Multi Criteria Decision Making (MCDM) and Decision Support System (DSS) as decision tools in BIM selection. A documental analysis was performed to gather information regarding the DSS building block and data needed to support the decision model development. Literature suggests that software selection criteria can be categorize under technical, managerial and cost consideration. 24 distinct criteria with 44 alternatives (from 11 vendors) are presented in the paper. In addition, a conceptual model of decision hierarchy is illustrates to be embedded in the DSS prototype. It is also anticipated that the work demonstrated in this paper may improve the development of DSS for BIM software selection as it is vital to increase productivity, construction project throughout building lifecycle.

Keywords: *Building Information Modelling, Multi Criteria Decision Making, Decision Support System;*

INTRODUCTION

The current Architechture, Engineering and Construction (AEC) industry building process has been fragmented and the paper based communication is considered to be the drawback (Gann, 2000). Errors, changes, omissions result in upgrading the design a number of times sequentially by different parties (Succar, 2008). In addition to this, the various interpretations of a single design intent by different parties lead to even more complexities. With the introduction of ICT technologies like 2D CAD, the time spent on redrafting a change in the design has been reduced (Gann, 2000).

Every phases and process that involve in construction project life cycle such as design, planning and scheduling phases required an effective management in order to ensure the successful of the project outcome. Generally, construction project is complex especially in design phase. Yet, the current practice such as 2D AutoCAD tool is incapable to fulfil the project needs (Hergunsel, 2011). This limitation always leads to the construction problem such as project delay and cost overrun. From this situation, the new ICT technology is significant in order to support the management of project life cycle process such as designing process. In this paper, it will highlight one of the emerging ICT in construction which is Building Information Modelling (BIM).

In construction management literature, BIM is understood in a number of definitions. For instance, BIM can be describe as an innovative way to manage a project with the purpose of utilizing the quality and productivity of the construction project, through planning, design, implementation and demolition phases of the project (Arayici, Coates, Koskela, & Kagioglou, 2011; Eastman, Teicholz, Sacks, & Liston, 2011; Hergunsel, 2011; Ruiz, 2009). It can also be defined as "a set of digital tools that manage construction project effectiveness" (Latiffi, Mohd, Kasim, & Fathi, 2013).

The innovation of BIM has gained much attention among construction players around the world. Traditionally, the 2D (CAD) method currently use in building practice becomes inadequate with the development of construction industries. Comparing to the traditional one, BIM is more than drawing purpose. The functionalities of BIM have enabled the architect to extent the design process to three-dimensional visualization. In simply stated, through the 3D visualization it would allow the architect to create build in model for the project final outcome look like in detail and precisely (Sebastian, 2011) .On the others hand, 3D visualization also would solve a major problem among construction project i.e. clash detection. Through this advanced visualization, it would extent the capability of Architect in detection and analysis of this problem and automatically reduce the design error (Eastman, et al., 2011).

Furthermore, the advantage of BIM is not only limited to the design process only, BIM would encourages the collaboration through the an effective flow of information sharing among the stakeholders in the project (Hergunsel, 2011). Most of the stakeholder involves in each decision process during the project phases. This concept leads to an increasing quality of the project in term of time, cost and sustainable of the project. Information sharing among the stakeholders is a significant factor for the purpose of successful planning and scheduling of the project in order to avoid problem such delay and cost overrun in the project (Azhar, Nadeem, Mok, & Leung, 2008). The adoption of BIM is not only limited in information sharing, but also as knowledge storage. One of the characteristic of BIM is to serves as database or keeping construction document such as model record. This could be used as a references for the construction company in the future project (Sebastian, 2011). According to Sebastian (2011), the advantages of BIM adoption can be described BIM as 'POWER'. The term "POWER" refers to Product information sharing (P), Organization roles synergy (O), Work process coordination (W), Environment for teamwork (E), and referring data consolidation (R).

Research shows that BIM is being broadly adopted across the construction industry with over 50% of each survey segment - architect, engineers, contractors and owners utilizing the tools at moderate levels or higher (Liu, 2010). Liu (2010) also identified that architects are the heaviest users of BIM with 43% using it on more than 60% of their projects in 2009. In addition, the study also reveal that contractors are the lightest users of BIM with nearly half (45%) using it on less than 15% of projects and a quarter (23%) using it on more than 60% of projects. At the moment, there are variety of BIM software packages available in the market for AEC inductry. According to Pinheiro (2013) and Penn State University BIM Research Group (2013), BIM software can be grouped under 6 categories such as Architechture, Sustainability, Mechanical, Electrical & Plumbing (MEP), Construction, and Facility Management. Figure 1 illustrates 25 possible uses of BIM throughout building lifecycle (Rohena, 2011). Due to the variability of BIM functional, it is essential to identify the appropriate BIM uses for a target project from Planning to Operating Phase.

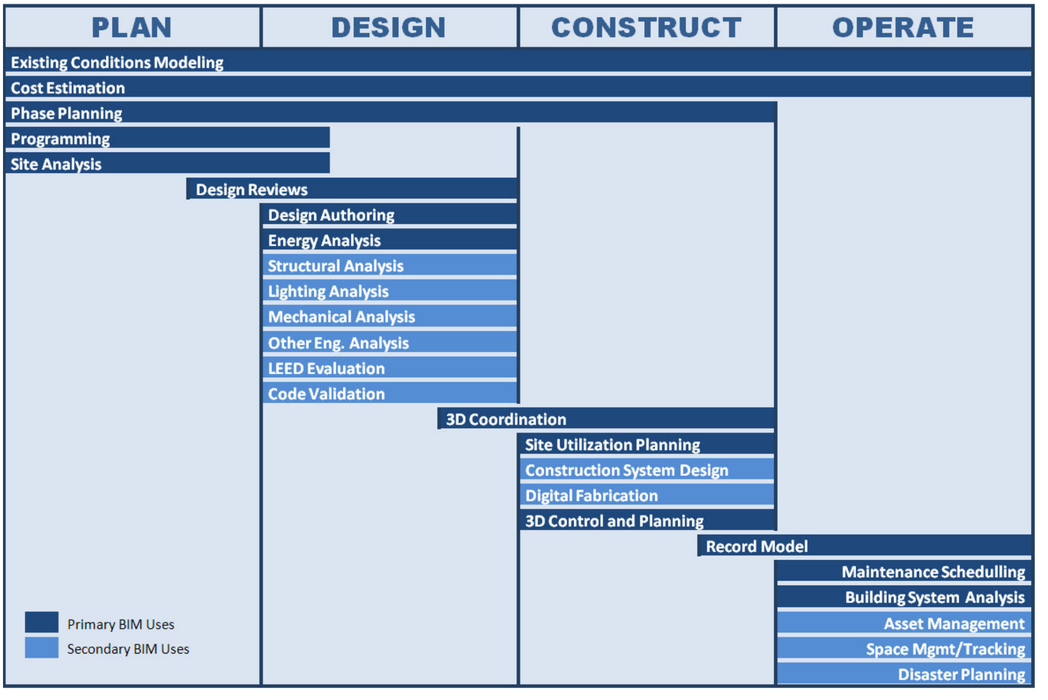

Figure 1. BIM Uses Throughout A Building Lifecycle (Rohena, 2011).

At the moment, the use of BIM in construction projects is growing rapidly. As a result, many commercial BIM software available in market are developed to cater demands for BIM. Appendix A shows the list of BIM software available in the market with its functionality. According to Ruiz (2009), there are 11 vendors with 44 software packages which offer variety of functionality throughout building life cycle.

In literature, there is limited study attempt to thoroughly investigate the criteria and decision process to select appropriate BIM software. CREAM (2012) indicates that availability, affordability, diffusion, training, and support are among some generic criteria to select a BIM software. Hence, there is a needs to aid decision making towards BIM software selection to cater the project and client's need. Till date the study to identify the critical criteria and decision support for BIM selection in construction are largely neglected. Only Ruiz (2009) proposed a model for evaluation of BIM software package where the study only uses simple descriptive statistics and does not consider MCDM technique. Thus, by considering the aforementioned issues, the main research problem is identified as follows *"The lack of multi criteria decision support framework to assist BIM software selection for construction project"*. Due to unavailability for decision support, it is desirable to a develop a computerised multi-criteria decision support system for BIM software selection.

BIM SOFTWARE SELECTION AND MULTI CRITERIA DECISION MAKING APPROACH

According to Eastman et al. (2011), the issue of selecting the right BIM software is a difficult task in construction domain. Due to increasing BIM software in the market, construction companies are anticipated to face decision problem of choosing the right BIM software that suit with the company and project needs. BIM software as listed in Appendix A offers different functionalities, features and cost. In practice, construction organization tent to purchased BIM software based on popularity of the software and fully depend on recommendation form software vendor (Ruiz, 2009). Due to the nature of BIM software selection problem which involve a set of criteria and an array of alternatives, it can be regarded as MCDM type of problem.

MCDM has been used as decision analysis since late 1960's (Alias, Hashim, & Samsudin, 2008). Most of the researcher agreed that the general purpose of MCDM is to help the decision makers determined the best alternative that involve process such as evaluation and comparison between the alternative (Alias, et al., 2008; Mateu, 2002; Opricovic & Tzeng, 2007; Xu & Yang, 2001). MCDM method can be divided into 2 major group, namely Multi Objective Decision Making (MODM) and Multi Attribute Decision Making (MADM) (Kabli, 2009; Mateu, 2002). In precisely MODM is more focusing on mathematical framework in order to build a set of decision alternative which is not given. In the other hand, MADM is decision analysis that concentrate on problem in which alternative have been predetermined in advance (Kabli, 2009).The utilization of MCDM method has proven to be beneficial in numerous field as a decision analysis. Our focus will be on MADM, in order to assist the selection of BIM software for the construction company. Furthermore, the application of MCDM methods are also widely used in previous study in construction management (Carr & Tah, 2001; Cheng & Li, 2004; Dikmen, Birgonul, & Han, 2007; Hsieh, Lu, & Tzeng, 2004; Jaskowski, Biruk, & R., 2010; Mahdi & Alreshaid, 2005; Pan, 2008a). Table 1 outlines some applications of MCDM in construction project management.

Table 1. Applications of MCDM in construction project management

Problem Description	Analytical Technique	Authors
Group decision making for contractor selection	Fuzzy AHP	(Jaskowski, et al., 2010)
Bridge Construction Method Selection	Fuzzy AHP	(Pan, 2008b)
Risk assessment to rate cost overrun risk in international construction project	Fuzzy AHP	(Dikmen, et al., 2007)
Project Delivery Method selection	AHP	(Mahdi & Alreshaid, 2005)
Planning and Design selection in Public Office Building	Fuzzy MCDM	(Hsieh, et al., 2004)
Contractor Selection	AHP	(Cheng & Li, 2004)
Construction risk assessment and analysis	Fuzzy MCDM	(Carr & Tah, 2001)
Budget allocation for transportation in construction project	Fuzzy MCDM	(Teng, Huang, & Lin, 2009)

Based on Appendix B, software selection problem can be regarded as a classical problem in MCDM field. According to literature in MCDM, substantial work of general software selection problem has been performed in the past (refer Appendix B). For example, the selection of Multimedia authoring system through Analytical Hierarchy Process (AHP) (Lai, Trueblood, & Wong, 1999),' application of the AHP for selection of forecasting software (Altug et al., 2006) and a case study using AHP in software selection (Lai, Wong, & Waiman, 2002). These studies suggest that MCDM is a useful tool for software selection type of problem. However, limited study has been done in the area to evaluate BIM software using MCDM technique. Hence, we attempt to solve BIM software selection by using MCDM technique with an appropriate decision support. For instance, Averweg (2008) has provided a decision support framework which integrates the structured, semi-structured and unstructured problem with type of control and technology that can be supported.

Structured problems refer to daily and routine problem arose and the procedure in obtaining the best solution is predetermined in advance. Meanwhile unstructured problem refer to the problems that is no standard solution available. It would involve intuition and experience among the decision makers (Niu, Lu, & Zhang, 2009). The semi-structured lies between structured and unstructured which is it contain a few factor from the other both type. In Table 2, DSS and other AI technique are possible to be adopted in semi-structured and unstructured type of problem. The structured of a certain problem might be influence by the type of data and complexity of problem to be solved. Table 2 below suggests that BIM software selection is possible to be supported by DSS and AI technique. Thus, DSS will be developed on top of MCDM technique to provide easy and purposeful user interface for decision makers to use the mathematical model.

Table 2. Decision Support Framework (adapted from Averweg 2008)

	Type of Control			
Type of decision	**Operational Control**	**Managerial Control**	**Strategic Planning**	**Support Needed**
Structured	account receivable, order entry	Budget analysis, short-term forecasting, personnel reports, make-or-buy analysis	Financial management (investment), warehouse location, distribution system	MIS, OR models, transaction processing.
Semi-Structured	production scheduling, inventory control	Credit evaluation, budget preparation, plant layout, project scheduling, reward system design	Building of new plant, mergers and acquisitions, new product planning, quality assurance planning,	DSS
Unstructured	Selecting a cover for a magazine, **buying software**, approving loans	Negotiating, recruiting an executive, buying hardware	R&D planning, new technology development, social responsibility planning	**DSS, AI techniques**
Support Needed	MIS, management science	Management science, DSS, ES, EIS	EIS, ES, DSS, neural networks	

INTEGRATING MCDM IN DSS

According to Turban et al. (2005), DSS is "a computer information system that combined model and data in an attempt to solve semi structured and some unstructured problem with extensive user involvement". DSS is also an approach of computer could be contribute to support managerial decision making (Alhunaishel, 2001; Arnott & Pervan, 2005; Averweg, 2012; Power, 2007). DSS basically deal with the structured, semi-structured and unstructured problems. Figure 2 depicts common component in DSS such as data management, model management, knowledge management, model base, knowledge base, user interface and raw data (Turban et al, 2005). Mathematical model such as MCDM is often placed under model management module and link with several subsystems such as data management, knowledge management and graphical user interface. Thus, the development of DSS for BIM software selection will be based on this model.

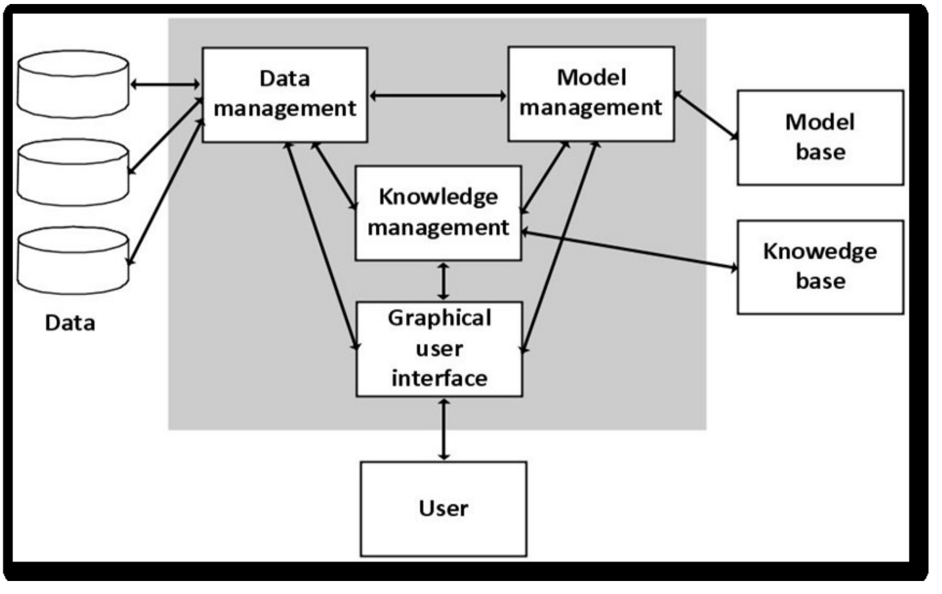

Figure 2. Standard model of DSS (Turban et al 2005)

RESEARCH APPROACH AND FINDINGS

In order to address the research objective, this study deploys a qualitative approach to gather information regarding initial requirement prior design a functional DSS. Before conducting the fieldwork, we've designed a conceptual DSS architecture for BIM software selection. Figure 3 illustrates our model which consist of four components i.e. user interface, model management, web server and internal data management sub system. The user interface is a platform for connecting the user and the system. In our research, we attempt to embed the DSS user interface with social network (e.g. Facebook, Twitter, Google+) Application Programming Interface (API). The model management consists of modeling language for building this model and decision engine (analytical model for BIM software selection).

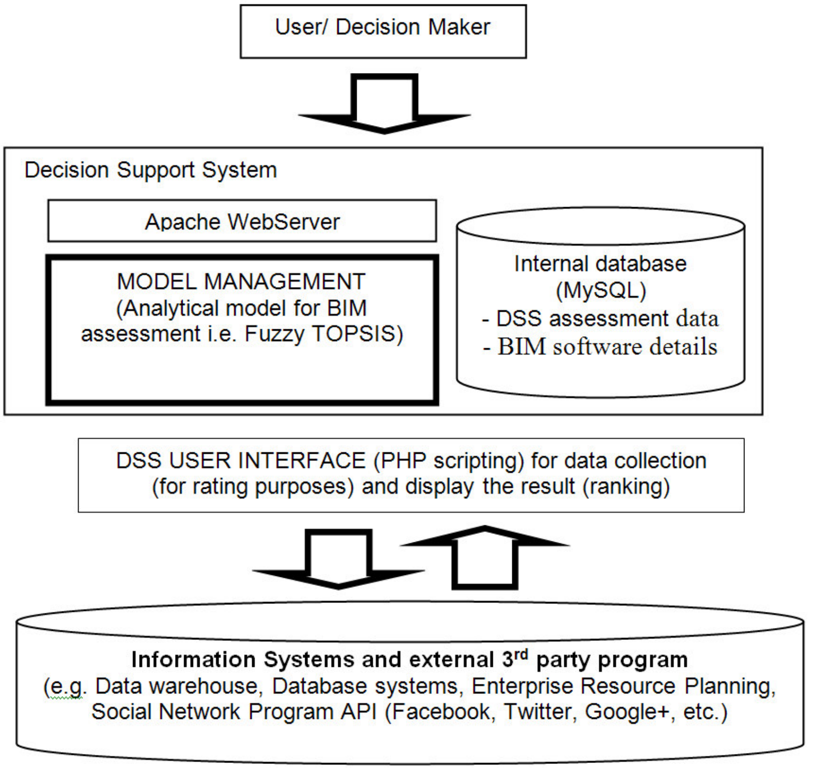

Figure 3. Integrating MCDM in DSS for BIM software selection process

For the purpose of acquiring initial requirement of DSS for BIM software selection, we use documental analysis to gather the criteria (Appendix B) and list of alternatives (Appendix A). Initially, 8 journals regarding software selection by using MCDM technique were chosen. An exhaustive list of criteria from the journals is cleaned by filtering and categorizing the recent set of criteria to "Technical", "Managerial" and "Cost" similar to Lai, Wong and Cheung (2002) study. The classifications of criteria are made by experts through interview. These experts consist of academicians and practitioner in the area of construction IT. The set of criteria is important to further develop research instrument to be validated with decision makers in the next phase.

Our finding indicates that there are 58 criteria were found, and only 50 were related to BIM software selection attributes. For example, we ignore a few unrelated criteria to assess forecasting software as it possesses different and unique functionality. From the 50 related criteria, 35 fall under *technical*, 11 *management* and 4 *costs*. We also found that there are redundancies in the data where some criteria are similar or expressed within the same context. Thus, the final result yield 15 *technical*, 8 *managerial* and 1 *cost* as tabulated in Appendix C. Below is the graph indicating the frequency of Criteria found and filtered in software selection literature (Figure 4). Meanwhile, Figure 5 illustrates the decision hierarchies for BIM software selection based on attributes that has been collected from Appendix C. There are 3 main criteria i.e. *technical* with 15 sub criteria, *managerial* with 8 sub criteria, and cost. In addition, alternative is denoted as BIM software A_n

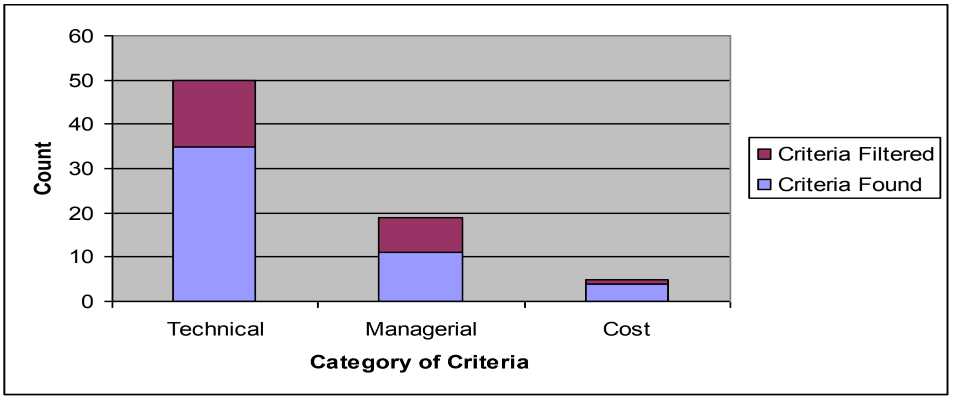

Figure 4. Frequency of Criteria Found in Software Selection Literature

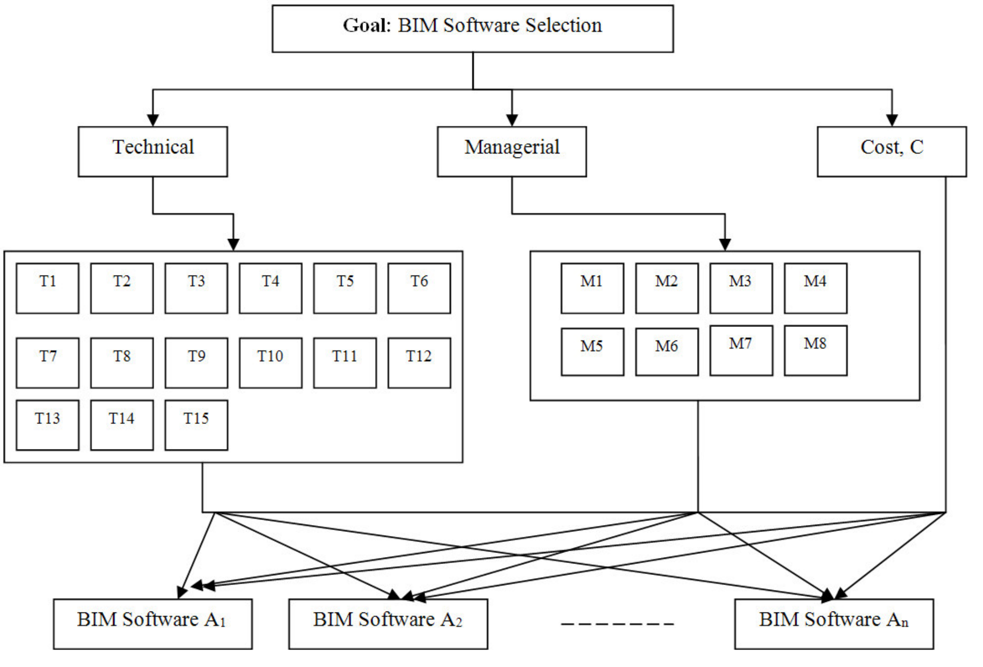

Figure 5. Initial Decision Hierarchies for BIM Software Selection

DISCUSSION AND CONCLUSIONS

BIM can be define as a digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition (Liu, 2010). The adoption of BIM software has proven to be beneficial to the construction organisation in terms of design, analysis, construction, operation and data management. In general, BIM software could be used for visualization tools, clash detecting, building design, as built model, building assembly, construction sequencing, environmental analysis, model based estimation, facilities management, direct fabrication and others.

This paper introduced an innovative approach of Multi Criteria Decision Making in Decision Support System for providing assessable decision support tools for the selection of BIM software. This is a new approach for solving BIM software selection compare to the previous study which is only focusing on the development of evaluation model. Our finding indicates that most study in software selection prioritizes technical aspect (62.5%), and followed by managerial (33.33%) and cost (4.17%). A set of criteria from literature are gathered and will use as an instrument for our next phase of the research. Substantial work is still needed to finalize the criteria used and alternative considered by decision makers in BIM related project in Malaysia. Once, the set of criteria has been reviewed by decision makers, we intent to develop a mathematical model for MCDM and DSS.

To the best of our knowledge, the DSS and social networking approach in construction project management is still far immature. Instead of decision model development, this study will also focus on constructing a new architecture of DSS through BIM software selection problem. Case study approach will be utilized to develop the model. A real case in Malaysia that utilized BIM in their project will be selected to test and validated with the decision model and DSS. It is expected that this innovative approach to produce not only an efficient IT artefact but an effective decision making approaches. Furthermore, the proposed approach is anticipated to be generalized to other related MCDM problem in construction project management.

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Appendix A. List of BIM Software (Ruiz, 2009)

Vendor	BIM Tools	Explanation
Autodesk	Autodesk 3ds Max Design Autodesk Design Review Autodesk Navisworks Revit Architecture Revit Structure Revit MEP	Autodesk is focusing from drafting, model capabilities and clash detection analysis.
Bentley	Bentley architecture V8i Bentley Structural V8i Bentley Building Electrical System V8i Bentley Building Mechanical System V8i ProjectWise Navigator ConstructSim	It is offer tools from drawing and modeling capacity to design rule review and bidirectional capabilities with power and lighting analysis.
Nemetschek AG	Vectorworks Graphisoft Archicad 12	Vetorworks is a drawing and modelling tool. Graphisoft is the first software that implemented BIM technology. Archicad 12, offering upgrade for different solutions.
Innovaya	Innovaya Visual BIM Innovaya Visual Quality Take Off Innovaya Visual Estimating Innovaya Design Estimating Inovaya Design Simulation	It more focus on the BIM environment and specifically to the building construction.
Synchro Ltd	Synchro Project Contruction (basic software) Synchro professional Synchro Express Synchro Server Synchro Workgroup	All of the software from Synchro Ltd focus on project management and specifically to scheduling.
VICO software	Vico Constructor Vico Estimator Vico Control Vico 5D Presenter Vico Cost Explore Vico Change Manager	The company offer complete set of program from design, planning modelling, controlling and analysis.
Gehry Technologies (GT)	Digital Project Software	Design view 2D and 3D model.

Vendor	BIM Tools	Explanation
Tekla Corporation	Tekla Structure, Full Detailing Tekla, Structure Construction Management. Tekla Structure, Steel detailing. Tekla Structure, Precast Concrete Detailing. Tekla Structure, Reinforced Concrete Detailing. Tekla Structure Engineering.	Offer a division of Building and Construction where it more focus on structure area.
Onuma	Onuma Planning System (OPS)	It main strength is Onuma Planning System, an internet sever that allow several of user are able to interact during the modeling process. Onuma basically more to design tools.
Solibri	Solibri Model Checker Solibri Issue Locator Solinri Model Viewer Slolibri IFC Optimizer.	Solibri is more to analysis tools that analyze the models in term of integrity, quality and physical security.
Project Blueprint Ltd	Zero Defect	Provide an Internet accessible database and tracking tools for reviewing a project.

Appendix B. List of software selection problem using MCDM approach

Problem Description	List of Criteria	Alternatives	Analytical Technique	Authors
Software Engineering Selection	1. Usability 2. Performance 3. Security 4. Modularity	1. MVC 2. Blackboard 3. Client-server	Hybrid Assessment Method (AHP, Weighted Average and TOPSIS)	(Ribeiro, Moreira, Broek, & Pimentel, 2011)
Selection of the simulation software	1. Cost 2. Update 3. Decision Support 4. Connect (connectivity issues with external software) 5. Ease (User friendliness)	1. Witness 2. Arena 3. Specific	AHP	(Otamendi, Pastor, & Garcia, 2008)
Evaluation of Point Cloud software	1. User interface 2. Processing Speed 3. Speed Requirement 4. Documentation 5. Technical Features 6. Lifecycle Cost	1. PolyWorks 2. MicroSurvey CAD 3. Virtual Geomatics	AHP	(Soni, 2012)
Selection of a multimedia authoring system	1. Development interface 2. Graphics support 3. Multi-media support 4. Data file support 5. Cost effectiveness 6. Vendor support	3 alternatives	AHP	(Lai, et al., 1999)
Evaluation of software development project	1. Functionality 2. Technical aspect 3. Cost 4. Service and Support 5. Vision 6. System reliability 7. Compatibility with other system 8. Ease of customization 9. Market position of the vendor 10. Better fit with organizational structure 11. Domain knowledge of the vendor	5 alternatives	Fuzzy VIKOR	(Buyukozkan & Ruan, 2008)

Problem Description	List of Criteria	Alternatives	Analytical Technique	Authors
	12. References of the vendor 13. Methodology of software 14. Fit with parent/allied organization systems 15. Cross module integration 16. Implementation time			
Selection for forecasting software	1. Data preparation 2. Method selection 3. Method Implementation 4. Method evaluation 5. Assessment of uncertainty 6. Forecast presentation 7. Ease of use	1. NCSS 2. DecisionPro 3. Minitab 4. Forecasting Tool 5. Aura 6. Systat	AHP	(Altug, et al., 2006)
Computer aided maintenance management system selection	1. System factor • Functionality • Flexibility • Friendliness • Implementation 2. Vendor factor • Technic capability • Reputation • Service	3 alternatives	Fuzzy AHP	Duran (2011)
ERP software selection	1. System cost 2. Vendor support 3. Flexibility 4. Functionality 5. Reliability 6. Ease to used 7. Technology advance	3 alternatives	Fuzzy ANP	Ayag and Ozdemir (2007)

Appendix C. Filtering and Categorizing the Criteria

Author	Assessment Criteria	Related BIM Attributes	Category	Variables	Notes
Ribeiro, Moreira, Broek, & Pimentel, 2011	Usability	✓	Technical	T1	
	Performance	✓	Technical	T2	
	Security	✓	Technical	T3	
	Modularity	✓	Technical	T4	
Otamendi, Pastor, & Garcia, 2008	Cost	✓	Technical	T5	
	Update	✓	Managerial	M1	
	Decision Support	✓	Technical	T6	
	Connect (connectivity issues with external software)	✓	Technical	T7	
	Ease (User friendliness)	✓	Technical		Within T1 context
Soni, 2012	User interface	✓	Technical	T8	
	Processing Speed	✓	Technical		Similar to T2
	Speed Requirement				
	Documentation	✓	Technical	T9	
	Technical Features	✓	Technical	T10	
	Lifecycle Cost	✓	Cost		Similar to T5
Lai, et al., 1999	Development interface				
	Graphics support	✓	Technical		Within T8 context
	Multi-media support	✓	Technical		Within T8 context
	Data file support	✓	Technical	T11	
	Cost effectiveness	✓	Cost		Similar to T5
	Vendor support	✓	Managerial	M1	

Author	Assessment Criteria	Related BIM Attributes	Category	Variables	Notes
Altug, et al., 2006	Data preparation	✓	Technical		Within T11 context
	Method selection				
	Method Implementation				
	Method evaluation				
	Assessment of uncertainty				
	Forecast presentation				
	Ease of use	✓	Technical		Within T1 context

Author	Assessment Criteria	Related BIM Software Attributes	Category	Variables	Notes
Buyukozkan & Ruan, 2008	Functionality	✓	Technical		Similar to T10
	Technical aspect	✓	Technical		Similar to T10
	Cost	✓	Cost		Similar to T5
	Service and Support	✓	Managerial		Similar to M1
	Vision				
	System reliability	✓	Technical	T12	
	Compatibility with other system	✓	Technical		Similar to T7
	Ease of customization	✓	Technical	T13	
	Market position of the vendor	✓	Managerial	M2	
	Better fit with organizational structure	✓	Managerial	M3	
	Domain knowledge of the vendor	✓	Managerial	M4	
	References of the vendor	✓	Managerial	M5	

Author	Assessment Criteria	Related BIM Software Attributes	Category	Variables	Notes
	Methodology of software	✓	Technical	T14	
	Fit with parent/allied organization systems	✓	Managerial	M6	
	Cross module integration	✓	Technical		Within T4 context
	Implementation time	✓	Technical		Within T2 context
Duran (2011)	Functionality	✓	Technical		Within T10 context
	Flexibility	✓	Technical		
	Friendliness	✓	Technical		Within T1 context
	Implementation	✓	Technical	T15	
	Technic capability	✓	Technical		Similar to T10
	Reputation	✓	Managerial	M7	
	Service	✓	Managerial	M8	
Ayag and Ozdemir (2007)	System cost	✓	Cost		Similar to T5
	Vendor support	✓	Managerial		Similar to M1
	Flexibility	✓	Technical		Similar to T7. T7 is suggested to change to “flexibility” to be more representative
	Functionality	✓	Technical		Within T10 context
	Reliability	✓	Technical		Similar to T12
	Ease to used	✓	Technical		Within T1 context
	Technology advance	✓	Technical		Within T10 context

IMPROVING INTEGRATED PRACTICE THROUGH BUILDING INFORMATION MODELING-INTEGRATED PROJECT DELIVERY (BIM-IPD) FOR MALAYSIAN INDUSTRIALISED BUILDING SYSTEM (IBS) CONSTRUCTION PROJECTS

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Abstract
Current studies shows that most of the Industrialised Building System (IBS) project procurement or delivery methods in Malaysia are still based on the traditional approach. This traditional construction process has been widely criticized for its fragmented approach to project delivery and its failure to form effective teams. Due to that problem, a number of issues have recently arisen in current construction methods, such as reworks, time delay, rising costs, lack of communication and coordination, and wastages. This paper through literature review aims to explore this fragmentation issue thus effects to the Malaysian IBS construction projects especially during the design and construction stages. Suggestion on how an integrated approach such as Building Information Modelling (BIM) and Integrated Project Delivery (IPD) can contribute for design and construction process in order to minimise the fragmentation issue will be concluded.

Keywords: *Industrialised Building System (IBS); Building Information Modelling (BIM); Integrated Project Delivery (IPD); Fragmentation Issue; Malaysian Construction Industry.*

INTRODUCTION

The magnitude of the construction industry and its many significant contributions are also noted by many studies (UKCG, 2009; Khan, 2008; and Dlamini, 2012) specifically in terms of impacts on Gross Domestic Products (GDP), economic activities, government revenues, benefit of investment and nation-wide employments.

However, it should be emphasized that the construction industry requires large sums of capital and resources due to its dynamic and complex nature of activities. Adnan et al (2008) argues that due to the factor of the size and diversity of the construction industry, its major industry players are easily exposed to conflicts and numerous issues. This could be due to the misunderstanding of roles and improper risk and project procurement management within the industry.

Typically, there are a minimum of four or five parties directly involved with the process of a construction project such as clients, design consultants, contractors and material manufacturers or suppliers (Hatmoko, 2008). These parties have different levels of involvement and at different stages in the process. Bowron (2002) identified that current methods of procurement have a major impact on the state of the industry by their approach to project delivery and in particular to:

- Procurement occurs across the development process from briefing to construction;
- Determines the relationships between parties involved in the process;
- Risks are apportioned between the parties involved in the process;
- Contract terms are identified including payment, insurance, etc.

As highlighted by previous studies (Hanifa, 2013; Nawi et al., 2012a; Fish, 2011) this segmented nature of the construction industry is the result of firms having various specialities working together towards the completion of construction projects in distinct separate stages, as cultured by the traditional procurement system. Apart from their specialities these firms may also have different perceptions of priorities which lead to friction, misunderstanding and issues within either in conventional or Industrialised Building System (IBS) construction industry. As a response to that challenge and consistent with the needs of the current construction industry, this paper, therefore, is generated to discuss this fragmentation issue that particularly in Malaysian IBS projects.

THE FRAGMENTATION ISSUE IN IBS CONSTRUCTION PROJECTS

Previous studies highlighted that the process of IBS project delivery is associated with problems of fragmentation, including the isolation of professionals, lack of co-ordination between design and construction, and as it is carried out in a sequential manner it leads to time delays, poor communication, conflicts and misunderstanding between design consultants and contractors (Nawi et al., 2012a, Kamar et al., 2011, Nawi et al., 2011a; CIDB, 2009). Typically, fragmentation within the IBS construction industry arises from two areas within the traditional construction process; the construction work process where the most significant division is in the separation of the design and construction phase, and the construction structure itself.

For overcoming the fragmentation issue, many industry-led reports such as Strategic Forum for Construction (2003); Egan (1998) and Latham (1994) have all called on the industry to change from its traditional modus operandi and perform better through integrated practice. Recent follow-up reports such as the UKCG (2009) and Egan (2002), challenged the construction industry to create a fully integrated service capable of delivering predictable results to clients through processes and team integration. Implementation of integrated practice can create a lot of benefits such as; could bring together various skills and knowledge, and removes the traditional barriers towards an effective and efficiency delivery of the project (Nawi et al., 2014; Baiden et al., 2006; Fleming and Koppelman, 1996).

Consequently, many approaches and concepts have been identified, developed, introduced and tested to support integrated practice in construction. Such of them are, to name a few, concurrent engineering (Anumba et al, 1998; Love and Gunasekaran,1997), web based project management (Anumba et al, 2008; Alshawi and Ingirige, 2003), partnering (Bresnen and Marshall, 2000; Barlow et. al, (1997), Building Information Modelling (Eastman et al., 2008; Sacks et. al., 2010; Howard and Bjork, 2007), 4D modelling (Fischer, 2001; Heesom and Mahdjoubi, 2004), *n*D modelling (Aouad et al., 2007; Lee, 2002) and Integrated Project Delivery (AIA, 2007).

Initially, the developments of BIM are targeted at solving the common practice of information sharing and communication. According to Eastman et al. (2008) the delivery process depends on paper based communication. Errors and omissions in paper documents often cause unanticipated costs, delays and eventual lawsuits between various parties in a project team. They further indentified that one of the most common problems associated with paper-based communication during the design phase is the considerable time and expense required to generate critical assessment information about a proposed design, including cost estimates, energy-use analysis, structural details, etc. These analyses are normally done last, when it is already too late to make important changes.

Therefore, there is a need to develop integrated product and process information that offers the potential for improved collaborative working as agreed by Anumba et al. (1998). While, McKinney and Fischer (1998), focus more on IT tools to support collaborative working by identifying the need to incorporate 4D principles with other construction and built environment software tools like GIS, cost estimation and safety and health. Meanwhile, in the AIA (2007) guidelines they also agreed that new technologies have emerged, that when utilised in conjunction with collaborative processes, are demonstrating substantial increases in productivity and decreases in requests for information, field conflicts, waste, and project schedules. They suggested that Integrated Project Delivery with the utilisation of Building Information Modelling (BIM) could improve the traditional fragmented construction process.

Although, there are various stakeholders in IBS value chain for instance, manufactures, designers, local authorities, suppliers and clients, from author's point of view, there are still lacking of research that looking into Malaysian IBS industry perspective on BIM-IPD per se.

Recently, research by Fish (2011), Gotthelf (2011) and Kulkarni, Rybkowski & Smith (2012) have look at the framework, obstacles and potential of implementation in the general construction perspective on BIM-IPD. The researches scrutinized the drivers, barriers and proposed recommendations to improve implementation on BIM-IPD which is possibly the frontier of knowledge in this field. However, rather than duplicating or imitating the research output from those respective scholars, this research aim to add new findings into the body of knowledge related to this area. Therefore, this research will specifically look into the potential features of BIM-IPD for improving integrated practice in the perspective of Malaysian IBS construction industry stakeholders towards enhance the adoption of IBS level in the Malaysian future projects. The detail explanations of growing for improving construction project delivery processes through Integrated Project Delivery (IPD) will be highlighted in the following section.

METHODOLOGY

This research is still at the initial stage; therefore, the information presented in this paper is primarily based on the thorough review of the relevant literature within the scope of Integrated Project Delivery (IPD) and Building Information Modelling (BIM). A literature review is a "critical analysis of a segment of a published body of knowledge through summary, classification, and comparison of prior research studies, reviews of literature, and theoretical articles" (Wisconsin, 2008). In the course of the literature review, the definition, characteristics, benefits, and related issues of IPD in the construction industry is examined and highlighted. At the same time, the potential tool and strategy of BIM and IPD for improving process in the traditional practice and its applicability for IBS project will be discussed as well. All the data and information gathered directly from libraries, books, articles and other printed materials searched in the international and national journals, proceeding and bulletin.

DEFINITION, CHARACTERISTICS AND BENEFITS OF INTEGRATED PROJECT DELIVERY (IPD)

Integrated Project Delivery (IPD) is referred to by many names such as whole building design, integrated building design, etc (Fish, 2011). Principally, IPD is defined as a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all project participants to optimise the results, increase value to the owner, reduce waste, and maximise efficiency through all phases of design, fabrication and construction (IPD, 2007). In addition, IPD has been described as a business model for design, execution, and delivery of buildings by collaborative, integrated and productive teams composed of key project participants such as client, designer, contractor, manufacturer, and supplier (Anderson, 2010).

The principles of IPD can be applied to a variety of contractual arrangements for highly effective collaboration among the owner, the prime designer (i.e. architect) and the prime constructor known as the "core group" (Anderson, 2010; Perlberg, 2009). These individuals are involved with the project from the early stages of design through construction, building occupancy, and operation (AIA, 2009). This concept has been inspired by various alternative delivery models for building a project around the world, most notably the Project Alliance method that, in the last few years, has been successfully implemented in Australia on 30 to 40 projects (Khemlani, 2009).

In addition to being highly collaborative and seeking input from project team members at the outset of the project, as highlighted earlier, many reports (such as Fish, 2011; AIA, 2009; IPD, 2007) suggested that IPD should be operated together with Building Information Modelling (BIM). According to the reports, this integration process allows member of projects to leverage Building Information Modelling (BIM) by creating a virtual design of every element of a construction project's process. Furthermore, BIM can play a valuable role in IPD by enhancing communication between parties in the architectural, engineering, and construction industries (Shourangiz et al., 2011). Using BIM in IPD, digital images are created to precisely depict every aspect of a construction project and to simulate real-world performance and operation of a facility (Eastman, 2008).

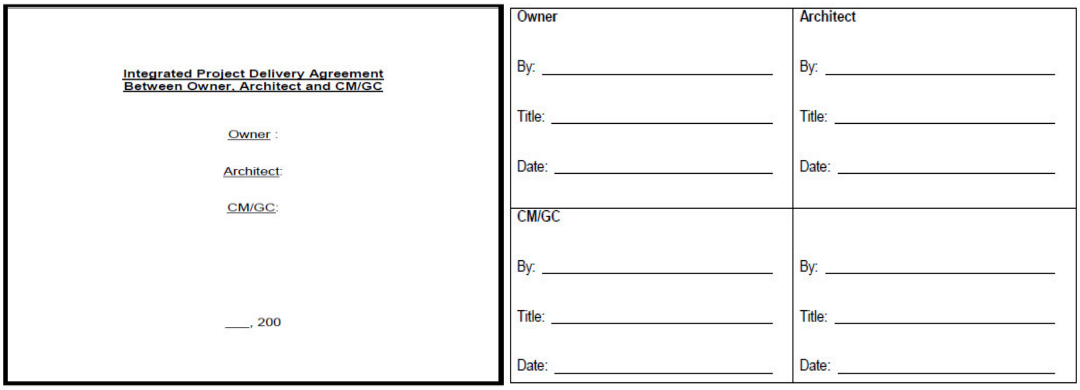
Building upon early-phase contributions of team members' expertise, the integrated team development is guided by the following principles (Fish, 2011; AIA, 2009; Khemlani, 2009; Perlberg, 2009; IPD, 2007):

- Mutual respect and trust
- Mutual benefit and reward
- Collaborative innovation and decision making
- Early involvement of key participants
- Early goal definition
- Intensified planning
- Open communication
- Appropriate technology
- Organisation and leadership
- Multiparty agreement

Based on the definition and characteristics that has been previously explained, it emphasizes that IPD is different from other delivery methods in the fact that early and continual collaboration of all the parties involved in the design and construction process is essential. Ultimately the goal of IPD is to "make better buildings faster for less" (Thomsen, 2008). Through mutual collaboration and shared project goals the IPD process can be highly effective whereas the collaboration can result in a better end product for the owner since all parties are invested in the project and working toward common goals (Fish, 2011).

Previous studies (AIA, 2009; Khemlani, 2009; Perlberg, 2009; IPD, 2007) declared that IPD is not just a utopian vision but a practical reality that can actually be implemented on large, as well as small, projects for greater efficiency results. For example, it has been estimated that the construction cost will reduce an average of 2-10% (for single projects) and up to 30% (over a series of construction projects) through the implementation of an integrated teams approach (Achieving Construction Excellence, 2003). Based on the case study conducted by Khemlani, (2009) who claimed that time for structural design was reduced from an expected 15 months to 8 months, and planning using information from other disciplines that is not usually available which led to better design quality. The same author further highlighted that despite all the time spent planning the design process and meeting to do 3D coordination (all of which were billable hours), the cost for design was at or below what was anticipated. Thus, up to the design stage, the process was completed faster, with no quantifiable increase in cost, and better quality work. Beyond these benefits, IPD also provides other positive values to the project such as strengthening the project team's understanding of client's needs and streamlines the communication among the project team (IPD, 2007). This approach also allows constructors to contribute their expertise in construction techniques early in the design process which will, indirectly, help the designers to produce an accurate budget of estimation and reduce design-related issues during the construction phase such as, constructability, reworks, wastages etc. (AIA, 2009; Perlberg, 2009; IPD, 2007; Matthews & Howell, 2005).

Furthermore, the use of IPD and BIM is advancing the construction industry overall by making it easier to not only predict, but also, to achieve high-quality outcomes (IPD, 2007). Finally, IPD also puts the owner in control of the entire collaborative process for example; through the multiparty contractual arrangement or agreement (refer Figure 1) of IPD, the owner maintains privacy with both the design and construction agents which are totally difference practice with others types of project delivery such as Design-Build (DB) method. A multiparty agreement is one contract encompassing all concerned parties (Kent & Becerik-Gerber, 2010). This is different from the methods used in the others project delivery methods where each entity has their own contract with each of the other concerned parties/groups. The purpose of a multiparty agreement is to create a unified group and to eliminate separate motives and separate contracts (Kent & Becerik- Gerber, 2010). These principles also drive the core group to work toward a set of common goals (refer Figure 2).


Integrated Project Delivery Agreement
Between Owner, Architect and CM/GC

Owner :

Architect:

CM/GC:

___, 200

Owner	Architect
By: ___	By: ___
Title: ___	Title: ___
Date: ___	Date: ___
CM/GC	
By: ___	By: ___
Title: ___	Title: ___
Date: ___	Date: ___

Figure 1. Example of IPD Multiparty Contractual Agreement

As highlighted by Brenna (2011), although DB is a more integrated approach than traditional (Design-Bid-Build), the owner does not have the same control of the design process as in the IPD method. Depending on the weighting and statistical significance the research observes, the results of the study may be interpreted by owners as demonstrating IPD as superior to both DBB and DB.

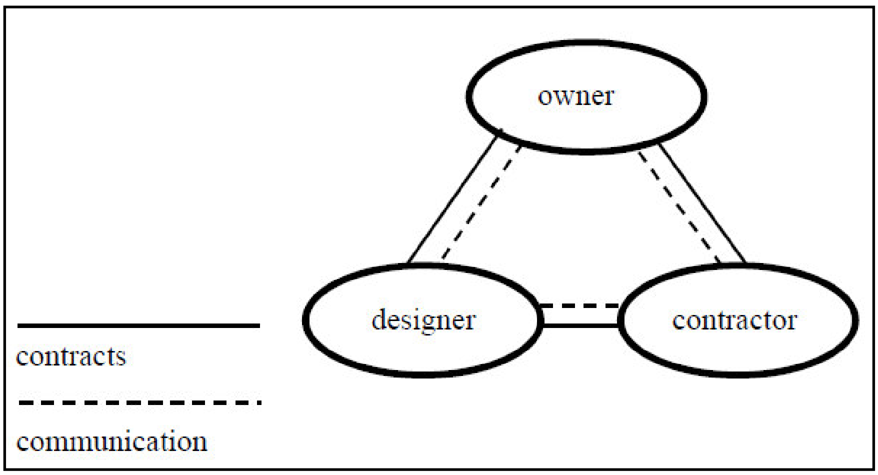


Figure 2. IPD Contractual Relationship (Fish, 2011)

Moreover, the unique of IPD to be compared with others project delivery method is the shared risk and reward of all members. This characteristic will be dictated by the contract and the timelines set forth by the core group. This principle is designed to create a unified core group and hopefully add more incentive for the parties to work together to create a better project for the owner (Fish, 2011). An example of shared risk and reward is "covering budget overages with each entity's overhead and profit, but if the project is under budget the team may receive a compensation bonus" (Kent & Becerik-Gerber, 2010).

THE POTENTIAL OF IPD IN MALAYSIAN IBS CONSTRUCTION PROJECTS

Generally, IPD is a new project delivery (started from US construction industry) in which the project stakeholders such as design team, owner, and contractor work together to develop a building from the initial concept until the handover of a project. Architect, engineer, contractor, developer, client and manufacturer are also working together more closely than ever towards fully integrated team. As has been discussed earlier, the inefficiencies inherent in the process of design and construction in the Malaysian IBS projects are necessitating a shift to greater multidisciplinary collaboration and information sharing among project team members. Previous researchers (i.e. to Eastman et al., 2008, AIA, 2007) also suggested that Integrated Project Delivery (IPD) with the utilisation of Building Information Modelling (BIM) could improve the traditional fragmented construction process. Compared to other integrated procurement approaches such, as Design & Build, Constructing Management or Partnering; the IPD implementation are required the principle of early involvement in concurrent processes to integrate people, systems, business structures and practices in order to reduce waste and optimise efficiency through all phases of design, fabrication and construction (Nawi et al., 2012b). These key principles significantly contribute to the success of overcoming the issue of lack of integration existing in current Malaysian IBS projects. Some of the documentation required to convey certain information in the traditional design process may also be reduced or eliminated all together. This will result in savings of time and money in Malaysian IBS projects. Therefore, improvement of the weaknesses in the current construction industry (i.e. fragmentation) towards integrated practice by using IPD-BIM as a toll of implementation will indirectly make an IBS project delivery process more effective.

CONCLUSION

Based on the previous discussion, it could be concluded that process and team integration are key drivers of change necessary for the industry to become more successful. However, more studies are required to be focused on the fragmentation issue especially during the design and construction work process as this best reflects the current demand by the Malaysian IBS industry. This is still one of the largest issues in the implementation of BIM-IPD in Malaysian IBS projects since the current contracts do not include the parameters of IPD. Therefore, a further study in this particular issue is required in order to fully utilize IPD and BIM in Malaysian IBS construction industry.

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ENHANCING SERVICE DELIVERY IN FM: CASE STUDY OF A MALAYSIAN HEALTHCARE FACILITIES DIRECTORATE

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Abstract
Today, the need to have a strategy in the healthcare facilities services is essential. Malaysian healthcare services are lacking in both professionalism and competency. Facilities Management (FM) in Malaysia also focuses more on maintenance management rather than on a “core” business strategy that would add value within the organisation. Recognition is usually only be given to the corporate departments whereas the FM contribution within the healthcare organisation is perceived as subsidiary. Based on the observation, FM function in Malaysian healthcare is very weak. It is because FM activities in Malaysian healthcare are separated and disaggregated. The paper aims to investigate the hospital operational FM activities and propose the Directorate Activity Hierarchy Diagram in Malaysian healthcare as a strategic system planning framework for FM. Via focus group of two organisations, the gap of FM services in healthcare is identified. The respondents were divided into four groups as a Group A, Group B, Group C, and Group D. Each group consisted of representatives from different organisations. Thus, this information is very useful to Malaysian healthcare to manage the facilities properly and more organized.

Keywords: *Facilities Management, healthcare, operational activities, facilities directorate*

INTRODUCTION

FM has traditionally been regarded as the poor relation within the real estate, architecture, engineering and construction (AEC) sector. This is because it was seen in the old-fashioned sense of caretaking, cleaning, repairs and maintenance. Nowadays, it covers real estate, management, financial management, change management, human resources management, health and safety and contract management, in addition to building and engineering services maintenance, domestic services and utilities supplies. (Atkin & Brooks, 2009). FM is a discipline that becomes pertinent and growth in many part of the world (Egbu, 2010).

FM is one of the disciplines that integrates several more disciplines which levels up the performance and profit margin of organization or project. Implementing FM in planning and execution phase of strategic management could contribute to the success of achieving organization’s core objectives. The aim of FM would not limit to optimizing the cost but moreover it covers efficiency and suitability of the management of space and other related asset management for people and processes. It is a process of getting through quality support services, delivering organization and working environment (Egbu, 2010). According to Pillay (2002), the development of FM in Malaysia started in the second half of 1990s. In 1996, the government privatized the non-critical support service in government healthcares to three FM companies. It was the biggest FM contract by the government at that time. Although FM nowadays is gradually accepted by the construction industry, it is still placed at unrecognized field in Malaysia (Hamid and Sarshar, 2002; Hamid and Alshawi, 2004).

Malaysia needs to focus and emphasis on the development of FM, particularly in the public health sector. It is because FM in healthcare is dealing with human life. The service delivery and performance in healthcare sector require most sophisticated approach compared with other organization. FM is always perceived as a support service rather than making its own dynamic contribution.

Based on information gathered from observation and investigation of the current implementation of strategic FM in Malaysian healthcare, it is found that although FM management is in place, the implementation of a strategic FM approach is lacking. The tension between the current practice of FM and these requirements has made this research essential. In order to respond to the need for strategic FM activities, it is vital to develop a Facilities Directorate with responsibility for a strategic system planning framework for FM.

LITERATURE REVIEW ON FM PRACTICED IN HEALTHCARE

Overview of Facilities Management

FM had started a decade ago, and for the last 10 years dramatic growth can be seen in FM. The concept of FM started to evolve in the era of seventies and eighties in the United States, and had developed into an independent industry. There are almost as many definitions for FM as there are people trying to define it. (IFMA, 2011) explained FM as a profession that encompasses multiple disciplines to ensure the functionality of the built environment by integrating people, place, process and technology. This definition clearly illustrates the holistic nature of the discipline and interdependence of multiple factors in its success.

FM is the total management of all services that supports the core business of an organization. Good FM makes a huge difference to the efficiency and productivity of a company, its staff and even its clients. Institutions will value support services that offer the best possible standards to internal and external customers in terms of quality, time and value. FM is not about ‘contracting out’ key services to external service providers. It is about establishing an integrated management and resources infrastructure that will enable the institution to meet the clearly identified and agreed requirements (needs, not wants) of its stakeholders.

According to Barret and Baldry (2003), FM is an integrated approach to operating, maintaining, improving, and adapting the buildings and infrastructure of an organisation in order to create an environment that strongly supports the primary objectives of that organisation. For many organisations, the effectiveness and behaviour patterns of the workforce and the effectiveness of their information technology and communication systems are of considerable importance and the profession of FM. Whatever is adopted as a definition by a practitioners communicating with their clients and customers, it should stress the importance of integrative, interdependent disciplines whose overall purpose is to support an organisation in the pursuit of its (business) objectives (Atkin & Brooks, 2009).

Evolution of FM

According to Rondeau, Brown & Lapides, (1995) FM was conceived from a company in the United States in 70's. At that period, FM was more focused on supporting activities as a core business rather than a strategic approach. While in Europe, FM was seen as managerial practice on 1980's starting in UK and further expanded to other countries. In Malaysia context, FM started with the introduction of privatization model in 1990's. The Government has privatized some contract services in public health sectors. In 2001, the FM industry started to engage building managers in private and public buildings to oversee the building maintenance and asset management. As a building and FM managers, it need an established association and institute to upkeep and promote the development of profession. Through the association and institutes, the FM practitioners will share their knowledge and collaborate networking with their counterparts internationally and locally. Internationally, there is a few recognized associations in FM and building managers. Table 1 and table 2 shows the FM international associations and Malaysian associations.

Table 1. FM International Association

No.	FM Related Association	Roles and Function
1	International Facility Management Association (IFMA) Established in 1977 known as Facility Management Institute (FMI) by Herman Miller Inc and turned to National FM Association (NFMA) (IFMA, 2011)	Based in United States (USA), it is a platform for facility managers to establish networking, conducting research, educational and certification programmes and also organizing conferences/exposition in FM related
2	FM Association (FMA) (FMA, 2012)	UK's leading association engaged in delivering non-core services from a public and private organization. FMA also is a trade body in assisting them in improving trade linkages through innovation and leadership
3	FM Association New Zealand (FMANZ, 2012)	Establish collaborative network among FM professionals, demonstrate best practices, skills enhancement and increase awareness of standards of conduct
4	British Institute of FM (BIFM) (BIFM, 2012)	Founded in 1993, the institute provides training, continue professional development, information sharing, professional standards and also effective relationship with stakeholders and government

Table 2. Malaysian Asset and FM Association

No	Association	Roles and Function
1	Malaysian Association of Facility Management (MAFM)	Previously known as Malaysian Association of Facilities Managers (MAFM) with its main agenda to bridge the link between FM academician and practitioners in FM related activities in a legal society. It is a platform to interact, sharing information and disseminate best practices either locally or internationally
2.	Malaysian Asset and Project Management Association (MAPMA)	MAPMA was initiated by the Public Works Department (JKR) Malaysia in November 2008 to drive the professionalism of asset and project management in Malaysia across all sectors with a strategy to significantly lift the level of asset and project management by focusing on competency development, membership & international recognition. The prime objectives are: • To promote awareness of applications of asset and project management as a powerful tool for the management of routine and non routine activities. • To advance the profession of asset and project management and the knowledge on which it is based and

No	Association	Roles and Function
		stimulates its application for the benefit of industry and public. • To support Member Associations in the implementation of asset and project management knowledge and standards nationally and internationally. (Source: MAPMA Website)
3.	Malaysian Institute of Professional Property Managers (MIPPM)	MIPPM was founded in 2011, through the spirit of cooperation and professional commitment by the private practitioners, MAPPM has worked tirelessly to promote the role of Property Managers in Malaysia. This is also in line with our Mission Statement which is to advance professionalism, foster fellowship among property managers to provide support to members (Source: MAPPM Website) Objective of MAPPM; • To promote the role of property managers, asset managers and facilities managers in Malaysia and uphold the integrity of the profession of property managers • To set up and maintain a panel for the appointment of arbitrators, mediators and adjudicators for the resolution of disputes that are in the areas of competence of property managers, asset managers and facilities managers to resolve as arbitrators, mediators and adjudicators • To upkeep and promote the development of the profession of property managers with other stakeholders related to property • To encourage and promote research relating to the practice of property management, asset management, facilities management or any allied subjects (Source: Website MIPPM)
4.	The Institute of Asset Management (IAM) Malaysian Chapter	The IAM is a not for profit membership organisation that exists to advance the public benefit the science and practice of asset management. Our priorities are to promote and enable the generation and application of knowledge, training and good practice, and to help individuals become demonstrably competent. Our mission is to: • raise awareness of the existing knowledge base • generate growth in the knowledge base • disseminate knowledge • influence public policy and industry practice • deliver valuable services to our members • manage a robust, sustainable organisation. (Source: IAM Website) IAM Malaysian Chapter was established in September 2012 initiated by Tenaga Nasional Berhad (TNB) to promote asset management in Malaysia.

Developing Strategy for FM

In order to manage facilities efficiently and effectively, robust strategies is developed within the context of the organization's strategic business and accommodation strategy. These should include the development of strategic objectives and a business plan for the FM function, with proper reference to the organization's business plan and accommodation strategy in which it might be contained. A business plan for FM should have the following goals (Atkin & Brooks, 2009).

- Consider the needs of the organization, differentiating between core and non-core business activities.
- Identify and establish effective and manageable processes for meeting those needs.

- Establish the appropriate resource needs for providing services, whether it is obtained internally or externally.
- Identify the source of funds to finance the strategy and its implications.
- Establish a budget, not only for the short term, but also to provide a basis for effective control of FM.

The organization should follow three stages-analyses, solution and implementation to produce an effective strategy for the management of its facilities:

- Analysis – all relevant facts are assembled, including the organization's objectives, needs and policies, a review of resources, processed systems and the physicals assets, together with their attributes in terms of space, function and utilization.
- Solution – criteria for judging options are defined and evaluated against the objectives of the organizations of producing the FM strategy.
- Implementation – this completes the strategic planning and development process through the establishment of an implementation plan that incorporates the key elements of procurement, mobilization, training, communication, review and feedback.

Table 3. Technique and Tools to Support Development of a FM Strategy

Development stage	Phase	Technique or tool
Strategic analysis	Services audit/review	Benchmarking
	Assessment of expectations and objectives	Political, economic, social and technologies (PEST) analysis Strengths, weakness, opportunities and threats (SWOT) analysis Mega trends Quantitative analysis Scenario analysis
	Portfolio audit	Space analysis Real estate register Maintenance plan Risk assessment
	Resource audit	People and skills profiling Service provider audit (existing internal arrangements) Business process analysis Service providers (external) Real estate availability Market trends
Developing solutions	Generating options	Outsource modeling Business process re-engineering (BPR)
	Evaluating options	Maintenance plan Risk analysis Stakeholder analysis Cost-benefit analysis Life-cycle cost appraisal Feasibility analysis
	Selecting option	Optimization model Sensitivity analysis
Strategy implementation	People and systems	Change management Training and personnel development Business Process Re-Engineering (BPR)
	Communication	Organization's intranet Newsletters, notice boards and memoranda

Development stage	Phase	Technique or tool
		Workshops and seminars
	Resource planning	Project planning, scheduling and control Resource leveling/optimization
	Procurement/purchasing	Service provider selection Market testing Benchmarking

FM in Malaysia: An Initiative

Currently in Malaysia, FM is still at the beginning stage even though it has been practiced by the organization many years ago, but then people do not realize the important of FM. This was supported by Jamilus (2011) that mentioned despite the fresh existence of FM in Malaysia, it has contributed immensely to the development of the country since 1990s. The evolution can be traced back to the mid of 1990s when the Government decided to privatize Hospital Support Services (HSS) to three concessionaires. The basic understanding of this approach is that, medical personnel should only concentrate on its primary function. Since then, the government has decided to privatize the maintenance to the public building under the purview of federal government. So far, it is still at the early stage to identify the person who are championing in this areas. Even though the country has many experts in FM but their expertise and knowledge are still scattered around. CIDB Malaysia has taken a step forward to collaborate with government and industry in its initiatives. Under Strategic Thrust 2 of Construction Industry Master Plan (CIMP 2010-2015) that has been outlined by CIDB Malaysia to make quality as the hallmark of the construction industry. One of the programmes introduced by CIDB Malaysia is to register those contractors involved in FM services. Therefore, Table 4 shows the key functions, area of roles and responsibilities for each stakeholder involved in FM.

Table 4. Stakeholders involved in FM (Source: CIDB, 2011)

Stakeholders	Key functions	Area of Roles & Responsibilities
Asset Owner/Investor	Ownership	Initiate projects or works defining the needs.
Authorities (Federal/state)	Governing bodies & approvals	Compliance to Act & regulations standards etc.
Developer	Undertake the development activities	Planning, implementation Compliance with statutory and by laws.
Consultant	Design (Conceptual & detail)	Advisory, supervision, submission, Cortication
Bankers	Financial facilities and service	Housing Loan, Bridging Finance, Bonds, Guarantee, and credit facility.
Insurance Company	Insurance policy and service	Provide insurance coverage
Contractors	Build and construct operate & maintain	Undertake physical activities within time, cost and quality as per contract.
Asset/Property Manager	Provide input during design stage manage built asset	Ensure proper running operation and functioning of asset.
Facility Manager	Manage and maintain facilities	Provide input during design and construction stage.
Service Provider	Solutions & services	Provide secondary utility services.

Stakeholders	Key functions	Area of Roles & Responsibilities
End User	Users of common facilities	Formal education, competency training.
Public	Users of common facilities	Proper usage of assets.
Academia	Capacity building	Formal education, competency training.
Institution/Association	Provider interaction platform for the development of FM practices.	Strengthen the FM industry through knowledge sharing and best practices amongst Malaysian FM players.

METHODOLOGY

The researchers had employed several methodologies to gather information as detailed as possible. First, an observation was conducted to determine the existence of FM practice in Malaysian Healthcare named as a Hospital X and Hospital Y. The observation method included operational FM activities in Hospital X and Hospital Y. A chart is obtained from the hospital X and hospital Y. There are facilities management departments involved in this study and both hospitals have two different organizational charts. For hospital X, the hospital's functions are divided into four parts, Quality Management System, Clinical Services, Professional Development and Human and Academic Departments. For hospital Y, the hospital's functions are divided into four main sections which are Deputy Director (professional), Deputy Director (administration), Public Relation and Deputy Director (development).

The main purpose of this phase is to identify gaps in work that had been previously conducted. In this study, the method used to obtain information is focus groups. Focus groups were originally called "focused interviews" or "group depth interviews". The technique was developed after World War II to evaluate audience responses to radio programs (Stewart & Shamdasani, 1990). Since then social scientists and program evaluators had found focus groups to be very useful in understanding how or why people hold certain beliefs about a topic or program of interest.

A focus group could be defined as a group of interacting individuals having some common interest or characteristics, brought together by a facilitator, who uses the group and its interaction as a way to gain information about a specific or focused issue. A focus group is typically consisted about 7-10 people who are unfamiliar with each other. These participants are selected because they have certain characteristics in common that are related to the topic of the focus group. The facilitator or interviewer creates a permissive and nurturing environment that encourages different perceptions and points of view, without oppressing participants to vote, plan or reach consensus (Krueger, 1988). The group discussion is conducted several times with similar types of participants to identify trends and patterns in perceptions. Careful and systematic analysis of the discussions provides clues and insights as to how a product, service, or opportunity is perceived by the group.

This phase focus on focus groups because the researcher can interact with the participants, pose follow-up questions or ask questions that probe more deeply, results can be easier to understand than complicated statistical data. The researcher also can get information from non-verbal responses, such as facial expressions or body language.

Through focus group, can be gathered more quickly compared to gathering information from people who were interviewed separately. There are three phases of focus groups used in this study which are conceptualization phase, interview phase and analysis and reporting phase. For the conceptualization phase, researchers will bring up the issue and provide a questionnaire to the respondents. Issues and questionnaire reworked based on the essential information to be obtained, consider information needs, what information is needed and why is it needed. Researchers also identified the special group as respondents. In this study, a special group was hospital X staff, hospital Y staff and industry parties that involved facilities management in hospital. Also identified demographic characteristics of those who had experience working in a hospital for 10 years onwards were invited.

For the interviewed phase, the respondents are divided into four groups: Group A, B, C, and D, where each group consists of different industry. Group A consisting of Hospital X representatives and facilitator, Group B consisting of Hospital X representative, Hospital Y representative, industry representative and facilitator. Group C consisting of Hospital Y representative and facilitator while Group D consisting of Hospital X representative, Hospital Y representative, industry representatives and facilitator. Facilitator was appointed to record the discussion that was taking place and draw conclusions from the results discussion. Facilitator (interviewers) plays a key role in the success of focus groups. That is why the facilitator should have characteristics that are similar to participants and be skilled in group processes. Their role is to keep discussions flowing and on track, guide discussions back from irrelevant topics, make transitions into another question, and stay sensitive to the mood of the group, also know when to move onto another question. Facilitators should also have some background knowledge about the topic that is being discussed so that they can lead it efficiently.

At this phase, respondents are free to express their opinion and a facilitator will record and provide guidance for unclear questions. Time taken for focus group is between 3-4 hours depending on the reaction of the respondents. Questions posed consist of 10 questions ranging from open-ended question so that it will be easier for them to express their ideas and opinions. Based on Krueger (1988), for best results, a focus group session should include around five or six questions and it should always include less than ten questions.

The third phase is analyzing and reporting phase. Data and information that are gathered from group discussions will be combined. Besides laptops, recorders were also used during the focus group discussions. Immediately after the session, facilitator and assistant spot checks the tape recorder to make sure it is recorded.

The facilitator and assistant will have to write down summary comments and listen to the complete tape to write a more complete summary of the discussion. This written summary should be prepared within hours after the session and before the session of the next focus group. After that, facilitator and assistant compared the notes, share observations and talk about participant responses to key questions. The process then continues by gathering together brief summary reports, tape recordings, list of questions and demographic information. All summaries were read at one sitting.

After that, raw data will be presented as statements from respondents. The raw data obtained is FM Operational Activities in Hospital X and FM Operational Activities in Hospital Y. The differences between FM Operational Activities between the two hospitals are analyzed. The results of analysis are shown in the next section. Further, the Directorate Activity Hierarchy Diagram in Hospital X and Y Hospital are developed.

Operational FM Activities in Malaysian Healthcare

The organization charts below (Figure 1) show the operational FM activities in Hospital X and Hospital Y.

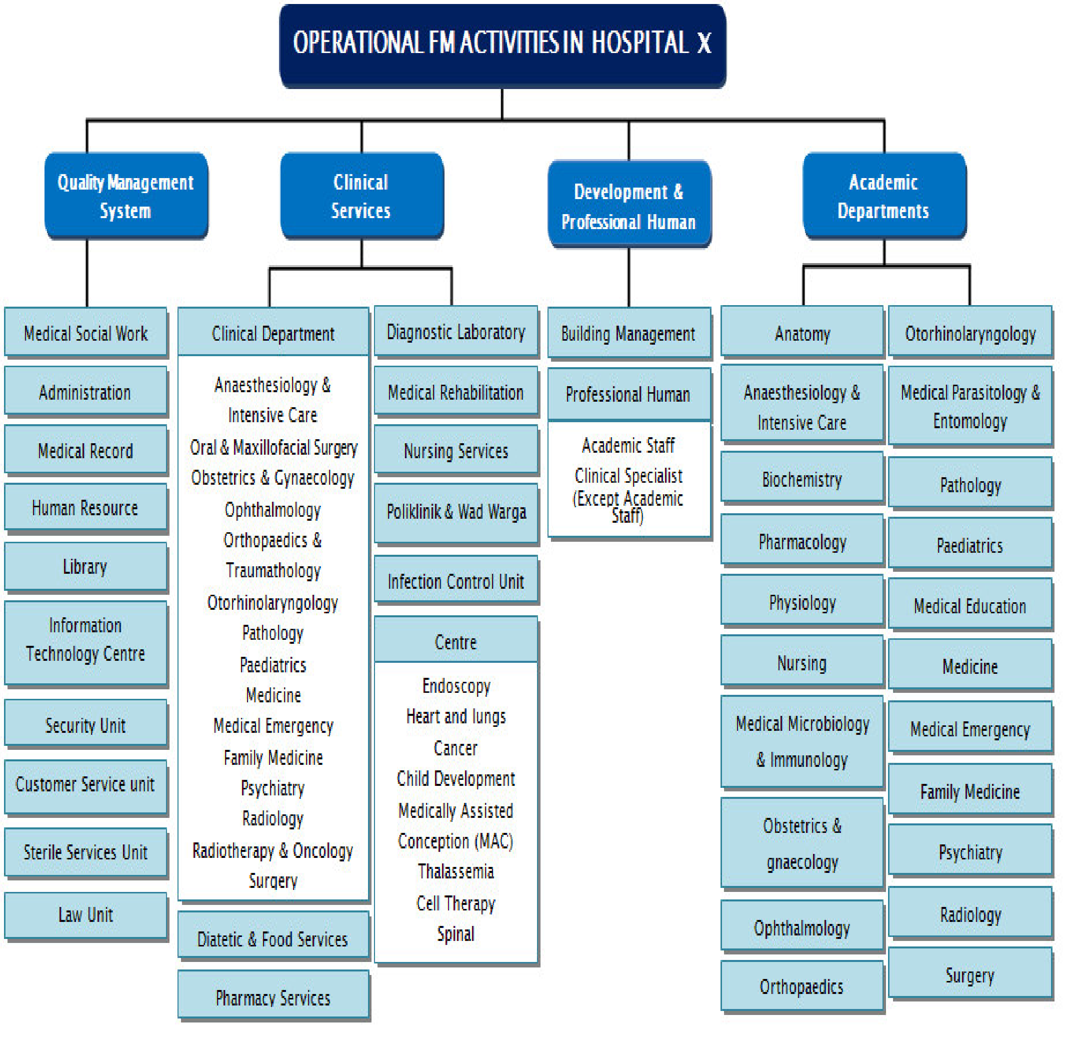

Figure 1. Operational FM Activities in Hospital

Operational FM Activities in Hospital Y

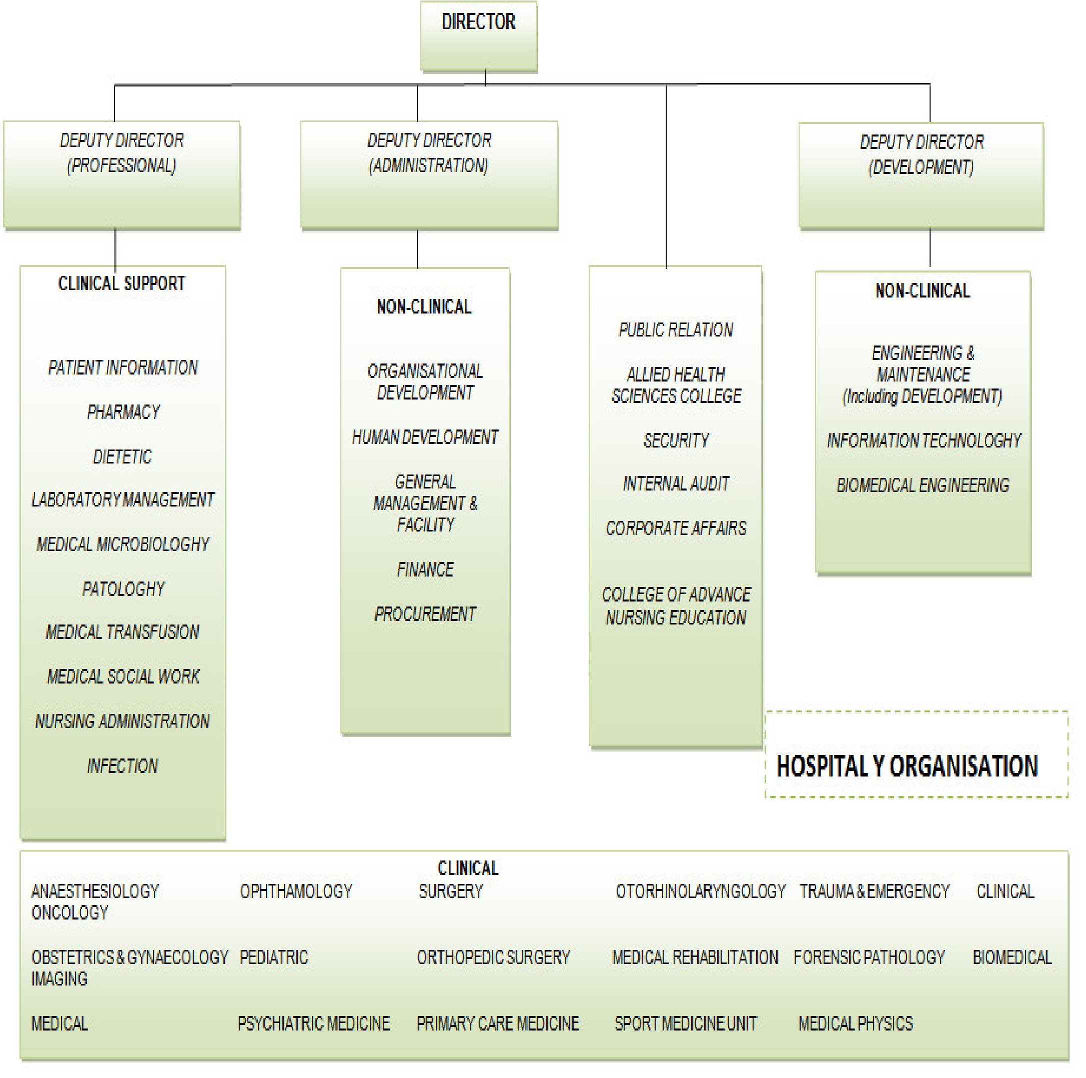

Figure 2. Operational FM Activities in Hospital Y

Developing of Directorate Activity Hierarchy Diagram in Hospital X and Hospital Y

Based on the Figure 1 and Figure 2, it is noticed that the FM activities are separated and disaggregated. The FM function is under the direction of many departments at Hospital X. It is obvious the FM unit is managed by different departments, both non-clinical and clinical. There is no direct link between all FM functions or activities in the Hospital X under one director. As such, the strategic FM functions are dependent on individual departments. The Hospital X needs an approach to enable a strategic FM direction to be developed.

The organisation chart of Hospital Y, Figure 2, shows that the functions of FM also to report to different departments. The Director of Hospital Y oversees the whole healthcare that includes clinical and non-clinical departments under the administration of three deputy directors. It will also be seen that the FM functions and activities are not integrated with one another. The FM function at Hospital Y needs to be integrated so that it can be put under one director with sole responsibility for FM.

Based on findings, Group A which comprises of members from Hospital X, it was proposed that FM is managed in an integrated way headed by the Chief Operating Officer (COO) rather than the current practice which FM disaggregated at all departmental levels. This proposal shows that FM is headed-up by COO who will report to the Dean/Director of Hospital X and oversee all activities. The COO would be responsible for formulating and implementing the strategic plan to ensure everything runs smoothly. FM activities will be divided into two functions: hard and soft FM services. The Building Management and Information Technology Department will be located under hard FM services. Under soft FM services the unit of Administration, Dietetic Department, Public Relation Office (PRO), Safety and Security Department, Information Technology Centre, Customer Service Unit and Nursing Management have been re-organised.

The proposed restructuring of FM implementation in Hospital Y was discussed by group B whose members were drawn from Hospital Y itself and the FM industry. The group is not only proposing to separate FM into hard and soft FM functions but the new FM department should also consider the management of outsourcing and insourcing. Both functions would actually play important roles in FM at Hospital Y. The establishment of FM as a main department in Hospital Y would ensure the importance of the role of FM in the healthcare. The hard function of FM could subsume engineering, administration, IT, biomedical engineering and security. The soft function of FM could have two responsibilities: administration and professional. It can be seen that currently there is duplication of the administration function in soft and hard FM. In hard FM, administration covers maintenance works, planning and engineering related activities; in soft FM it relates more to housekeeping and record keeping. Soft FM (professional) also includes dietetic and nursing administration. Detailed proposals for Hospital X and Hospital Y, respectively, may be referred to Figure 3.

Group C also discussed the proposed structure of FM in Hospital X. The representative from Hospital X provided the contribution on current practice and suggested how to overcome the existing problems. Members of the group agreed that FM should be located in a department under the Chief Executive Officer (CEO). The CEO should report directly to the Dean/Director of Hospital X. The CEO's background could be neither clinical nor non clinical with regards to overseeing the FM roles and functions. The FM could also be divided into two parts, hard and soft. The group proposed that Hospital X should establish FM as a department with equal status to other main departments and be leaded by a dedicated FM manager to carry out FM services. The benefits of having a dedicated FM department will include having more strategic focus, greater efficiency of service delivery, value added to the services, better value of money for customers and more efficient use of equipment and facilities. The Figure 3 shows the detailed FM Directorate Activity Hierarchy Diagram for Hospital X and Hospital Y and Figure 4 shows the proposed FM Directorate Activity Hierarchy Diagram for Hospital X and Hospital Y.

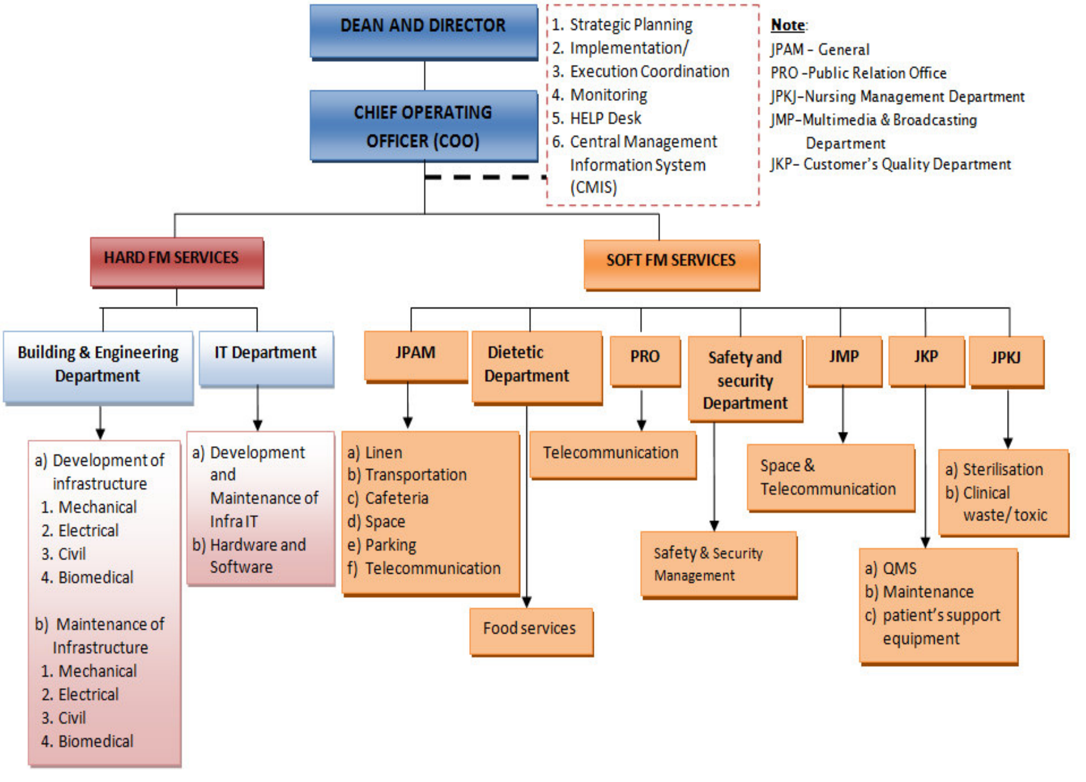

Figure 3. Proposed FM Directorate Activity Hierarchy Diagram in Hospital X and Hospital Y

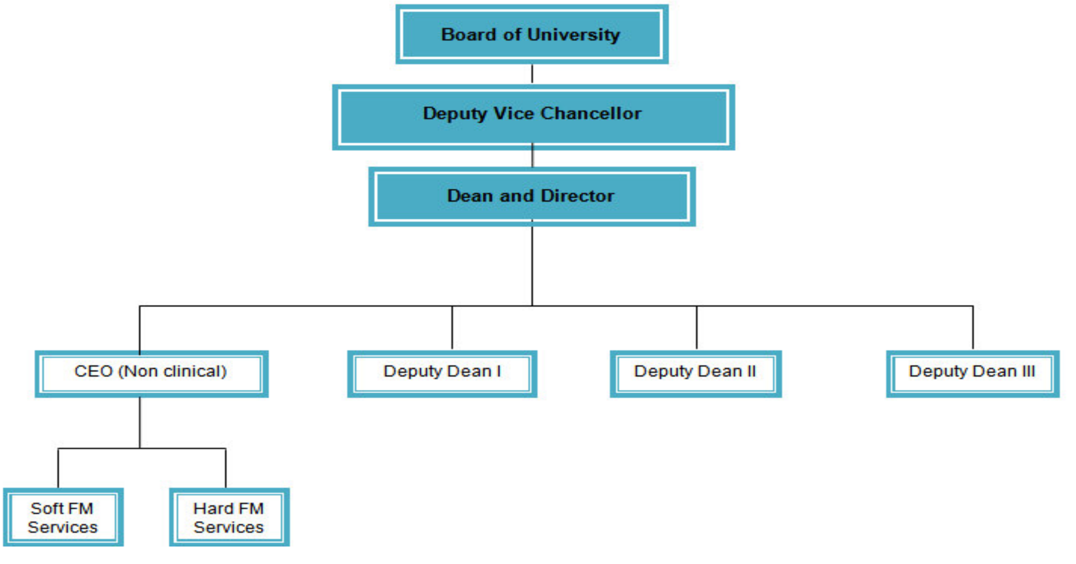

Figure 4. Proposed Directorate Activity Hierarchy Diagram for Hospital X and Hospital Y

SUMMARY

Process improvement and evaluation is an essential issue in recent management developments. In order to be flourish, FM must be planned strategically and accepted as a core service provider in healthcare. FM needs to be a dedicated professional department in order for it to acquire the honorable status like other healthcare departments. It is very important for a healthcare department to have a structured and organized FM activities to ensure that it runs efficiently according to what has been planned.. This study suggests the Directorate Activity Hierarchy Diagram in Malaysian healthcare as a strategic system planning framework for FM. The method used is focus group. The case study involved four (4) groups from Hospital X, Hospital Y and Industry. It consists of Group A, Group B, Group C and Group D. Each group is placed with facilitators. The case study findings assisted the hospital management to identify the gap between strategy and operational practices. It highlighted specific operational improvements, which will lead the organization forward.

Further research is necessary to develop a strategic performance management model for hard FM in Malaysian healthcare. This study will focus on strategic performance management criteria for hard FM in healthcare. Performance management criteria will be determined using the Analytical Hierarchy Process (AHP). Using this method, the most important criteria will be determined in the form of an index. Weighing formula is being used to determine the ranking of performance management criteria. Next, performance management model can be produced through PMI (Performance management Index).

Thus, performance management is important because it will thereby provide standards for business comparisons; provide transparency and scoreboard for individuals to monitor their own performance especially in healthcare sector.

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MICROSTRUCTURAL STUDY OF CEMENTITIOUS BINDER CONTAINING NANOSILICA

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Abstract
The aim of this study was to investigate the pozzolanic reaction of nanosilica binder composites (nSBC) through the characterization of the morphology of Calcium Silicate Hydrate (C-S-H) and Calcium Hydroxide (CH) using Fourier Transform Infrared Spectroscopy (FT-IR), X-Ray Diffraction Technique (XRD), Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDS). nSBC paste samples were prepared with water-binder ratio of 0.50. Nanosilica (nS) of 10-20 nm particle size was used as 2%, 3%, 5%, 7% and 10% replacement of cement by weight. Samples were cured at room temperature in the range of 18-28°C and 65-90%, respectively. Powdered and polished samples were prepared and tested at 28 days of binder hydration. It was found that the characterization techniques used were able to give satisfactory qualitative indication of pozzolanic reactivity of nSBC by the presence and absence of C-S-H and CH. nSBC exhibited a higher pozzolanic reactivity compared with conventional cement paste by which cement performance was enhanced with 3% as the optimum level of replacement. However, further study should be performed to quantify the extent of pozzolanic reaction at the optimum pozzolan dosage.

Keywords: *Nanosilica, CH, C-S-H, FT-IR, XRD, SEM/EDS*

INTRODUCTION

Concrete is the most widely used material in the construction industry and consumes almost 90% of the total cement production in the world. The consumption of large quantity of cement will cause greenhouse effects and increasing global warming issues. This is due to the emission of significant amount of carbon dioxide, CO_2 as by-product from the combustion of fossil fuel and calcination of limestone during its production. As much as 1.25 tonnes of CO_2 is emitted for every tonnes of cement produced which is responsible for 5% of the total global CO_2 emissions (Malhotra, 1999). One of the alternatives to reduce the amount of CO_2 emitted is by reducing the amount of cement used in cement based material. This can be achieved by partially replacing it with industrial by-product materials such as fly ash, ground granulated blast furnace slag and silica fume which have pozzolanic characteristic.

Pozzolan is a siliceous and/or siliceous and aluminous materials that in itself possesses little or no cementitious value but can, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide (CH) at ordinary temperature to form compounds having cementitious properties; calcium silicate hydrate (C-S-H) (ASTM C-125). Pozzolanic reaction is a simple acid base reaction between CH and silicic acid (H_4SiO_4, or $Si(OH)_4$) in cement mix as represented by equation (1) (Maria et al., 2012).

$$Ca(OH)_2 + H_4SiO_4 \rightarrow Ca^{2+} + H_2SiO_4^{2-} + 2\,H_2O \rightarrow CaH_2SiO_4 \cdot 2\,H_2O \quad (1)$$

Pozzolanic reaction in cement system is the reaction of silica with Portlandite or Calcium Hydroxide (CH), which is formed during the hydration of the OPC binder producing additional Tobermorite or Calcium Silicate Hydrate (C-S-H) which is the main constituent for the strength and density in the harden binder paste. The pozzolanic activity includes two parameters that is the maximum amount of CH that pozzolan can react with and the rate of reaction. The rate of the pozzolanic activity is related on the surface area of pozzolan particles whereby the higher the surface area of pozzolan particle or the finer the particle, the more reactive it would be (Malhotra and Mehta, 2004). Hence, the research and development for cement based material is on the interest to find new cement supplementary material which have a particle size of nanoscale (10^{-9} m). The incorporation of nanomaterials in cement and concrete production can lead to major improvement in the civil infrastructure because durability and sustainability of cement based product is determined by its micro-structural mass transfer in nanoscale (Hanehara and Ichikawa, 2002).

With the advent of nanotechnology, such nanoscale materials have been developed for the application in building materials namely concrete and mortar. From previous research, it was found that a remarkable improvement in the mechanical and chemical properties of cementitious materials can be observed with incorporation of nanomaterial such as ZnO_2, Al_2O_3, TiO_2, carbon nanotubes, nano-clays, carbon nanofibers and other nanomaterials. In the recent development, a new synthetic material, namely NanoSilica (nS), has been produced and available in the market. It is based on silica particles that are much smaller than those of silica fume (microsilica) which contains particles as “big” as 0.1-1 μm (Sobolev and Shah, 2008). It has attracted increasing interest because of its potential filler effect which can improve the particle size distribution thus reduced the porosity and permeability of cement based materials that in effect increase its durability and sustainability (Sobolev, 2009). Furthermore, the aspects that makes nanosilica as an excellent cement replacement material is due to its high pozzolanicity that by addition into cement paste will improve the microstructure of the paste and reduce calcium leaching as nS reacts with CH and form additional C-S-H gel (Ershadi et al, 2011). Previous studies have shown that due to the very high specific surface area (80-1000 m^2/g) and the spherical shape of the nanosilica particles, it can potentially enhance the performance of cement based material mainly due to the reaction of silica with calcium hydroxide (CH) to develop more of the strength-carrying compound in cement structure: calcium silica hydrate (C-S-H) as explained by previous researchers (Ershadi et al, 2011; Olar, 2011; Sobolev et al, 2009; Quercia et al, 2010; Sobolev et al, 2005; Richardson, 2000). Furthermore, it has been found that the concentration of CH, commonly known as Portlandite, can be used to quantify the C-S-H formed in the same specimen (Larsen, 1961).

To date there are limited knowledge on the effects of nanosilica as a binder replacement on the pozzolanic reaction. Therefore, this study aimed to investigate the evidence of pozzolanic reaction of nanosilica binder composites (nSBC) by the characterization of Calcium Silicate Hydrate gel (C-S-H) and Calcium Hydroxide (CH) crystal using Fourier Transform Infrared Spectroscopy (FT-IR), X-Ray Diffraction Technique (XRD), Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDS).

MATERIALS AND METHODS

Materials

The nanosilica (nS) used in this study was Aldrich Silicon Dioxide Nanopowder of 5-15 nm and 10-20 nm particle size (BET) with 99.5% silica content. The binder used was Ordinary Portland Cement (OPC) (ASTM Type 1 recognized by ASTM C150) manufactured by Cahaya Mata Sarawak Cement Sdn. Bhd (CMS) and it exceeds the quality requirements specified in the Malaysian Standard MS 522: Part 1: 1989 Specifications for OPC. The chemical and mineralogical characteristics of the OPC and nS are given in Table 1.

Table 1. Chemical Composition of OPC

Composition (%)	CaO	SiO_2	Al_2O_3	Fe_2O_3
OPC	63.0	21.79	5.75	3.25
nS	-	99.5	-	-

In order to investigate the extent of pozzolanic reaction of nSBC, characterization of C-S-H and CH using FT-IR, XRD, SEM and EDS were performed. The nSBC paste samples were prepared with water-binder ratio of 0.50 and containing 2%, 3%, 5%, 7% and 10% of nanosilica as partial cement replacement on mass-for-mass basis for nSBC-2%, nSBC-3%, nSBC-5%, nSBC-7% and nSBC-10% binder, respectively. Universal Containers 30ml, diameter 28x85 mm were used as mould. All samples were cured in the laboratory at daily temperature (T) and relative humidity (RH) in the range of 18-28°C and 65-90%, respectively. The fine powder samples (passing 75 μm) and polished coated small samples were prepared and analyzed at day 28. Ethanol was used to stop the hydration process of these samples.

Characterization by using FT-IR, XRD, SEM and EDS techniques

Shimadzu Fourier Transform Infrared Spectroscopy (FTIR) 81001 Spectrophotometer was used to perform the FT-IR analysis. The spectrum measurement method applied was Attenuated Total Reflection (ATR) method. Transmission infrared spectrum of each sample was recorded using a Fourier Transform Infrared Spectrophotometer (IRAffinity-1) in the region of 400 to 4000 cm^{-1} with 2.0 cm^{-1} resolution. The samples were scanned 20 times. X-Ray Diffraction (XRD) analyses for all prepared samples were performed using PANalytical equipment with Cu Kα radiation and λ of 0.1546 nm. The specifications were; count step: 4 sec/step, step size: 0.02 degree and range: 50 - 650 (2θ). SEM/EDS micrographs for all prepared samples were captured by Scanning Electron Microscope with Energy Dispersive X-ray Spectroscopy (JSM-6701F) supplied by JEOL Company Limited, Japan that followed the ASTM C 1723-10 (2010) code of practice.

RESULTS AND DISCUSSION

The purposes of doing characterization and morphological analysis are to observe the evidence of pozzolanic reactivity and to find the optimum dosage for nS as cement replacement in cement based product. Analysis was carried out by comparing the intensity of CH and C-S-H band at day 28, as shown in Figure 1 for all six samples (OPC, nSBC-2%, nSBC-3%, nSBC-5%, nSBC-7% and nSBC-10%). The infrared spectrum wave number of Calcium Hydroxide (CH) and Calcium Silicate Hydrate (C-S-H) are 3,640-cm^{-1} and 970 -cm^{-1}, respectively (Ylemén et al, 2009).

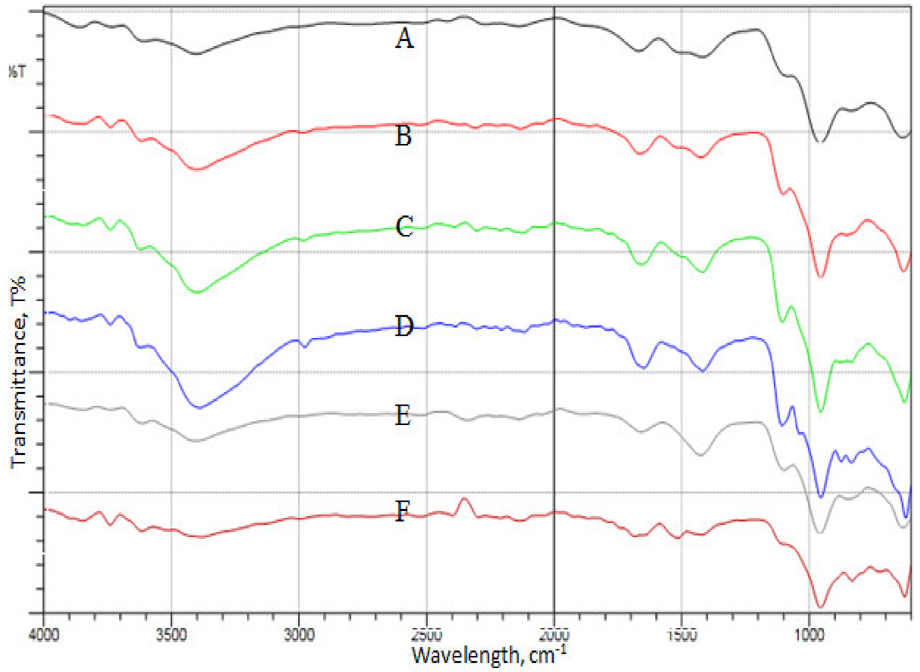

Figure 1. FT-IR spectra of 10-20 nm nS modified cement paste sample at 28 days (A) OPC (B) nSBC-2% (C) nSBC-3% (D) nSBC-5% (E) nSBC-7% (F) nSBC-10%

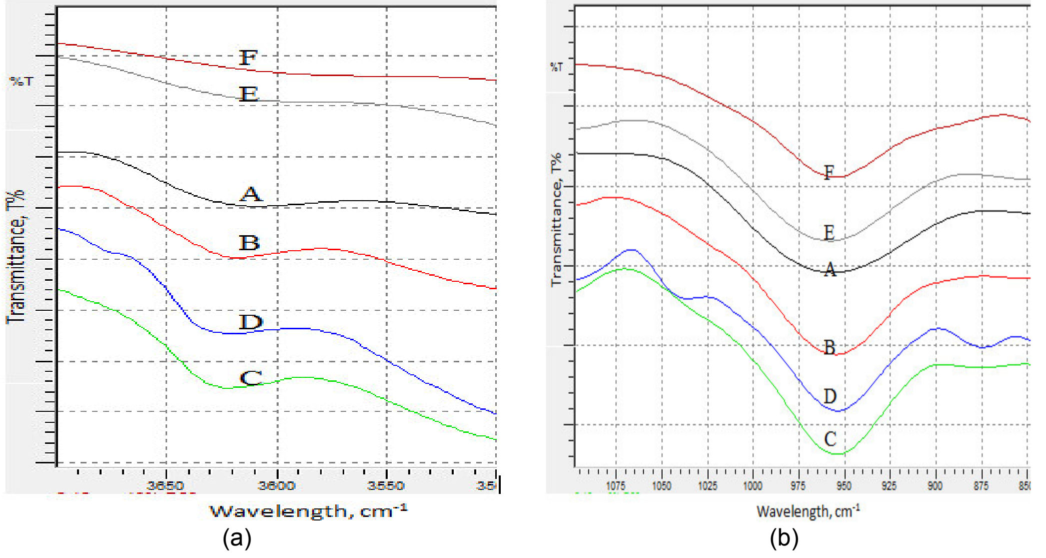

Figure 2. CH band around (a) 3630 cm^{-1} and C-S-H band around (b) 970 cm^{-1} for 10-20 nm nS modified cement paste sample at 28 days with (A) OPC (B) nSBC-2% (C) nSBC-3% (D) nSBC-5% (E) nSBC-7% (F) nSBC-10%

Figure 2 shows (a) CH and (b) C-S-H band for all samples. Figure 2(a) clearly shows that samples with 2%, 3% and 5% nS replacement have higher intensity compared with OPC, 7% and 10% nS samples. This is due to the addition of nS in cement paste that accelerated the hydration rate which caused more CH to be formed. On the other hand, CH bands for nSBC-7% and nSBC -10% have lower intensities than OPC because of the agglomeration and dilution effects that was caused by higher percentage of cement replacement. Other studies had also reported that 7% and 10% nS replacement showed no participation in the hydration of cement paste and caused less CH to be produced (Elkady et al, 2013; Mostafa and Brown, 2005). Meanwhile, Figure 2(b) shows that, for C-S-H, samples with 2%, 3% and 5% nS replacement have higher intensity compared with the OPC sample. The increase in C-S-H band intensity indicates that there was more C-S-H produced with the addition of nS due to the pozzolanic reactivity of nS with CH. As nSBC-3% sample shows the deepest and steepest downward peak for the C-S-H band, it can be concluded that the optimum dosage for nS as partial cement replacement in cement paste is 3%.

Further characterization on the three critical samples was performed in comparison to the control sample using XRD to confirm the FT-IR results. Figure 3 shows the X-ray diffractograms for OPC, nSBC-2%, nSBC-3% and nSBC-5% at day 28. Crystalline CH appeared on all samples at 2θ angle of around 18.07°, 34.17° and 47.19°while amorphous C-S-H can be analysed at peak around 29.54°. In the same figure, significant intensity of C-S-H can be found on sample nSBC-3% which substantiated the FT-IR findings.

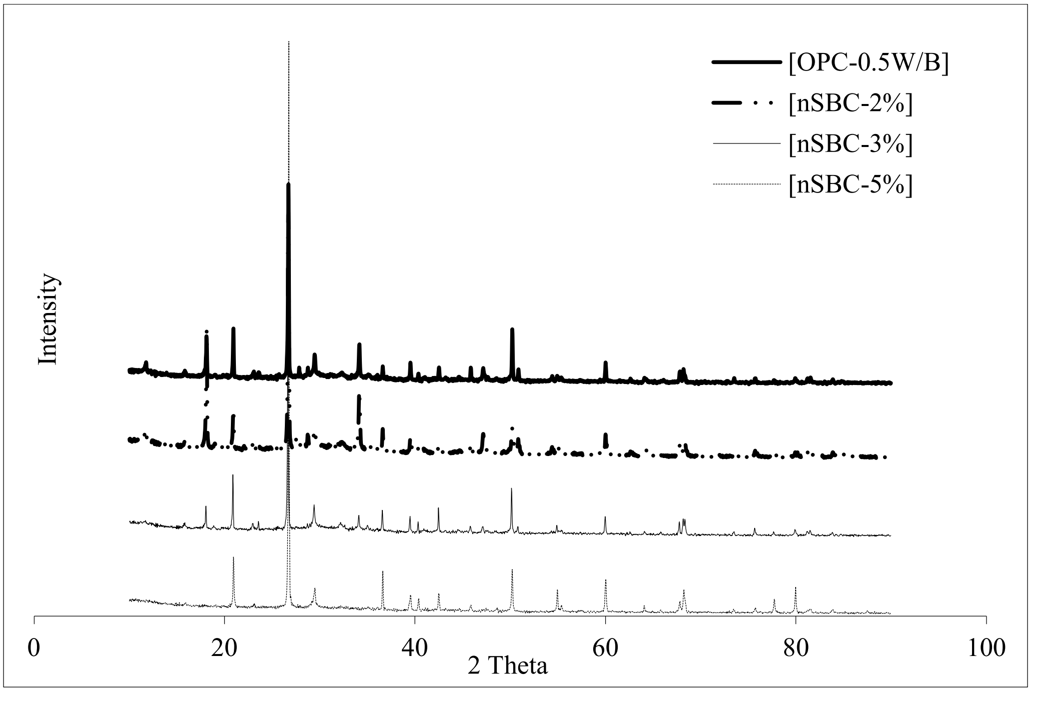

Figure 3. XRD pattern (CuKα radiation) of OPC (control) and nSBC at day 28

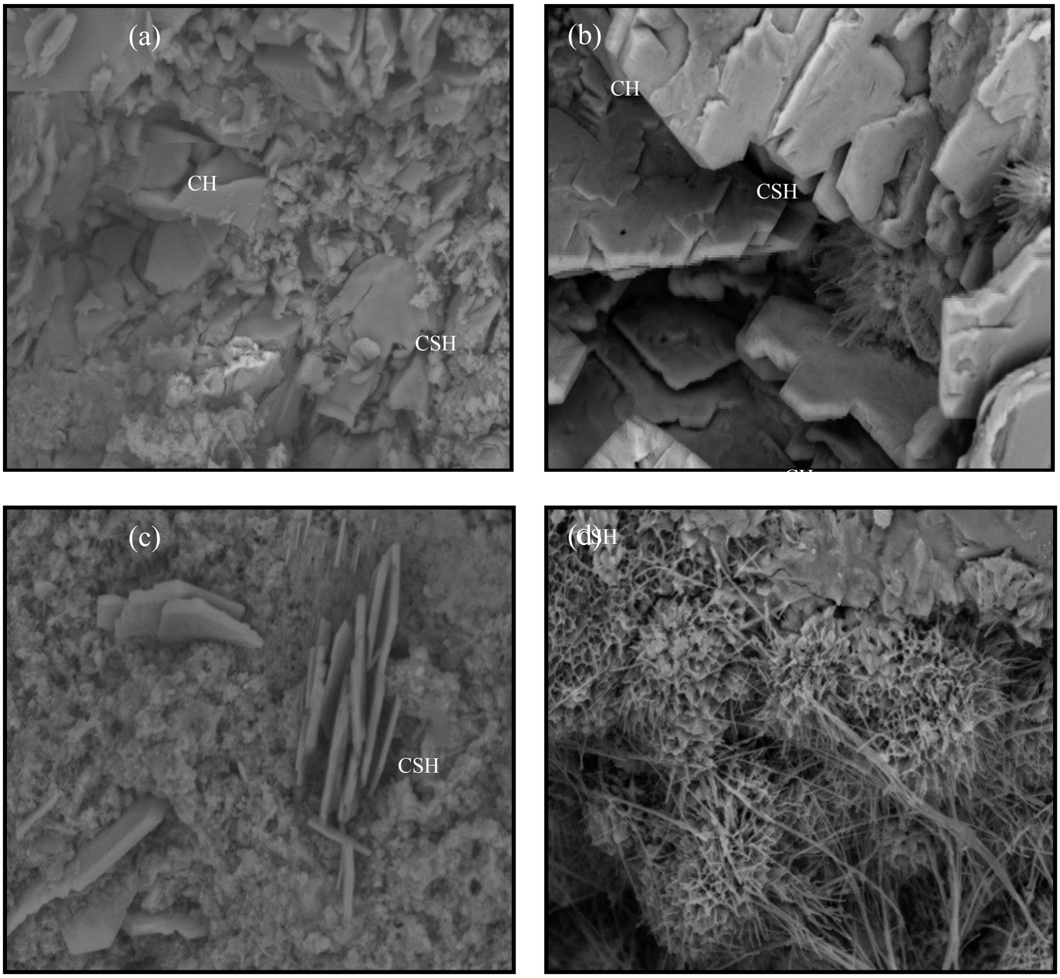

Figure 4. SEM micrographs of: (a) OPC, (b) nSBC-2%, (c) nSBC-3% and (d) nSBC-5% at day 28

Morphology and mineral ratio analysis using SEM/EDS were used to further corroborate the FT-IR and XRD results. Figure 4 shows the SEM micrographs of the four samples (OPC, nSBC-2%, nSBC-3% and nSBC-5%) after 28 days. CH that has plate-like morphology can be seen present on all samples except for poor view on nSBC-5% (Figure 4(d)). For OPC sample, reticulated or lace-like morphology that implied C-S-H produced at early hydration stage can also be seen on nSBC-3% and more obvious on nSBC-5% sample. C-S-H of middle-stage hydration products that look like needles radiating from grain can be seen in all samples though at different density. In the meantime, spherical agglomerates that can be observed on the CH structure in OPC, nSBC-3% and nSBC-5% samples were attributed to the C-S-H that was formed during late stage of hydration process (Gartner et al, 2002).

The higher density of the C-S-H compared with CH when the composition of nanosilica had been increased indicates that the pozzolanic reaction increased with the increase in nanosilica content. The characteristic of C-S-H produced can be further investigated through its Ca/Si ratio which can be estimated using EDS as shown in Figure 5.

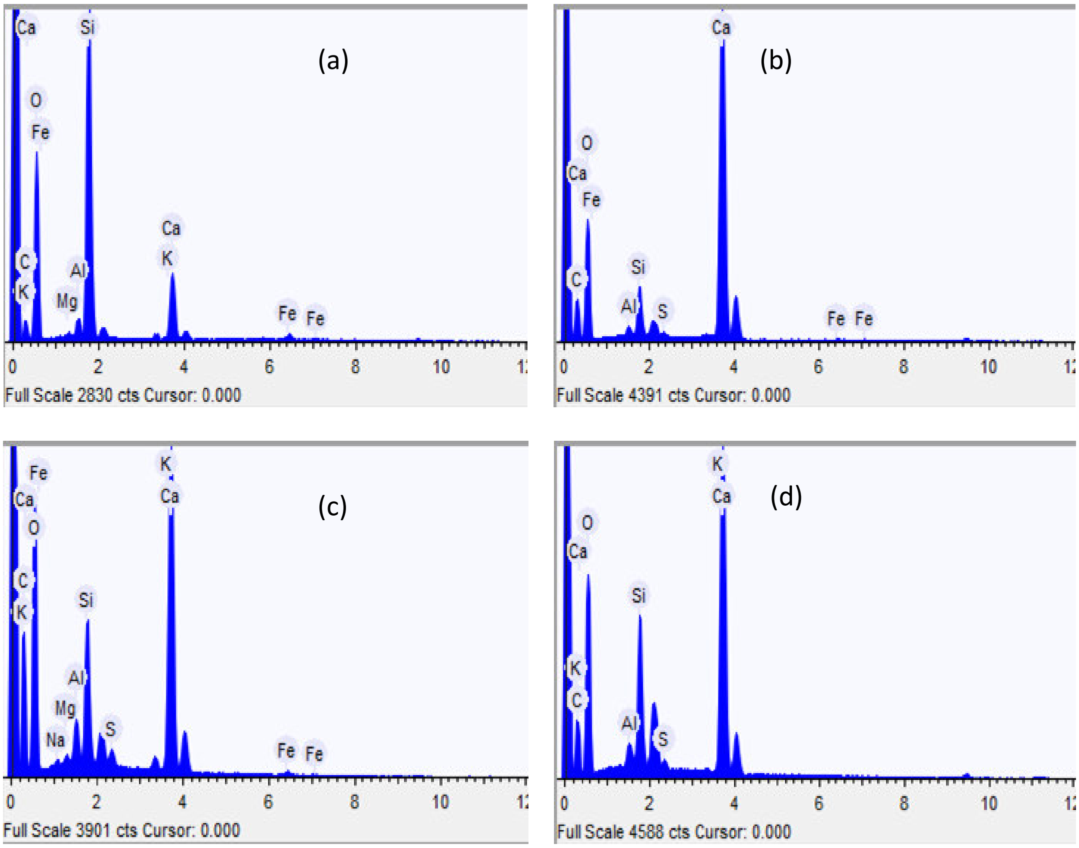

Figure 5. EDS pattern (CuKα radiation) of: (a) OPC, (b) nSBC-2%, (c) nSBC-3%, and (d) nSBC-5% at day 28

The Ca/Si ratio of C-S-H in OPC, nSBC-2%, nSBC-3% and nSBC-5% samples had been calculated as 0.276, 8.812, 3.014 and 2.756, respectively. Previous research showed that the Ca/Si ratio for Tobermorite and Jennite are 0.83 and 1.5, respectively (Chen, 2002). Besides, ratio of more than that means C-S-H is of more amorphous structure and ratio near 2 resembles C-S-H with Tobermorite and Jennite structure in mixture. The former can be applied here to describe that OPC, nSBC-2% and nSBC-3% possessed C-S-H structure far more amorphous than Tobermorite while the latter explained that the structure of C-S-H in nSBC-5% can be approximated to be Tobermorite-Jennite mixture.

CONCLUSIONS

CH and C-S-H had been characterized in OPC and nSBC samples using FTIR, XRD and SEM-EDS to investigate the progress of pozzolanic reaction. By using FTIR, cement paste samples replaced with 2%, 3% and 5% nS in 10-20 nm size can be shown to have enhanced the pozzolanic reactivity. The reduction of the CH was due to the pozzolanic reaction with nS that produced additional C-S-H gel. While for the samples with 7% and 10% nS, no sign of accelerated pozzolanic reaction can be observed due to the not well-dispersed nS and dilution effects within the cement paste matrix and the tendency to form agglomerates that limit the amount of nS joining the hydration process. Furthermore, XRD analysis proved that samples that contained 3% nS has the highest pozzolanic reactivity and the SEM-EDS was utilized to validate this analysis. As a conclusion, pozzolanic reactivity in the microstructure of the cement system can be investigated using FTIR, XRD and SEM-EDS where the optimal nS replacement can be determined (ie. 3% of 10-20 nm of nS). However, further study should be performed to quantify the extent of pozzolanic reaction so the optimum pozzolan dosage can be further confirmed and validated.

ACKNOWLEDGEMENTS

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SEISMIC BEHAVIOUR OF PRECAST SHEAR KEY WALL UNDER IN-PLANE LATERAL CYCLIC LOADING

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Abstract
A full-scale of single bay double-storey house (5.1m x 4.5m x 3.9m) was constructed using precast shear key wall panel and cast-in-situ concrete for column, floor slab and foundation beam at Construction Research Institute of Malaysia (CREAM), Malaysia. This building is designed using British Standard (BS8110) which did not have any provision for seismic loading and no specific detailing connections at its joint. The aim of this study is to determine the global seismic behaviour of non-ductile double-storey house under quasi-static lateral cyclic loading. Two actuators were attached to strong wall and they were simulated using in-plane lateral cyclic loading and control displacement method. Fourteen(14) linear potentiometers were used to measure lateral displacement of precast wall panels and twenty six(26) strain gauges were used to monitor strain in steel and concrete. The experimental results showed that the house reached yield displacement at 0.3% drift and yield strength at 220kN. A lot of cracks were observed at shear key wall-column joints and wall-beam joints. The ultimate lateral strength of the structure recorded as 250kN with ultimate lateral drift of 0.4%. The house started to loss its strength known as strength degradation at 0.5% drift and became unstable at 0.7% drift. The biggest opening crack width is 15.95mm was measured at wall-column joints of second floor. The precast shear key wall panel has bigger crack width and low lateral strength capacity because it did not connect with any extruder bars from foundation beam. As a result, the shear key wall panel will collapse in out-of-plane direction and experience severe damage under medium and high intensities of ground motion. As a conclusion, this type of house can only survive under low magnitude of earthquake loading with PGA=0.08g and long distant-earthquakes which centered in Sumatra, Indonesia.

Keywords: *Quasi-static lateral cyclic loading, shear-key precast shear wall, yield displacement, wall-column interface, wall-beam interface.*

INTRODUCTION

Sustainability of residential houses is very important especially at maintenance and repairing stage due to frequent earthquake attacks. Nowadays, a lot of residential houses in Malaysia are constructed using modular system and it requires tilt-up construction method to assemble the precast structural components into the precast houses. Furthermore, almost of the residential houses in Malaysia are designed in accordance to British Standard where there is no provision for earthquake at all. Besides that, the quality of construction is still questionable especially in terms of workmanship, quality of the materials and lack of supervision at site. In order to solve these kinds of problems, tilt-up construction method was introduced in the construction of precast buildings to increase the quality of the houses. This technique has been developed in the United States since 1908 (CCANZ,1990) and widely used in Malaysia since 1960's (Thanoon et. al, 2003) for the construction of apartments, residential houses, schools, hypermarkets, commercial/industrial buildings and others.

Most of the tilt-up precast wall panels have the potential to carry lateral loads and gravity loads without any intermediate columns (Hamid, 2006). If the walls are squat (generally when the height is less than 150% of the panel width) significant transverse shear reinforcement is required to resist horizontal shears arising from seismic and wind loading. Historically, tilt-up wall panels have been amongst the most vulnerable type of structures under earthquake excitation due to lack of attention in providing adequate detailing at their connections, structural integrity and quality of workmanship (Hamid, 2009). Even though precast wall hollow core panel is vulnerable to earthquake but it can be designed in such as that its can resist earthquake excitation by using the concept of Damage Avoidance Design and rocking structures (Hamid and Mander, 2014). It is evidences through a good and excellent experimental results using a hybrid precast hollow core wall tested under biaxial lateral cyclic loading (Hamid and Ghani, 2013) and a multipanel precast hollowcore walls under in-plane lateral cyclic loading (Hamid and Mander, 2010).

In Malaysia, there are various types of precast wall panels such precast hollow core walls, solid precast wall panel, precast shear key wall panels and light weight precast wall panel are commonly used in the construction of residential houses. Nevertheless, these types of wall panels are designed only subjected to gravity and not design to resist earthquake loading. The seismic assessment of precast shear key wall panel showed that this type of wall are not survive under MCE (Maximum Considered Earthquake) and experience partial collapse of this type of house (Hamid and Mohamad, 2013). Therefore, the aim of this paper is to examine the seismic behaviour of precast shear key walls which used in the constructed of double-storey residential house and tested under in-plane lateral cyclic loading. A full-scale of single-bay of double-storey house was constructed using precast shear key wall panel and tested until failed under quasi-static cyclic lateral cyclic loading. The seismic performance of this house is measured in term of damages based on visual observation, lateral strength capacity, analysis of hysteresis loops, ductility, effective stiffness, deformability and equivalent viscous damping. Detail model and analysis on behavior factor and displacement estimation of precast shear key wall panel are performed by Tiong et. al., (2013). Their study showed that the modeling analysis has a good agreement with the experimental results.

DESIGN OF DOUBLE-STOREY HOUSE USING SHEAR-KEY PRECAST WALL PANEL

In Malaysia, most of reinforced concrete double-storey houses are designed using British Standard (BS 8110) by considering the gravity load only (dead load and imposed load) and disregard the impact of lateral load such as seismic loading. The structural components of the prototype double-house comprise of precast shear-key wall panel, foundation beam, cast-in-situ floor slab and cast-in-situ column which acting as connection between two wall panels were designed according to current standard. Foundation beam is designed to carry axial load from double-storey house and the hole in the foundation beam is used to anchor the house to the strong floor.

Table 1 shows the design parameters for construction materials, nominal concrete cover, dead load and imposed load on the structures. The dead load includes the self-weight of concrete, brick, finishes and M&E while the imposed load is $3kN/m^2$. However, this design load (vertical loads) did not include the lateral load and base shear which come from seismic loading and wind loading.

Figure 1 shows the plan and isometric view of double-storey house which constructed using precast shear-key wall panels on both side of the building. The size of the floor slab is 3500mm x 3000mm x 150mm, dimension of the foundation footing is 4500mm x 3900mm x 300mm, height of the house is 5000mm and the cast-in-situ column acting as connection between two walls is 300mm x 300mm x 150mm. This type of building is consider as partially Industrialized Building System (IBS) where forty percent (40%) of total construction are precast shear key wall panel structural component whereas another sixty percent of the construction are the cast-in-situ concrete beams, columns and floor slabs.

Table 1. Design parameters and types of loading

Design Parameter	Values
Compressive strength of concrete, fcu	30 N/mm^2
Characteristic strength of high yield steel, fy	460 N/mm^2
Characteristic strength of mild steel, fyv	250N/mm^2
Characteristic strength of BRC, fy	485 N/mm^2
Nominal concrete cover for slab	20mm
Nominal concrete cover for wall panel	20mm
Nominal concrete cover for column	25mm
Dead load for concrete	24kN/m^2
Dead load for brick	19kN/m^3
Dead load for finishes	1.2kN/m^2
Dead load for M&E	0.5kN/m^2
Live load on the floor slab	3 kN/m^2

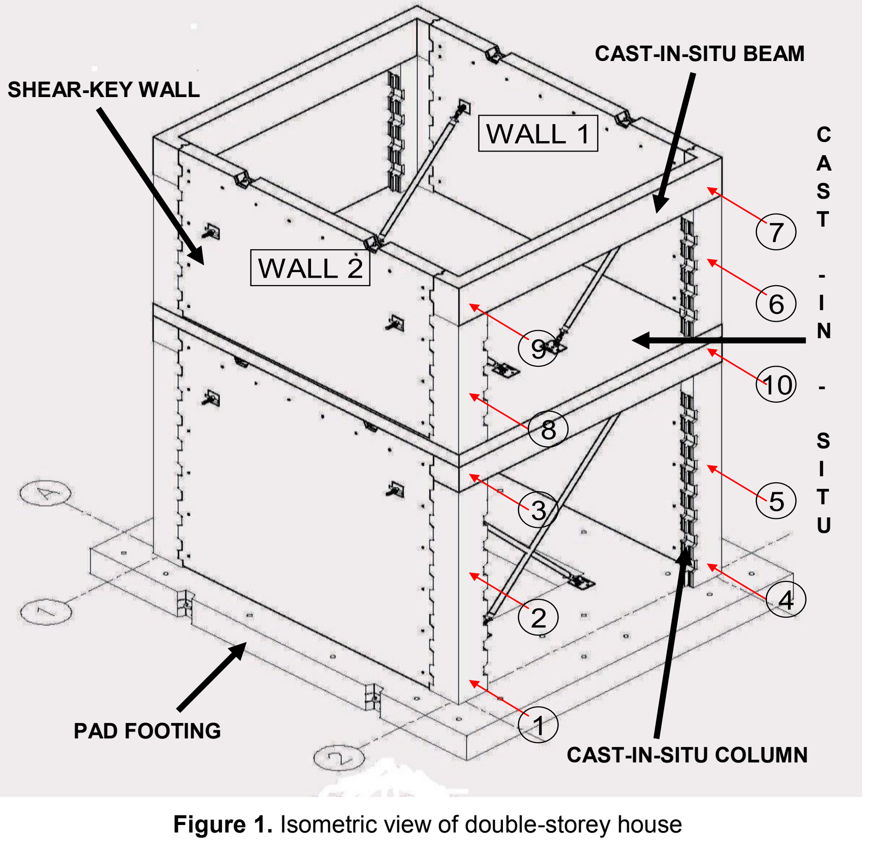

Figure 1. Isometric view of double-storey house

CONSTRUCTION OF PROTOTYPE DOUBLE-STOREY HOUSE

After finished designing a single bay of double storey house, the next stage is to construct the specimen on strong floor in heavy structural laboratory. Figure 2 shows the location of first precast shear-key wall panel sitting on pad footing in the laboratory. Tilt-up construction method was employed in the construction of double-storey house. Figure 3 demonstrates that the second wall panel was positioned in opposite direction of the first wall using two steel props to support precast wall panel. These two walls were resting on top of pad footing and no extruded bars were used to connect between precast wall and pad footing. Ten tonnes of crane was used to lift and holding precast shear-key in vertical positioned. Figure 4 displays two precast walls connected to each other using cast-in-situ beam and slab concrete. The extruded bars from precast wall were used to connect with cast-in-situ beam and then, the beam was connected to the floor slab for the first floor. Figure 5 exhibits the construction of first floor of double-storey house using two precast shear-key wall panels, cast-in-situ floor slab and cast-in-situ beams.

Figure 2. Precast shear-key wall is placed on pad footing at strong floor.

Figure 3. Construction wall panel at ground floor.

Figure 4. Cast-in-situ beam and slab are used to joint two wall panels.

Figure 5. Construction of first floor of the house.

EXPERIMENTAL TEST-UP

When the double storey house achieved the sufficient strength, it is important to paint the specimen with white colour water based paint before start testing the specimen. The main reason of painting the specimen with white colour is to observe the opening and closing gap of the joints and to mark the crack on the specimen. Figure 6 shows the systematic arrangement of ten (10) linear potentiometers in-plane directions of WALL1 and WALL2. Each wall consists of five potentiometers to measure the in-plane lateral displacement of WALL1 and WALL2. The hysteresis loops (load versus displacement) are plotted based on the data captured by potentiometers. Figure 7 exhibits the location of ten(10) strain gauges which attached to the transverse reinforcement bars in BRC-A7. Strain gauges were attached to the fabric wire mesh prior to pouring concrete to the steel mould. Strain gauge is used to measure the elongation of transverse reinforcements bar during testing. Fabric wire mesh was used in shear-key precast wall panel as the replacement of normal reinforcement bars which arrange in vertical and transverse directions.

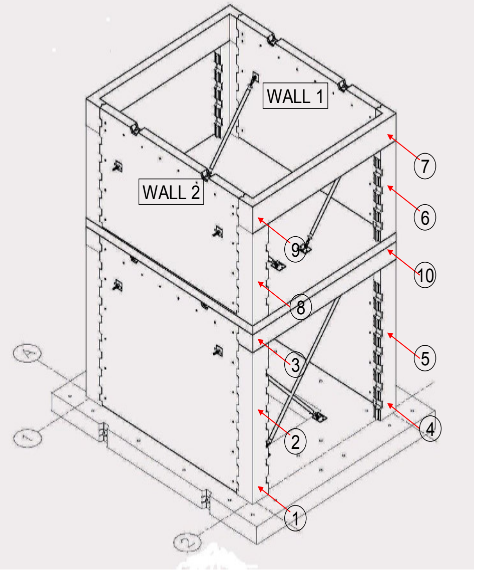

Figure 6. Location of linear potentiometers

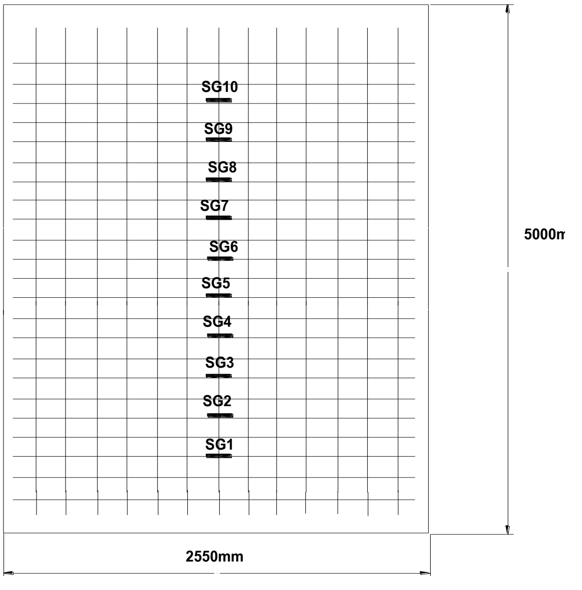

Figure 7. Location of strain gauges in BRC-A7.

EXPERIMENTAL RESULTS

Cracks at Wall Interfaces

It is important to monitor the progressive cracks and damages of the prototype model under in-plane lateral cyclic loading starting from initial drift until ultimate drift. The initial drift of the testing began at ± 0.05% drift with frequency ratio of 0.006. The prototype model was subjected to 2 cycles for ±0.05% drift under in-plane direction. Although, there are very small hairlines crack visible between the foundation and ground floor of wall panel during the test but the wall still behave in the elastic regions. Second drift of ± 0.1% is applied on top of the specimen and the diagonal crack become wider which appeared at column as shown in the Figure 8. By increasing the drift up to ±0.3%, wider and longer cracks were observed on both sides of column surfaces. Figure 9 displays several mark-line cracks on wet connection of column and it started to propagate from edges to inners part of the column. Further increment in drift, more hairlines cracks were developed and wider cracks were observed in the column and beam of the double-storey house under in-plane lateral cyclic loading.

Figure 8. Hairline cracks observed at +0.1% drift between the joint of wall and column.

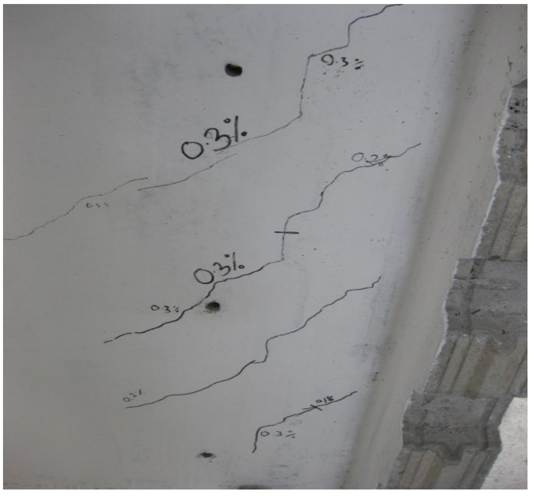

Figure 9. More hairlines cracks were observed at +0.3% drift with cracks width of 0.5mm.

Figure 10 exhibits bigger cracks emerged at first floor beam which connected slab and wall panel together when +0.4% drift was applied on both walls. Diagonal crack was detected on cast-in-situ beam and spalling of concrete cover occurred at wall-column interface. Figure 11 illustrates wider cracks were observed at wet joint between wall-column interface during +0.5% drift as the cyclic load applied on top of the wall. Wall-column interface is considered as the weakest point in the structure where the precast shear-key wall panel and cast-in-situ column behave independently when lateral cyclic force applied to the structures.

Figure 10. Cracks occur at first floor beam during +0.4% drift.

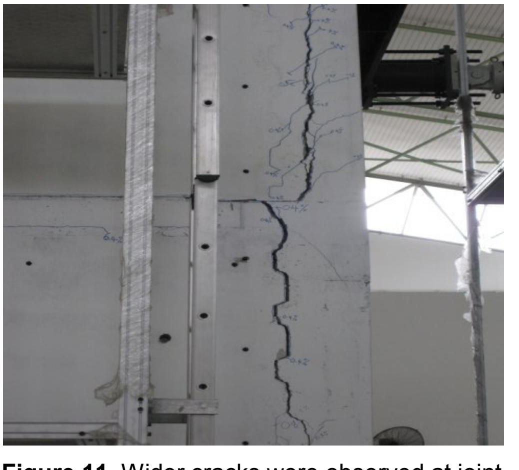

Figure 11. Wider cracks were observed at joint wall-column interface during +0.5% drift.

Figure 12 displays the visual observation of wall-column interface when subjected to +0.6% drift with 2 cycles for each drift. Instability of the prototype house occurred when the applied strength exceeding the yield stress of longitudinal reinforcement bars in cast-in-situ column. It was detected at Point 6 with crack width of 10.46mm during the opening gaps of ACUATOR 1 located on top of WALL 1 and ACUATOR 2 located on top of WALL2. Figure 13 exhibits wider crack at the same location (Point 6) when +0.7% drift applied on in-plane direction of the both walls. It is also observed that more spalling of concrete cover occurred at wall-column interface when the concrete experience tension zone on both surfaces of wall and column.

Figure 12. Cracks on wall-column interface during 0.6% drift at Point 6.

Figure 13. Cracks on wall-column interface during 0.7% drift at Point 6

Hysteresis Loops of Wall1 and Wall 2

The hysteresis loops (load versus displacement) were plotted based on displacement data obtained from five(5) linear potientiometers marked as LVDT4, LVDT5, LVDT10, LVDT6 and LVDT7 which located on edge of WALL1. LVDT7 experienced the biggest displacement as compared to the others linear potientiometers because its located parallel to applied load marked as ACUATOR 1 and it is also indicates that maximum reistance strength of wall panel supplied by the double acuator. Figure 14 displays the hysteresis loops for LVDT7. The maximum load is 300kN occured at +0.4% drift with lateral displacement of 18mm. After ±0.4% drift, the structure lost its strength which known as strength degradation. Strength degradation occurred at ±0.5% drifts and ±0.6% drifts. Figure 15 displays the hysteresis loops for LVDT9 which on edge side of WALL2 and the closest distance to ACUATOR 2.The maximum lateral load recorded is 320kN at ultimate drift of 0.4%. Strength degradation occurs at 0.5% and 0.6% drifts when WALL2 experienced inelastic behaviour with wider opening gap between wall-column interfaces. The elastic limit occurrs when there is a linear relationship between load and displacement before the wall yielded. The inelastic occurs when the wall behave above elastic limit under plastic zone and there is no linear relationship between load and displacement.

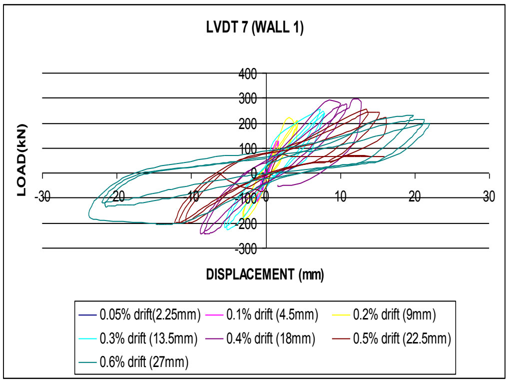

Figure 14. Hysteresis loops of LVDT7 on WALL1.

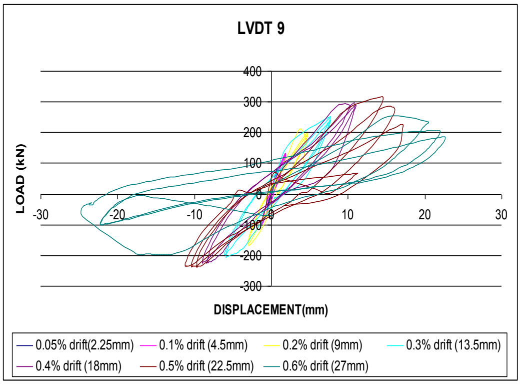

Figure 15. Hsyteresis loops of LVDT9 on WALL2.

Stiffness and Ductility

Beside strength capacity of WALL1 and WALL2, another two parameters which is important to measure are stiffness and ductility using hysteresis loops as shown in Figure 14 and 15. From experimental results, the stiffness and ductility of WALL1 and WALL2 are calculated in order to monitor the strength and seismic behaviour of prototype model from elastic to inelastic regions after applying lateral cyclic loading.

Stiffness is defined as the ratio of load (kN) over lateral displacement (mm) and there are two different types of stiffness. The first stiffness is known as elastic stiffness (Ke) calculated as the ratio of yield load over yield displacement. Elastic stiffness is only cover within the elastic region. The second stiffness is called secant stiffness (K_{secant}) and cover inelastic region. The secant stiffness is covered between yield and ultimate load. Usually, elastic stiffness has bigger value than secant stiffness. Based on this experimental work, shear key of WALL1 has an average elastic stiffness of 21.31kN/mm and an average of secant stiffness of 5.19kN/mm. Therefore, it can be concluded that the elastic stiffness is four times higher the secant stiffness. Table 2 tabulates the experimental results of the stiffness and ductility of shear key for WALL1 and WALL 2 starting from 0.05% drift until 0.6% drift. The average elastic stiffness for shear key of WALL2 is 21.27kN/mm and secant stiffness is 9.7kN/mm. The elastic stiffness for shear key of WALL2 is three times bigger that secant stiffness.

Ductility is defined as the ratio of applied displacement over yield displacement. Both of WALL1 and WALL2 have the similar ductility starting from 0.05% drift until 0.6% drift as shown in Table 2. In order for the structure resist earthquake loading, the ductility of the building should range from 3 to 6. However, double storey house which constructed using precast shear-key wall panels has the ductility of 2. Therefore, the type of building did not survive under strong earthquake attack as the measured ductility is less than 3 as indicates in Eurocode 8 (EC 8).

Table 2. Stiffness and ductility for WALL1 and WALL 2

Drift (%)	Stiffness (WALL1)	Ductility (WALL 1)	Stiffness (WALL 2)	Ductility (WALL 2)
0.05	Ke= 29.3	μ = 0.17	Ke= 22.22	μ = 0.17
0.1	Ke= 27.11	μ = 0.33	Ke= 36.4	μ = 0.33
0.2	Ke= 19.5	μ = 0.67	Ke= 17.11	μ = 0.67
0.3	Ke= 9.33	μ = 1.00	Ke= 9.33	μ = 1.00
0.4	Ksecant= 3.78	μ = 1.33	Ksecant= 10.22	μ = 1.33
0.5	Ksecant= -3.78	μ = 1.67	Ksecant= 4.44	μ = 1.67
0.6	Ksecant= -8	μ = 2.00	Ksecant= -14.44	μ = 2.00

Equivalent Viscous Damping (ξ_{Eq})

Another important parameter which can be calculated using hysteresis loops of LVDT7 in WALL1 and LVDT9 in WALL2 is the equivalent viscous damping. The equivalent viscous damping is one of the key parameters in determining the amount of energy dissipated and efficiency of energy dissipators during earthquake excitation (Hamid, 2006). This energy is released during earthquake and the damage of the structure members is due to this energy. The total area under a single loop can be defined as the total amount of work done in positive and negative direction under one cyclic loading. It can be defined as the amount of damping that provides the same bandwidth in the frequency response curve as obtained experimentally for an actual system (Chopra, 2007).The following equation has been used by many researchers to determine the equivalent viscous damping of the system:

$$\xi_{eq} = \frac{1E_D}{4\pi E_{so}} = \frac{1}{2\pi}\frac{E_D}{F_{\max}\Delta_{\max}} \tag{1}$$

The energy dissipated in the actual structure is given by the area E_D enclosed by the hysteresis loop and E_{So} is the strain energy. The strain energy is defined as the area under the straight line within the elastic regions up to the maximum load and displacement for that particular loop. This parameter can be determined from the hysteresis loop for each cycle as shown in Figure 16.

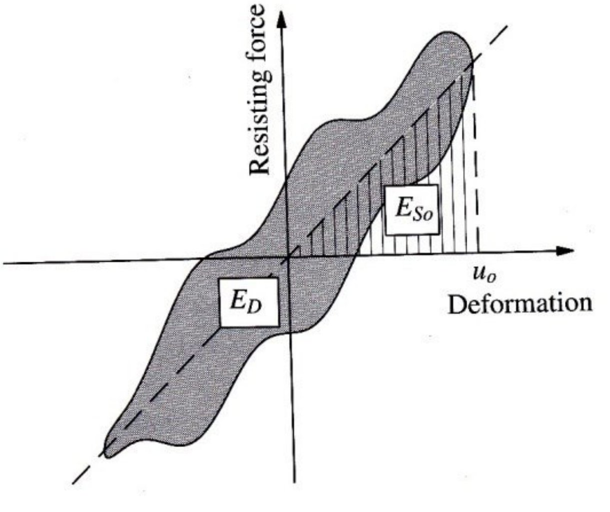

Figure 16. Energy dissipated E_D in a cycle of harmonic vibration determined from experiment work.

The equivalent viscous damping is calculated for WALL1 and WALL2. During experimental work, the testing was conducted using two cycles for each drift. Equivalent viscous damping is calculated for CYCLE1 and CYCLE2 for each drift. Figure 17 shows the equivalent viscous damping for WALL1 denoted as CYCLE1 and CYCLE2 for each drift. The equivalent viscous damping has higher value in CYCLE1 as compared to CYCLE2. Figure 18 shows the relationship of equivalent viscous damping with drift for WALL2 starting from 0.05% drift up to 0.6% drift. It can be seen that the equivalent viscous damping for the CYCLE1 is higher than CYCLE2. The area under each hysteresis loop is representing the amount of work done by pushing and pulling the prototype model under in-plane cyclic loading. The amount of work done is used to destroy precast shear-key wall panel labeled as WALL1 and WALL2, cast-in-situ beam, column and slab of the specimen. The visual damages of the structures can be observed during experimental work such as opening and closing of gap between wall-column interfaces, spalling of concrete and crack on the surface of column, wall panel, beam, slab concrete, spalling of concrete cover, yielding of reinforcement bars and instability of the structure.

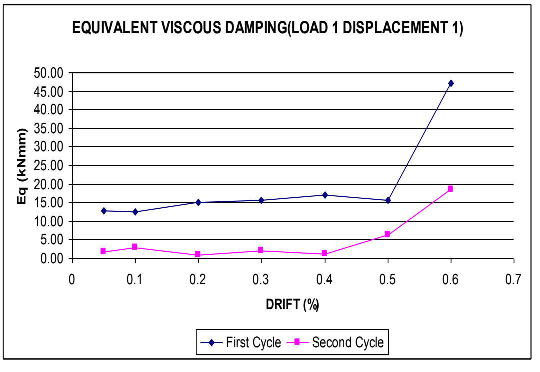

Figure 17. Equivalent viscous damping for WALL 1.

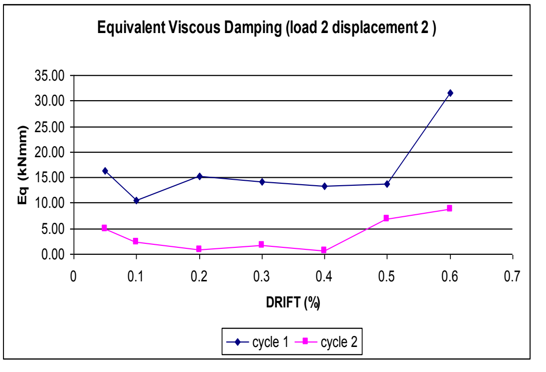

Figure 18. Equivalent viscous damping for WALL 2.

CONCLUSIONS AND RECOMMENDATION

The following conclusions and recommendations can be drawn as follows:

1) Visual observation shows that a lot of cracks were observed at wet joint between column and precast shear-key wall panel. Wall-column interface is considered the weakest point in the structure because reinforcement bars from wall did not joint to the reinforcement bars in the column.
2) The double-storey house which constructed using precast shear key wall panel only can survive under low intensity of earthquake due to small amount of ductility factor measured at 2 which known as Ductility Class Low (DCL). In order to survive under earthquake attack, the ductility of the structure should range from 3 to 6.
3) The percentage of equivalent viscous damping for the first cycle is higher than second cycle because more energy is required to resist the strength capacity at elastic region (first cycle) than in the inelastic region (second cycle).
4) It is recommended that the shear-key precast wall panel should be modified by considering the seismic loading. Redesign the shear-key precast wall panel by special attention need to be done at the connection detailing of wall-column interface. The

extruded bars from foundation beam should be connected to the precast shear key wall and the transverse reinforcement bars from precast shear key wall panel should joint to the cast-in-situ column in order for them to react as one system not as individual structural components under seismic actions.

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CODIFICATION AND APPLICATION OF SEMI-LOOF ELEMENTS FOR COMPLEX STRUCTURES

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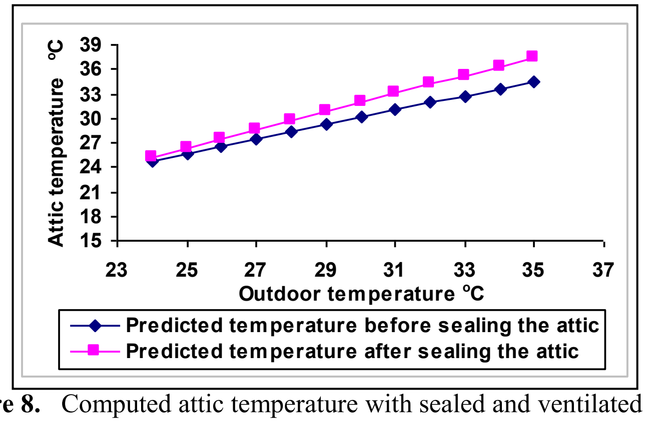

Figure 8. Computed attic temperature with sealed and ventilated attic

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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.

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