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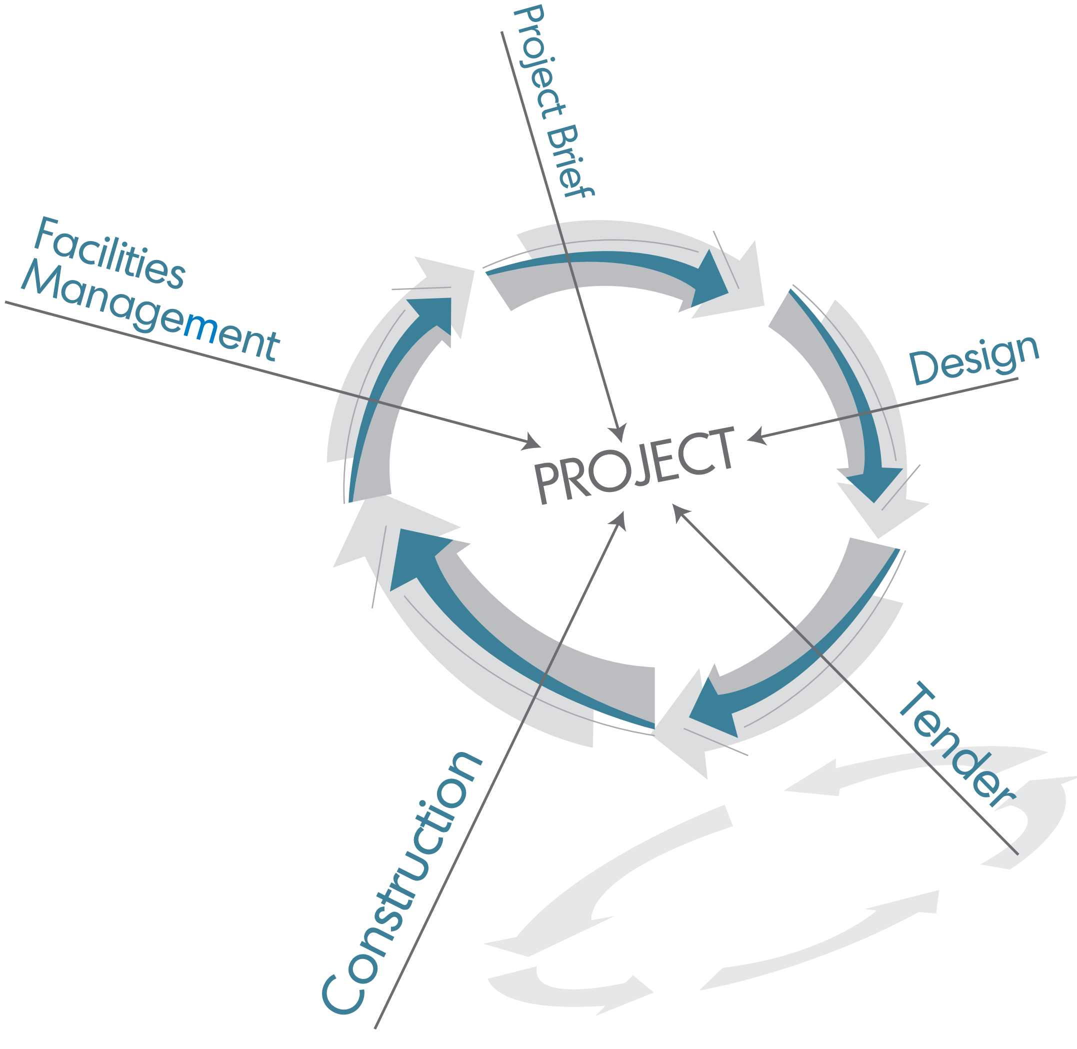

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Editorial

Welcome from the Editors

Welcome to the thirty-fourth (34th) issue of Malaysian Construction Research Journal (MCRJ). In this issue, we are pleased to include eight papers that cover a wide range of research areas in construction industry. The editorial team would like to express our sincere gratitude to all contributing authors and reviewers for their contributions, continuous support and comments.

In this issue:

Linariza Haron presented the project management curriculum review through project manager's viewpoints. Qualitative method using in-depth unstructured interview was used to meet the objectives of the study. Overall, the results of the interviews point to a positive direction particularly for the construction project management studies, provided that the dissemination of knowledge include subjects that matters, which are likely to contribute to the preparation of graduates to be industry ready.

S P Sreenivas Padala and J Uma Maheswari identified the problem related to the matrix-based methods for planning construction projects. Five matrix-based methods were involved as case study in this study using qualitative data from an underground metro construction project is utilized. The characteristics of the matrix-based methods are compared based on element types of dependency, aim, principle, method, analyse and output. In conclusion, matrix-based methods have the capability to model and analyse interdependent decisions systematically to meet a diverse range of project requirements.

Tan Let Hui et al., reviewed on the comparative study between the precast and conventional building construction. The area of comparison are the types and nature of the construction project, cubic content estimation, floor area and unit valuation, and bill of quantities. Besides that, the cost between the construction method is also compared. The cost comparison is between fully precast building system and conventional construction methods and also between precast slab and conventional building construction. It can be concluded that the precast construction method is still in concern for its higher direct cost for small-scale projects and the precast construction method in Malaysia is at a standstill while most project implemented the precast construction method by selecting only a particular system or partial-precast such as precast slab, wall-panel or beams instead of fully precast construction.

Farah Ain Zainudin et al., assessed the project risk management through Alternative Dispute Resolution (ADR) which promoting feasible means of settling construction disputes than via traditional litigation. Methodology used in this study is from secondary data sources. Secondary data collection involves an in-depth literature review of the areas of interest from pre-existing sources which come from previous and current work of experts in the field. In conclusion, based on the related literature, the Alternative Dispute Resolution (ADR) method is believed to be a feasible approach in resolving construction disputes unlike the intractable formalities of the traditional litigation system.

Akeem Gbenga Amuda et al., measured index properties such as moisture content, specific gravity, pH, liquid limit, organic and fibre content test of microstructure of amorphous peat through scanning electron microscope (SEM). The peat samples were collected from Kampung Endap, Kota Samarahan (KEP), Sarawak, Malaysia. The findings shows that the peat becomes more gelatinous, compact and relatively high specific gravity shown by the SEM micrograph.

Louis Teng Yeow Haur and Kelvin Kuok King Kuok forecast the precipitation in Kuching city by using salp swarm optimization neural network. The method conducted in this study is through input and output data determination, SSONN Model Development, SSONN Model Training, SSONN Model validation and testing and lastly performance evaluation. The findings encouraged to out new models which can really provide great performance and great consistency in forecasting water resources variables.

Ayub Awang et al., studied the building condition of heritage buildings at the Kuala Lumpur Police Training Centre (PULAPOL). This study aims to identify the type of damages and threats in the heritage buildings at PULAPOL Kuala Lumpur as well as analyse those particular damages and threats. Case study approach was conducted in this study. The findings show that the the heritage buildings at PULAPOL Kuala Lumpur face some damages and threats in the drainage and piping system, paint exfoliation, moss and rust formation, structural damage, attack from hitchhiker plants, and attack by insects.

Sia Ee Hou and Kamal Abdul Razak investigated the factors affecting construction delays of foundation works in Klang Valley, Malaysia. Qualitative approach utilised in this study to identify possible factors that cause the delays in foundation works. The findings show that all five independent variables, the geotechnical information, foundation design, plant and equipment, project progress payment and supply of materials are the factors that contributed to these delays. Based on the results, the geotechnical information and plant and equipment are the factors that mostly agreed by the respondents.

Editorial Committee

A PROJECT MANAGEMENT CURRICULUM REVIEW THROUGH PROJECT MANAGERS' VIEWPOINTS

Linariza Haron
Construction & Project Management Programmes, School of Housing, Building & Planning, Universiti Sains Malaysia.

Abstract
This paper presents the industry practitioners' perspectives on project management practice, expressed as narratives of their experiences, and their expectations and reservations toward the profession as a taught course. The main objective was to ascertain the topics and subject areas that are all-important and should be offered for instruction to ensure students have the knowledge to meet the demands of the industry. The data collection stage involved carrying out in-depth unstructured interviews with practicing project managers from the public and private sectors. The analysis phase begins after the interview transcripts were completed and compiled. Key themes were picked out, cross-compared, re-organised and interpreted to reflect the findings for project management knowledge and practice. At best, the narrative analysis has mapped out the essential modules for a project management degree *must* include general project management studies *before* specialization can take place. Some key areas and project management processes are business acumen, leadership, communication, soft skills, managing people, budget and finance. Next, when specializing in the construction sector, project management must be approached from the practice framework with more emphasis given to tools applied in the initiation, planning, executing, monitoring and closing processes. Lastly, the course of study can be strengthened with a research dissertation and a project management simulation exercise. This perspective potentially confirmed that managing by "trial and error" is no longer an option; particularly when graduate students are expected to undertake their project management assignments with speed and competency.

Keywords: *Project management; knowledge; practice; construction project management; narratives.*

INTRODUCTION

The MSc. Project Management Programme at the School of Housing Building and Planning, Universiti Sains Malaysia is perhaps one of the longest running programmes in the higher education sector in the country. The original scheme to the programme was prepared by members of the committee on Building Economics and Management of the School. They received strong support from prominent academics of the Master of Science degree course in Project Management at the University of Reading, UK and Professor Anthony Walker from the University of Hong Kong, then (Fisher, 1989). The scope of the course was formulated in such a way as to "cover wider [sic.] spectrum and encompass various disciplines that are related to construction project management" (Fisher, 1989). Therefore, in this respect, the programme prepares students for project management in the field of construction without losing the full meaning of project management for the client, from inception; design and planning; construction until completion and operation stages (Fisher, 1989). Over the years, the programme has grown from strength-to strength and the students have done very well and this is seen from the favourable figures for student intake, sometimes totalling 40 to 60 registrations per academic year. However recently, there has been a reduction in the intake that, at its worst, saw an average of only 10 registered students. Besides, there are a lot more project management courses on offer either at graduate or undergraduate levels. Today, in view of global and local challenges, it begs the question whether the programme is still relevant. Therefore, the School saw the need to review the MSc. Project Management programme, to find ways to improve the range and quality of its courses while remaining current.

The Curriculum Review Project began on 1st August 2013 and since then there has been four stages of data collection and these were reported elsewhere. The present report documents the findings from interview sessions carried out with Project Management practitioners in the industry. The main objective was to ascertain topic areas and subjects that are all-important and should be offered in a project management taught course. Morris, Patel & Wearne (2000) reported on a research with almost similar terms of reference except that it was for updating the professional project management Body of Knowledge.

METHODOLOGY

A key question that was raised in this study was, "What are the other important subject areas that should be taught in project management courses to ensure students have the knowledge to meet the demands of the industry?" Since the question demands a holistic view of the issue, it became apparent that a qualitative research inquiry has the defining characteristics and advantages over the quantitative approach in terms of its contextualized study, its flexibility in conduct, its reflexive nature and its focus on interpretation rather than quantification (Cassell & Symon, 1994). The data collection stage entailed carrying out in-depth unstructured interviews with practicing project managers in order to draw out their personal narratives that formed their perceptions and perspectives on the body of knowledge for Project Management. The open-ended interview allowed for both the interviewer and the interviewees to shape the course of the interview in an active manner.

The selection of Project Managers was sourced from the Associations of Project Managers registered in the country namely, The Association of Construction Project Managers (ACPM) and The Malaysian Asset and Project Management Association (MAPMA). Letters were sent out through e-mails to the Presidents of the Associations and subsequently, a few Project Managers were identified. The interviewer planned for two half day slots over a two-week period in April 2017; this provided up to 8 slots for the interviews. Six project managers agreed to participate in the interviews which were held in Kuala Lumpur (see Table 1).

Table 1. Schematic Interview Schedule – Actual Take-up

Dates	20 April 2017	21 April 2017	27 April 2017	28 April 2017
Morning session	Project Manager #1 ca: 9:00am – 11:30am	X	Project Director #3 ca: 10:30am – 11:40am and Project Manager #4 ca: 12:00pm – 02:00pm	Project Manager #5 ca: 9:00am – 11:20am
Afternoon session	Project Manager #2 ca: 2:30pm – 4:30pm	X	X	Project Director #6 ca: 3:30 – 5:30pm

Participants' Attributes

The participants were all active practicing project managers in the public and private sectors and prior to the interview sessions, they filled up the information sheets together with their consent forms, duly signed. This ensured their information would be kept confidential. A short description of each interviewee's bio-profile is given below:

- Project Manager #1 is a male with 30 years' working experience in a specialist industry sector and is currently a freelance trainer. He has been a Certified Project Manager (PMP) since 1995.
- Project Manager #2 is a female with more than 20 years' working experience in the public service sector and she was among the pioneers of assessors in the department. She is a Certified Project Manager (AIPM) CBAS (PWD).
- Project Manager #3 is a male with close to 30 years' experience with PMCs delivering projects from the private sector. He is a Certified Project Manager (PMP) CCPM (CIDB).
- Project Manager #4 is a female, who was the protégée of Project Manager#3. She is currently on track to vie for the CCPM (CIDB) certification and holds the MSc. Integrated Construction Project Management (UiTM) degree.
- Project Manager #5 is a male with more than 20 years in the public service sector and he was among the pioneers in the development of the risk management knowledgebase for public sector use. He was trained as an Electrical Engineer and is a Certified Project Manager (AIPM) CBAS (PWD).
- Project Manager #6, a male who has trained as a Civil Engineer and who had more than 20 years' experience with PMCs delivering mega infrastructure projects. He is now serving the company in the capacity of a Project Director and he is registered with the Board of Engineers Malaysia (BEM).

The Interview Guide

The session typically began with preliminary greetings and a summary introduction to the MSc. Project Management Programme offered by the school. Then, participants were shown the results of the comparative analyses undertaken by the Programme on current subject courses against other project management curricula that were offered locally and globally across institutions and professional bodies. After that, the participants began their narratives, guided by the main question, the occasional probes and follow-up questions (Rubin & Rubin, 2012) posed by the researcher throughout the sessions.

Analysing the Data

The outcome of the six interviews amounted to a total of nine and a quarter hours of recording time and many more hours were taken to transcribe. Each participant relayed their personal description of project management experiences and insights; each presented very rich data. The next task required "repeated listenings [sic.] coupled with methodic transcribing, which often led to insights that in turn shape how we choose to represent an interview narrative in our text" (Riessman, 1993:60). Elsewhere, Rubin & Rubin (2012) suggested a seven-step data analysis process of the interview responses which the researcher adopted and modified for this study. It began with a compilation of the full transcript of the interviews while simultaneously looking out for the themes and ideas to code. Next, the wordiness of the transcripts necessitates the use of a matrix to collate key themes and issues across the six respondents. These themes were sorted and re-sorted; cross-compared among the interviewees and reorganised to reflect the findings that were pertinent to the main subject matter. In essence, this analysis conforms to the categorical – content approach as described by Lieblich, Tuval-Mashiach, & Zilber (1998). The ultimate text will be consistent with the narrative analysis strategy on reporting the findings under two broad topics: i) Project management practice and ii) Project management knowledge.

RESULTS

Table 2 shows a summary of personal perspectives collated from the participants throughout their interview session. When their narratives were analysed collectively, the findings seem to suggest they must first set the scene by describing the practice, the person and the knowledge of project management. Following that, will be the discussion that led to the consequential results for industry's expectations on the important subject matters that should be taught in project management studies.

Table 2. A Summary of Perspectives Framed by Participants

Participants	Project Management and The Construction Industry	Subject Areas That Matters
Project Manager #1	Narrated from the perspective of a private sector practioner through some case studies he has worked on. To meet the industry's expectations, graduates are advised - *when you are not in the know, seek knowledge before you set out to manage projects*.	The PMBOK as the knowledge document; it is important to know and understand soft skills, techniques and interpretation; risk management; data, statistics and project management tools.
Project Manager #2	Reiterated the importance of a thorough understanding of the knowledge processes when managing projects; the need for individual assessment of knowledge, skill and attitude.	The importance of teaching a soft-skill module as this is likely to have a direct bearing on a project's success.
Project Manager #3	Narrated on the evolution of Project Management Consultants (PMC) – how project management has gained and lost its traction in the industry. There is a need for project managers but there is inadequate supply to meet the demand.	Advocated for the ACPM / CCPM (CIDB) programmes based on its comprehensiveness in dealing with construction project management.
Project Manager #4	A hands-on narrative of a Project Manager's job tasks and skills and industry expectations regarding PMCs. Able to appraise project management courses and advise on the building up of experience in managing projects.	Has a passionate pro-Alma Mater view on its project management studies; offering details of a syllabus.
Project Manager #5	*Do people actually employ project managers?* Reflected on public sector project management practice and the certification programme for Project Managers; raised awareness on how demand can be created.	Engineers do not see themselves as project managers – therefore their technical skills have precedence over other skills; they need to enhance their facilitation skills.
Project Manager #6	A systemic project management organised around years of practice in the field. The details are in the process.	The need for knowledge is tied to the situation and context when managing projects.

Project Management Practice

While the history of project management practice is well-documented elsewhere (Morris, 1994), there is a limited and unsystematic recording on the genesis of project management in Malaysia. The narratives presented below briefly outline the development of Project Management Consultants or Companies (PMCs) from its growth to its cessation in the construction industry. Take for example, one of the prominent mega structure project management of the 90s, was infrastructure development, namely the North-South Express Highway.

> "The main players then were the Renong Group; Renong, as the concession and as asset owner has a PMC arm which was Kinta Kellas. Therefore, any project by Renong, owned by Renong, money spent by Renong, was managed by Kinta Kellas Plc. Hence Kinta Kellas was one of the pioneer PMCs in Malaysia. Later, Kinta Kellas changed its name to OPUS International Group Plc. and to remain as technical support of project consultants, known as Independent Consultant Engineer (ICE), OPUS needed to be registered with the Board of Engineers Malaysia (BEM) and the Ministry of Finance (MoF)" (PM#6).

Another outstanding project of the 90s was the Petronas Twin Towers, which was developed and project-managed by Kuala Lumpur City Centre Berhad (KLCCB). The entity was formed in 1992 comprising members from KLCCB and the Lehrer McGovern Group, "as a means of fulfilling the requirement of international and financial bankers" (PM#3). Similarly with the Kuala Lumpur International Airport (KLIA) project, which took a radical turn because of its Project Management Organisation (PMO). The project team was multinational, comprising PWD personnel, British, Americans, Koreans, Somalians and Russians; "taking on a new company and a new procedure and culture in doing things together. They had one procedural system everyone adhered to." (PM#3) These were the models of successful project management then.

Unfortunately, public awareness on project management in this country was brought about by the disrepute it gained from poorly executed development projects; for example, of the Ministry of Education under the 8th Malaysia Plan (2001-2005). At that time, PMCs were appointed to supervise the implementation of public projects because the Public Works Department (PWD) was over-burdened. "Subsequently, with the privatization policy under way, and the design and build system in place, many engineering consultants would bid to be PMCs" (PM#3) and the increase in number of PMCs went unchecked. Consultants were set up with 1, 2 or 3 engineers and other professionals without an actual track record. "By 2004, the register has a total of one thousand PMCs, comprising professionals from Civil &Structural (C & S) and Mechanical & Electrical (M & E) and lawyers or bankers" (PM#3). In effect, everyone was taking the opportunity to register under the Ministry of Finance (MoF). "People were more concerned with registration than the services that were to be provided" (PM#3). So, when PMCs performed badly and could not deliver their projects, "the MoF decided that no more licences were to be issued or renewed. As licences expired, PMCs ceased to exist" (PM#3; PM#6). Since then, "PMC became a taboo, to a point that government implementation agencies such as the Ministry of Transport (MoT) or Public Works Department (PWD) could not gain approval from the MoF to appoint PMCs" (PM#6).

Hence, the findings from the narratives suggest that between 2004 until today, PMC entities for development projects are no longer given recognition by the MoF. "However, that did not stop one government agency from appointing a project management consultant (PMC) for a renovation job in its headquarters building" (PM#3). The PMC would conduct meetings with all contractors, suppliers and then reporting back to the client (PM#4). Effectually, physical development government projects have reverted the project management responsibilities to the Lead Consultants, who are either architects, engineers or quantity surveyors (PM#3, PM#5).

These narratives showed that there are demands for project management; whether they be small or big projects. “Small projects can be managed with all the knowledge areas applied and everything is within control, while big projects is a matter of scaling it up” (PM#1). “Even with having done projects for hundreds of times, and even if the project is the same, the logic is totally different; the team is different, and the environment is different” (PM#2). The narratives also suggested that, in the physical development project, the life cycle framework would be a helpful tool to identify the critical features of the management practice. The issues that arise throughout the phases would prompt for action for improvement. These indicate the potential subject areas that could be focused on taught degree courses (PM#6). The findings from the narratives have determined among others, the importance of dealing in land issues; managing design at preliminary level and monitoring design progress; procurement and procurement strategy that integrates design with tendering; line of communication; construction management and management tracking until the project is delivered (PM#6).

The Project Manager

At the same time, the recognition of the project manager’s crucial role was communicated throughout the interview sessions. The narratives confirmed that the project manager is the backbone of the project’s success; the person who will handle the project from A to Z; from scoping, planning through to handover (PM#2; PM#5). A Project Manager is a figurehead (sic.), an integrator, a communicator and he or she must have solid expertise regarding the knowledge areas and processes (PM#1). In the PWD, the designation of a project manager is known as the Head of the Project Team (HOPT). He or she is in-charge and responsible for the processes at the implementation stage to ensure the smooth delivery of the project. To date the HOPT is already embedded in many government documents and it is unlikely he or she will be re-designated as Project Manager.

Yet, it is also likely that anybody can be a Project Manager (PM#5) provided he or she clearly understands his or her role. But what defines the character of the project managers are the attitudes and behaviours (PM#5); the way they talk and interact with team members will translate into how they have managed their projects (PM#1; PM#2). Case in point, a project manager may need to supervise team members closely in order to create a learning environment especially where mistakes need to be rectified individually. This situation can be read in the managing people discussion later. In another circumstance, a project manager must avoid conflict of interest. Case in point, when the architect may also be the project manager. The architect must distance himself or herself from decisions of other architects. The project management office comprises people from different backgrounds and they all play their roles in managing the project by achieving the milestones that have been promised to the client. They will make the expert decisions, but as project manager, he or she will make the decision in collaboration with all these people (PM#2).

In some situations, it is likely that the project manager is a technical person holding a quantity surveying degree but may not possess a master’s degree in project management. In this case, the project manager plays the role as a client representative in managing the consultants but is unlikely to be involved in the project implementation (PM#4). However, for new graduates taking up the role of project manager, they are daunted with the industry’s expectation to “hit the ground running” (PM#2). He or she is supposed to work independently, in planning and in communicating with the client. Therefore, in preparation for this role, "graduates must choose the route to work for a few years in the industry, followed by the Master's degree course of study and then back to the industry again" (PM#4). Working in a PMC would be ideal; "as it is a multi-disciplinary entity and graduates are likely to benefit from the experience gained from doing all kinds of work, meeting many types of clients, enduring various project durations and knowing how much resources he has" (PM#4). Ultimately, after having gained the necessary skills, the graduates can apply for a certification as a project manager and can be planted anywhere (PM#2).

Competence and Certification Requirements

The narratives have established that, a project manager's competence is a major contribution to the success of projects (PM#2, PM#5). The question is, to what extent does generic skills and behavioural competence be adequate for him or her to function? Hence, in this section the issue at hand is the skills requirement that shape the competence of the project managers which ultimately lead toward their certification. This is important because there is a big difference between a project manager who is certified *vis*-à-*vis* an uncertified project manager; from the way he or she communicates, resolves problems, handles people and the human resources. Soft skills have become an essential criterion in the certification process (PM#5).

Therefore, the evaluation stage toward the certification of a project manager focuses on three dimensions: knowledge, skill and attitude. Knowledge is acquired during the course of studies and skills are manifested when knowledge is applied (PM#1; PM#2). As for attitude, probably only the behavioural aspect can influence this (PM#1; PM#5). So, to get a certification, there must be evidence to show if his or her knowledge is applied in their work (PM#2) or when he or she can follow the (project management) system. Only then is he or she ready for an assessment (PM#1). Certified project managers are qualified people who have the licence to sign off like professional engineers (PM#3) and gaining a certification, such as the Project Management Practitioner (PMP)®, is a symbol of self-actualisation (PM#1). The exception is when there is still no recognition for Project Managers at the national level (PM#5). Therefore, in anticipation of our country moving toward developed status, the task now is to create a lot more Certified Project Managers in the market. "A market study has not been carried out to see where we are now. If confined to the PWD, certified projects managers are surely not enough; and if it includes those from professional or regulatory bodies, there could be more, but we do not know where they are being employed" (PM#5). For now, the findings from the narratives offered two local models for project manager certification: The Competency-Based Assessment System (PWD) and the Certified Construction Project Manager (CIDB).

First, the Competency-based Assessment System (CBAS), was initiated in 2005. At that time, the top management in PWD realised that they needed to develop the Project Management competency. They saw that most of their engineering staff members had become too technical and there was no system in the assignment of projects. Junior engineers were being assigned complex projects and problems emerged because they were not competent to handle such projects. Therefore, it was imminent that top management strategized on how to appoint project managers (PM#5), "the engineers have to go through the process of assessment on their job and be assessed by the assessor" (PM#5). Subsequently, CBAS was developed as the PWD competency standard for project managers. It is equivalent to conducting a workplace assessment, which means that the candidate will demonstrate his or her knowledge from the degree study he has taken and the ways in which the knowledge have been applied (PM#2). However, before the assessment, one has to submit a project write-up and then sit for an interview. During the interview, questions are asked to test the candidate's knowledge and situations are given to gauge his or her attitude and in the way problems are handled. "It's not a what question but a how question" (PM#5). The idea is to discover how well he or she has understood all the knowledge areas. When an answer is satisfactory, the candidate gets a tick and so on until he or she passes all and is duly certified. For those who are unsuccessful, then the candidates get a 6-month period to do the rest and sit for another interview. For that time, "he or she is not competent yet" (PM#5).

The CBAS offers three levels of certification: i) the Qualified Project Practitioners (QPP) ii) the Registered Project Managers (RPM) and iii) the Registered Project Director (RPD). As a QPP, they do not follow any hierarchy and the level of responsibility does not entail decision making (PM#2). For those who are RPMs, it means they are registered as project managers, supervising the projects and make decisions at the project level. One can start showing evidence of having done scope management; cost management; risk management from all the Knowledge Areas (PM#2; PM#5). Lastly, as an RPD, one is an expert at looking at items at the programme level and is managing different project managers and managing separate teams (PM#2). Accordingly, the Project Management certifications ensured that those with the higher-level certifications who manage programmes and portfolios (the RPD) will take on very complex and high-cost projects; while the QPPs will oversee simple standard projects and the middle range projects will be supervised by the RPMs (PM#5).

The next certification model is the Certified Construction Project Manager (CCPM) which is specific to the management of physical development projects. Typically, a project has five phases or cycles, namely: planning, design, procurement, construction and handover. In essence, the scoping for a project covers the initial planning stage but the scoping for construction project management is limited to the construction site. So inadvertently, the Certified Construction Project Manager (CCPM) practitioner will be limited to the construction scope.

The CCPM was developed for the CIDB and it catered for the construction managers because they deal with the construction and site management. Hence, they are less likely to be involved in the early stages of planning and procurement (PM#5). The CCPM programme, was originally drafted in 2004 and there are two ways to achieve certification: 1) through a professional interview (registration and interview) and, 2) through a training scheme system which offers 15 learning packages (PM#3). The process may take months or even years (PM#4). In order to be registered as a Certified Construction Project Manager (CCPM), one is assessed on experience and competency rather than academic considerations. So, this is open to all those who have functioned in that role but do not have the paper qualifications. Hence, they can be certified because of their knowledge and their experience. For managers who have a Master's degree, the route is faster than those who gather experiences from working in industry; the latter may possibly take 20 years for the certification programme (PM#4). Nonetheless, CCPM is a personal journey because the practitioner fills up the forms personally and sits for the interview himself/herself. "The interview itself is very tough; there is knowledge-based and performance-based assessment. Those who finally achieve the CCPM really deserved it" (PM#4). There is no outright failure because, if say, a person may lack the communication skills, he or she has to go back and repeat the communication learning package (PM#4).

Presently, an estimated 10,000 Project Managers are needed in the construction industry at all levels: from project director, project manager, construction manager and so on. However, those who are qualified with the CCPM, the number is just over one hundred persons (PM#3). Therefore, there is a big gap in terms of the numbers of certified personnel available today. As such, the registration of project managers cannot be enforced due to the low numbers of qualified project managers. In future, when there is a likely possibility that all registered contractors from G4 onwards must have their registered CCPM personnel (PM#3), then, the implications are far-reaching; because a condition will be inserted in the tender document that the company must have their certified construction project managers to bid for projects (PM#4).

Project Management Knowledge

The findings from the narratives showed that all the participants agreed that the acquisition of knowledge is all too important before one can practise project management. Practitioners are recognised through the application of their knowledge. So, the ability to manage projects would begin with meeting the clarion call "with the 9 knowledge areas and 47 processes and 5 process groups, you start from scratch" (PM#1). From this section on, the narratives addressed the applicability of the project management body of knowledge (PMBOK) and the suitability of some MSc. Project Management programmes in the country.

The Body of Knowledge

The findings from the narratives suggest that the PMI Project Management Body of Knowledge (PMBOK) is generally taken as a good foundation for students and practitioners to study, so as to be able to enhance their job performance skills. Among the most fastidious proponents, PM #1, has positioned it as a standard for project management, maintaining that half the globe has adopted it while others may have adopted PRINCE2 (UK) or AIPM (Australia) (PM#1). This is because the PMBOK was structured like the Wikipedia, with materials developed by hundreds of authors and global experts giving input. In the case of China, the PMBOK has been translated into their language (PM#1) and their successful project managers were known to have the background of the PMBOK (PM #1).

To date, the PMBOK 6th edition has 10 knowledge areas and 49 processes and these are likely to increase as new knowledge is demonstrated in the industry (PM#1; PM#2). This is gathered from the constant reviews of project management application to physical and non-physical projects (PM#2); "that even the nursing, teaching and finance sectors have adopted its system and are using it" (PM#1). But as far as the construction industry is concerned, the general project management body of knowledge (PMBOK) remains valid. The BOK has included an extension for the construction sector with additional knowledge areas such as conflict management, contract management, finance and procurement that are specifically addressed in the industry (PM#1). In retrospect, basic technical specialisation knowledge is top priority while the project management is just another skill on top of that (PM#4); "If you are an engineer you need to be a good engineer first then you can manage better" (PM#2).

The MSc. Project Management Degree

During the interview session, participants were asked to examine the MSc. Project Management syllabus of the school. Some claimed that the range of subjects proposed was interesting, but they lacked depth (PM#2; PM#4). There were a lot of general subjects which, effectively will not equip the graduate student with sufficient knowledge. The range of subjects also demonstrated a bias toward say, economics. The question is, how to package it so that engineers can understand the materials from the beginning, bearing in mind that most project managers have a background in engineering. Some commented that the syllabus has good financial management topics but then, one needs to be in a senior position to apply the knowledge (PM #6). Quite a number of topics are not at application level for junior graduates. Take for example, organisational management: how do they prepare an effective organisational chart? That is more likely to be under the purview of a senior level position who will do such planning so that a team of 200 people can work together and deliver the project (PM#6). Other subjects such as Strategic Management, Sustainable Design Construction or sustainable development, international construction, innovation, are topics of construction rather than general project management (PM#2).

The participants also raise some concerns on the marketability of the course, the level of capability of the graduates, and the flexibility of option for non-technical project management and their demand (PM #1, PM #5). They also mentioned the other local public universities that have designed their curriculum in the same general approach (PM#4). They suggested that what could be better was perhaps for these universities to create electives for Project Management and Construction so that students can find jobs when they graduated (PM#4, PM #5). A notable mention was the MSc. Integrated Construction Project Management (ICPM) at UiTM. This course has focused on integration because construction has many sectors (PM#4) and they have used their diverse faculty of senior lecturers, who are practitioners with experiences of the real world to contribute toward the teaching arrangement (PM#4).

Consequential Results for the Project Management Subject Areas

We recap the purpose of the interviews was to examine and re-examine subject areas that should be offered in a Master's project management course of study. Therefore, upon a closer examination of the narratives, the results suggested that general management concepts should be taught early on and followed by the application areas that are industry specific. However, the fundamental entity of project management concept is the project; which, by definition has a beginning and an end. "It can be on daily operations which starts at 8 and end at 5. You need to ask, what deliverables; resources; budget; and all that coordination. At the end of the day, you deliver" (PM#1). Likewise, most people think about project as a physical project in construction, but it can also refer to non-physical projects such as poverty eradication and event management, where project management knowledge is applied (PM#1; PM#2; PM#3; PM#4; PM#5; PM#6). Table 3 shows a collation of themes and indicative statements distilled from the narratives on Project Management Practice and Project Management Knowledge.

Table 3. Collation of themes and indicative statements on Project Management Subject Areas

	Indicative Project Management Subject Areas
General Project Management Elements	General management principles is what the market wants (PM#6) We need to manage the data; normal documentation; drawings; this is the general management maybe not studied but is important (PM#6) Develop module for document management system (PM#6) General Project Management as a start; develop your own generic curriculum; then specialise (PM#1) Generalise the course of study to include those who are not into construction (PM#5) The INTAN project management course starts from initiation; good idea to incorporate into MSc Project Management HBP (PM#5) As a project manager, I must know business when I do a project (PM#1) All about business decisions and so the business case is a given (PM#1) Good to consider leadership and organisation either as a major subject or at best, a supporting topic (PM#5) Learn about communication – its important (PM#3) Communication Management & Communication Plan (PM#2) Where projects have been awarded, who are the authorised representatives to sign letters? Preparing meeting structure who should attend? Ensure meetings are planned 3 months ahead (PM#6) Different cultures, how do they work together in the same project? (PM#3) Most project managers are technically competent people in the fields of electrical, civil or mechanical engineering (PM#5) Learn about soft skills; negotiation with team (PM#2) Soft skills such as managing relationships (PM#2) If not in first degree course then in Masters can probably enhance soft skills (PM#5) Facilitation skills are equally important (PM#5) Nobody knows everything; one has to get the expert; the project manager has to search and source out the right person for the job (PM#6) Learn about managing people (PM#4) manage conflict; how to manage human resource; not all members have the same energy level and passion (PM#4) Personality assessment to make sure members are in harmony with each other (PM#4) managing at the individual level; managing relationships; work will get done when the team functions; due focus given to people management (PM#2) (PM#4) The right attitude is more important than being knowledgeable and smart (PM#2) Stakeholders - what do you need to do with each one of them; what information to share; different stakeholder must be handled differently (PM#2) Learn about budgetary & finances (PM#4) For example, the ministry initiates project; development and construction of a hospital or clinic; propose for an area; do the feasibility study; submit the proposal to EPU; budget approval is given according to the scope; then JKR will implement; see what relevant subjects you want to incorporate (PM#5) When doing cash flow, know how to present your financial ratios (PM#4) we studied using AVITA (PM#4)
Construction Project management application areas	Land acquisition – not many have studied this; 100 hectares for infrastructure project; at the beginning there are major encumbrances; land and squatters (PM#6) Authority approval- which is always killing the project – if there is a module how do you manage authority approval? (PM#6) There's a bureaucratic process to manage projects in Malaysia; You learn it as you make mistake; trial and error from scratch until the end; with that experience, you now know how to tackle the next project. If that can be learned, how good it will be (PM#6) First principles of project management - scope & WBS (PM#1) Project Management Plan (PM#2) Risk is born the moment a project is created; the project manager must integrate all the functions to manage risk (PM#1) From project data, the earned value showed the project is 3 months delay. This can be read off from the graph, unfortunately quite a number of industry people are ignorant of (PM#1) The question is how to integrate the design with tendering; a project has many disciplines; what procurement strategy to make sure that the right company bids (PM#6) In PPP projects, there must be in-depth knowledge about procurement types, understand concessionaire agreement (PM#4) Project managers must know all the legal instruments and familiarise themselves with various contract terms (PM#5) Usually this is covered during the degree course, so at Master’s level study about PAM- contract – PWD 2003; PWD design and build (PM#4)

	Indicative Project Management Subject Areas
Construction Project management application areas	The pre-requisite to Project Management is the Construction Management background; this has to be a mandatory module (PM#6) When tender has been awarded; between tender and construction there are many changes; this must be managed by tracking the drawing number (PM#6) If this is a module, then the junior project manager knows where to search (PM#6) Before work starts, there is proper procedure; there is method statement– there is safety plan(PM#6) When you have planned to complete the project in 5 years then you must plan the early stages and track if it's on schedule; we call it planning & monitoring, there is the plan then monitor, construction management at the site (PM#6) As the project progresses the critical path change – started here – ended up elsewhere – so we have to revise the program- no project is the same – change using primavera – you have a good programme – so let primavera think (PM#6) After everything that you do – you answer a few questions - what went well; what did not; why we didn't achieve our timeline (PM#2) when you assess your scope management what do you need to improve? (PM#2) Carry out value engineering every week, every month - it will be different from one case to the next; different people; different consultants; different behaviours (PM#2) Do I *do* the innovation or do I *manage* the innovation? Somebody else do the innovation – how do you teach innovation in construction? (PM#2)
Supplementary Topics	Conducting research dissertation and project simulation - these topics demand emphasis (PM#4) Research methodology explains on the research sequences; the dissertation trains them to think and write seriously and creatively (PM#4) In UITM, the international project simulation case was in Thailand; to develop the park and ride for the LRT; we work independently (PM#4) The project simulation in Malaysia was in Langkawi – everything from zero; you have one piece land how do you design; we do weekly presentations(PM#4).

(Note: The themes and indicative statements were distilled from the matrix of narratives on Project Management Practice and Project Management Knowledge of the participants)

General Project Management Elements

The general management principles in Project Management are what the market wants (PM#6). Graduate students must understand that in any course of study, the starting point is the theory. "If you jump directly into a practical situation without any theoretical basis, you are getting yourself into a lot of uncertainty which is not right" (PM#1). It is imperative to map out the "9 knowledge areas, 47 processes and 5 process groups" (PM#1). Therefore, the narrative analysis across all the participants have defined the breadth and depth of subject areas in the light of project management practice to include: business acumen, leadership, communication, soft skills, managing people and budgetary & financial concerns.

Firstly, "a project manager must have business acumen when he or she is doing a project" (PM#1). As in the private sector, the initiation is developed by the business development manager who must also understand projects. When a project is created, the project manager must understand the business idea, the business case and all about the business decisions. When the project is completed, "we deliver the assets (to which) we have already set the business target and the business case – in terms of savings, profits, etc." (PM#1). Secondly, it is inevitable that a project manager is also a leader. He or she must be in the know, able to read and give appropriate comments on outstanding issues. "It will be good to consider leadership and organisation either as a major subject or at best, a supporting topic" (PM#5) and he or she has undergone some kind of leadership training.

Next, the requirement on communication skills is perhaps most frequently expressed as important in project management. Every stage of the project process entails communication.

Take for example the situation where projects have been awarded; who are the authorised representatives to sign letters? There has to be a clear line of communication in power delegation upfront to avoid confusion later. Another example is when there are many packages involved, how to make sure the design team and contract teams are focusing on the same package? "How to make sure the left hand knows what the right hand is doing?" (PM#6). Or take the activity on meeting preparation:

> "How should the organisers manage and decide who should attend? How should decisions be shared? In the planning stage, all meetings are planned 3 months ahead; plan for the design coordination meeting say, every first Friday of the month; and plan for monthly progress meeting on say, every Monday. Then distribute to all parties and if there are 40 contractors, all must be in the know and ready. No one should say he did not know and neither can he attend other meetings" (PM#6).

Furthermore, where people of many different cultures are present in the team, the project manager must have internal communication skills and be able to manage multi-disciplinary and multi-cultural working environments and have empathy towards their members (PM#3, PM#4).

Another subject area could focus on soft skills. As most project managers are trained in engineering, they are technically competent people in the fields of electrical, civil or mechanical engineering. "Therefore, it is highly likely that they viewed all projects as an engineer and not likely as a manager" (PM#5). So, they will manage projects like technical people rather than managers as they lack the soft skills, as they have issues in communication, problem solving, and dispute resolutions (PM#5). Hence, due to this inadequacy, soft skills should be taught (as a subject). As a project manager, he has an objective to his client and is dependent on his team, so the question is, does he have the empathy for them? What if the team cannot deliver? Is he adept at negotiating for the best option to work as a team? The project manager has to resolve this (PM#2). A soft skill module would include negotiation skills, understanding what has been said and handling effective meetings and managing conflict. Other less developed soft skill is on arbitration (PM#2); "a must have subject" (PM#4). Corresponding to this is the facilitation skill, when the project manager has to search and source out the right persons or experts for the job (PM#6).

This leads us next to the subject on managing people - the human resource approach. The project manager has to look at personality assessment to make sure members can talk and be in harmony with each other through the use of personality categories to build a team. In this sense, the project manager has to have the right attitude and this is more important than being knowledgeable and smart. The question is, can attitude be taught? This means that the project manager must understand the context he is managing and leverage from strategic and system thinking (PM#2). That is why the focus area on managing people is very important as it is managing at the individual level and it is about managing relationships because the work will get done when the team functions. Therefore, due focus must be given to people management (PM#2) (PM#4). In managing stakeholder issues, "what do you need to do with each one of them; what are the items of information that we want to share and when will we meet them? Different stakeholder must be handled differently" (PM#2).

Finally, the subject area on budgeting and financial analysis is helpful. The feasibility study and its cash flow will differ from that of a construction project which is concerned with pre and post construction (PM#4). Therefore, the project manager must be proficient with their financial ratios and must understand fully the appraisal techniques such as Net Present Value (NPV) and Internal Rate of Return (IRR); so, he can explain to clients who are unaware of the likely acceptable ratios (PM#4).

Construction Project Management Application Areas

In a specialised sector such as construction, the tools and techniques pertinent to project management are at the initiating, planning, executing, monitoring and closing process groups. A case of concern on initiating issues, for example, on land matters relating to acquisition must be taught and studied. In some situations, the development land has major encumbrances or other obstructions relating to property owner, like the problem of land squatters. Hence the knowledge of Land Acquisition Act is essential (PM#6). Therefore, the project manager must have the knowledge and experience when implementing the project, so that land is acquired as soon as possible otherwise repetitive efforts will be costly (PM#6). Similarly, authority approval is also "killing the project" (PM #6); so how to manage authority approval? What are the types of authority approvals to gain? Engineers do not study this and are oblivious to the bureaucratic process in managing projects in Malaysia. It is likely that project managers learn it from the mistakes made so it is a trial-and-error process. Therefore, the knowledge of this process becomes incumbent for the project managers (PM#6).

In the Planning process, project managers make sure that all the phase managers are aligned to project timeline and that the Project Management Plan is prepared from the start right through to handover to the client and to closing. The expectation is that the project manager has knowledge of the right tools, techniques and the technology to carry out the function (PM#2; PM#4). A tool to check the consultant's or the contractor's understanding on the scope of work is through the use Work Breakdown Structure (WBS). At best, this is a mandatory criterion to see the "A to Z about the project" (PM #1). Where there is a gap, it means the project manager does not understand his scope of work (PM#1).

Next, risk is produced the moment a project is created. The project manager must integrate all the functions to manage risk. In estimating risk using say, the Monte Carlo simulation, always go for the schedule and its chances of success. The project manager must understand risk so that there are reasons to rationalise when the project experiences delays and when the probability of success has changed (PM#1). Another tool in the planning stage which manages the project progress is through Earned Value Management (EVM). A project manager has the data at hand to measure the project's progress and to anticipate delay.

When the project is managed properly before it is awarded, one can minimize a lot of things during construction; fewer changes to design; fewer re-design attempts and fewer delays. Integrating the design with tendering is a major issue. As the designer prepares drawings, the contracts department prepares the tender document. "But do they speak to each other? We need to merge planning with the procurement contract" (PM#6).

Usually contract studies are at undergraduate degree courses, so at Master's level, candidates should study about specific PAM contracts – PWD 2003 or the PWD design and build. “How does each instrument deal with dispute resolution and how would you advise your client” (PM#4). In other words, project managers must possess substantial knowledge regarding all the legal instruments and familiarise themselves with various contract terms (PM#5). On the other hand, a project has many disciplines so there must be a procurement strategy to make sure that the right company send in their bid. The reason is to restrain big players from having a monopoly. How does one ensure that small contractors are able to participate? “In the LRT project, each contractor will take care of small stations of RM40-50 million, parked as a nominated contractor” (PM#6). Therefore, small contract packages must be created.

The execution process embeds the award of tender so that construction can be started. But changes always occur so often between tender and construction. Many modifications may have to be done and this must be managed, for example, by tracking the drawing number (PM#6). If this is a taught module then the junior project manager will be quick to investigate and will know where to explore. “We teach them how to learn” (PM#6). More importantly, the pre-requisite to Construction Project Management is the Construction Management background. So, before work starts, the project manager has to be aware of the fact that he has to follow the proper procedure. Take for example, method statement. This means that the contractor has worked on it and the consultant has reviewed it. So, when an accident occurs, this accident is not due to negligence. “Method statement safeguards everybody” (PM#6).

Within the project processes, there are many phases that require monitoring: monitoring design progress, monitoring physical progress, monitoring planning and progress. Take monitoring design progress for instance, “there are those who do not know how to estimate their progress method” (PM #6). What tools do project managers use to estimate weightage and progress? In monitoring physical progress, you need to monitor resources and study the programme to ensure project completion will not be delayed. In planning and progress monitoring via engineering, procurement & construction (EPC), the use of monitoring and scheduling tools like primavera is crucial (PM#6).

Finally, in closing, an important stage pertaining to the project management practice is the assessment of outcome process or the lessons learned. In essence, the assessment of outcome occurs at the completion of the project to find out how well the project manager has performed. Some probing questions that the project managers may ask are, “What did I do today?”; “Did I do well or not?”; “What went well?”; “What did not turn out well?”; “How do I improve what has been done?” (PM #2). Therefore, as questions get answered, innovative measures may appear in increments to improve the processes. This has to be a regular procedure in project management (PM#2).

Supplementary Topics

Some participants agreed on another set of subject areas that would substantiate the Master’s degree course on offer i.e., conducting research dissertations and on carrying out project simulations. These topics demand some emphasis (PM#4). Firstly, an introduction to research methodology precedes the actual dissertation production. The methodology explains the research sequences to guide students in their investigation into the management topics of interest. On the other hand, the dissertation preparation and production trains students to think and write seriously and creatively. The benefits to graduate students are tangible when they are compelled to carry out documentation activities, data collection and analysis and report writing (PM#4). Secondly, the project simulation topic is a feature not only in the UiTM syllabus but also in the UTM (PM#4). What the UiTM syllabus offered was two different geographical simulation projects. The first is a local and domestic project and the other is foreign. The latter includes the internationalisation dimension of project management that deals with the process and procedures of construction work in a foreign country (PM#4). At best, project simulation exercises train the students to role play their project management insights (PM#4).

The narrative analysis has demonstrated how modules can be developed for the project management degree. These have been categorised under i) general project management elements ii) construction project management application areas and iii) supplementary topics to substantiate the courses. A strong emphasis must be placed on providing initial general project management studies, meaning the book of knowledge, before specialisation can take place. The essential subject areas such as business acumen, leadership, communication, soft skills, managing people and budgetary & finance knowledge and process areas have been discussed. Therefore, the current MSc. Project Management curriculum needs to be revamped to incorporate these elements. Subsequently, the construction project management sectoral subjects tend to gravitate toward the practice framework, hence there has to be more emphasis on tools and techniques applied in the initiation, planning, execution, monitoring and closing processes. Finally, the course of study can be substantiated by including a research dissertation exercise and a project simulation game.

These findings are somewhat in contrast to the conclusions drawn from Hodgson & Paton (2016) who has challenged the notion of applying a standardised body of knowledge to a pluralistic environment; and to Morris (2006) who has warned on the dangers of “self-fulfilling prophecies” (p.719) when academics are told “what to think and teach” (p.719) instead of research giving more systematic input into the dimensions of the discipline. On the other hand, the findings in relation to construction project management subjects concurred with Alireza & Ali (2018) citing Crawford and Pollack (2007), because “project management practice is heavily influenced by research emanating from the construction industry” (p.92). Finally, the findings that weigh on the simulation exercise may not be closely identified with Rumeser & Emsley’s (2018) review on the increasing use of software project management games, but it could be an alternative when travelling to foreign countries become costly.

Additionally, there were suggestions that a two-part curriculum be created. The essence is to establish a clear concept of Project Management issues first and then devise a way to take that knowledge into the construction environment. Even if one specialises in construction project management, the overall programme will not limit the graduate student to work only in construction (PM #1, PM #2, PM #5).

CONCLUSION

In summary, the overall results of the interviews point to a positive direction particularly for the construction project management studies, provided that the dissemination of knowledge include subjects that matters, which are likely to contribute to the preparation of graduates to be industry ready. These are as follows:

- The fundamentals of the project management body of knowledge must be taught up front in accordance with all–important "*9 knowledge areas and 47 processes*".
- Concurrent knowledge of industry practice is equally crucial as this simultaneously hones the project manager's skills in addressing issues that arise.
- As skills and competence are the likely critical success factors to managing projects, gaining the recognition from authoritative project management professional bodies will become imperative to project managers.
- The demand for qualified project managers will grow in tandem with the increasing supply of projects which will ultimately smoothen the route to the enforcement of project management professionals.

Finally, the findings presented from the industry perspectives have maintained that managing by "trial and error" is no longer an option when adopting project management practices and that an enhanced knowledge corpus could likely be achieved from the constant engagement between practitioners and academic researchers.

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A REVIEW ON PROBLEM – FOCUS IN MATRIX-BASED METHODS FOR PLANNING CONSTRUCTION PROJECTS

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Abstract
Planning of construction projects requires the collaboration of several stakeholders from different backgrounds to meet a diverse range of project requirements. Moreover, these projects are challenging to manage due to complex dependencies between numerous components. Researchers had identified various matrix-based methods such as Quality Function Deployment, Axiomatic Design, Affordance Structure Matrix, Design Structure Matrix, and Multiple Domain Matrix have potential to plan construction projects systematically. Matrix-based methods can process requirements, finalize specifications and analyze complex dependencies in a structured manner. Each matrix-based method is unique and considers different approaches to analyze different type of relationships between the elements. However, the appropriate usage of these methods across several stages of the construction project is still unclear for project planners. Due to its background in product design, the concept of these matrix-based methods poses challenges for project planners to adopt in practical usage. Therefore the objective of the present study is to critically review the five matrix-based methods to advance the understanding of different perspectives of each method towards managing decisions systematically in a construction project. To review these methods, qualitative data from an underground metro construction project is utilized. The advantages and disadvantages of each method across different stages of the project are discussed. The findings of this study suggest that each method plays a prominent role and collectively can aid in the systematic planning of construction projects.

Keywords: *Planning; construction projects; matrix-based methods; axiomatic design; quality function deployment; affordance-based design; design structure matrix; multi-domain matrix.*

INTRODUCTION

Effective planning is crucial for the successful delivery of construction projects. Improper planning or design can lead to changes, rework, decreased constructability, cost and time overruns (Ko and Chung, 2014). Managing construction projects involves the strong collaboration of stakeholders with different backgrounds, viewpoints and working principles (Pektas, 2010) to meet a diverse range of requirements (Gilbert III et al., 2014). Till date, several matrix-based methods such as Design Structure Matrix (DSM) (Steward, 1981), House of Quality (HoQ) (Akao, 1990), Axiomatic Design (AD) (Suh, 1990), Multi-Domain Matrix (MDM) (Maurer, 2007), and Affordance Structure Matrix (ASM) (Maier et al., 2007) have proven potential to plan the construction projects in a structured manner. Matrix-based methods can enable to process several project requirements systematically, finalize components specifications at early design stages, analyze dependencies between components and predict the impact of decisions in a structured manner. However, in the construction industry, there is a lack of clarity for project planners on what type of problem these methods are relevant, and how and where these methods can be applied across various stages of the construction project. There is a need for a systematic investigation on appropriate usage of these five matrix-based methods for broader application in construction projects.

Thus, the objective of the present study is to critically review the five matrix-based methods to advance the understanding of different perspectives of each method towards planning construction projects systematically. To illustrate these methods, qualitative data from the underground metro construction project is utilized. The scope of this study is limited to design phase planning due to its significant influence on construction project performance.

MATRIX-BASED METHODS

Matrix-based methods can be classified based on the type of elements involved and the application. Each method considers different elements to model different relationships as shown in Figure 1. AD, HoQ, and ASM are design-oriented methods which can aid to finalize project requirements and solutions in a structured manner. DSM and MDM can be referred to as design-process oriented methods which can model the dependencies of information exchanges systematically. As shown in Figure 1, AD, HoQ, and ASM represent and analyze relationships between different element types. They are a family of domain mapping matrixes (DMMs). DMM represents relationships of two-element types (Maurer, 2007). DSM focuses on representation and analysis between elements of the same type. MDM emphases on combined dependency analysis of same and different element types. Moreover, DSM, HOQ, and AD are basic methods whereas ASM, and MDM are derived methods as shown in Figure 1. For instance, ASM is derived from the integration of HoQ and AD. Similarly, MDM is an amalgamation of DSM and DMM. Further in this section, a brief overview of each matrix-based method is discussed.

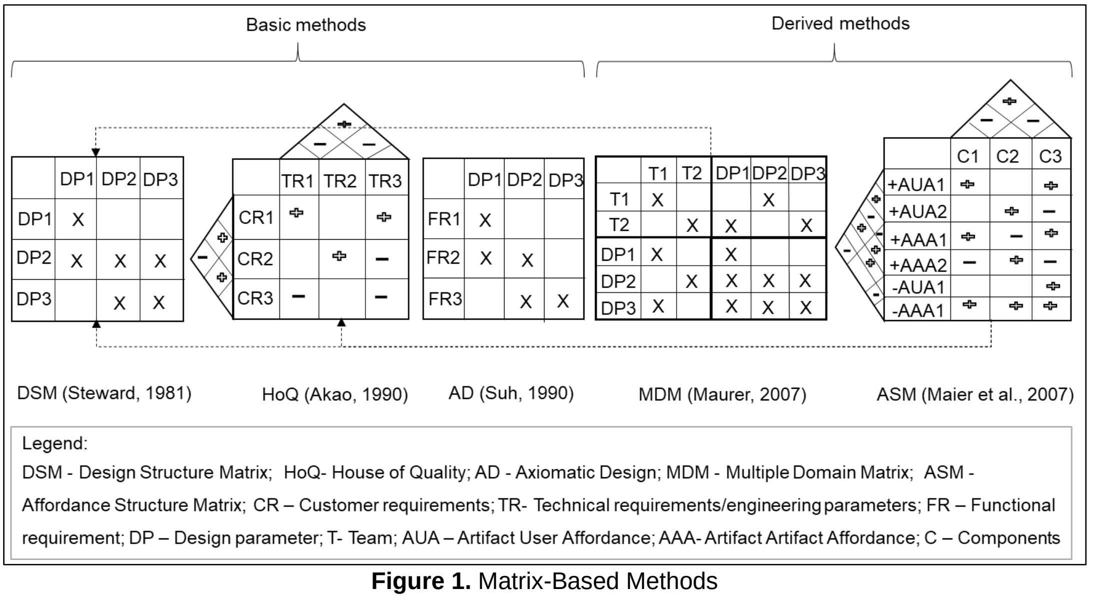

Figure 1. Matrix-Based Methods

Design-Oriented Methods

Quality function deployment (QFD) (Akao, 1990) provides a structured method to support the decision-making process (Yang et al., 2003). QFD guides the design and construction process using a series of matrixes. Each phase has a matrix called House of Quality (HoQ) consisting of a vertical column of “Whats” and a horizontal row of “Hows.”

“Whats” are customer requirements (CRs); “Hows” are ways of achieving them which are termed as technical requirements (TRs). Here, TRs refer to design requirements/engineering parameters (IS 15280:2003). In this study, only the first HoQ is explored to analyze the proposed design. As shown in Figure 1, the HoQ captures relationships between the CRs and TRs and dependencies among TRs. The strength of the relationship between these two elements is expressed by numbers (9, 3, and 1, for strong, medium, and weak relationships) (IS 15280:2003). Few applications reveal that HOQ can improve customer satisfaction in construction projects (Mallon and Mulligan, 1993; Gargione, 1999; Kamara et al., 2000; Eldin and Hikle, 2003; Haron and Khairudin, 2012).

Axiomatic Design (Suh, 1990) aids designers to translate customer needs (CNs) → functional requirements (FRs), then FRs → design parameters (DPs) and DPs → construction variables (CVs). The mapping between each domain is done in a zig-zag manner in various levels. Two axioms govern this hierarchical zigzag decomposition – (1) Independent axiom: Maintain the independence of FRs, (2) Information Axiom: Minimize the information content (Suh, 1990). In this study, only independent axiom concept is explored. In AD, Independent axiom states that once relationships between FRs and DPs are determined as shown in Figure 1, designers can categorize proposed designs into three types – coupled, decoupled and uncoupled designs (Suh, 1990). In coupled design, any change in FR cannot be satisfied by a change in DP independently. Coupled designs are unacceptable, and should be eliminated. In decoupled design decisions can be made in a derived sequence. In uncoupled design, decisions can be made independently due to independent addressing of FRs by DPs. Few studies partially investigated AD in construction projects reveal that systematic analysis of designs can be performed (Sohlenius & Johansson, 2002; Cavique and Goncalves-Coelho, 2009; Gilbert III et al., 2013).

In ASM, project requirements are interpreted in terms of affordances. An affordance is what one component provides to another component (Gibson, 1979). In a recent study, Maier et al. (2007) have developed ASM that maps the affordances to the components. The ASM integrates principles of HoQ and DSM. As shown in Figure 1, the centre of ASM depicts a matrix which captures helpful (+), harmful (-), or no relationships between affordances and components and the roof represents the DSM that captures components interactions (Maier et al. (2007). Affordances are classified into four types: Positive Artifact-User Affordances (+AUA), Negative Artifact-User Affordances (-AUA), Positive Artifact-Artifact Affordances (+AAA), and Negative Artifact-Artifact Affordances (-AAA) (Maier et al., 2008). Battacharya (2014) investigated ASM concept for the design of the offshore facility in construction projects.

Design Process-Oriented Methods

DSM (Steward, 1981) can aid to schedule the decisions by modeling information dependencies of elements of one kind. For instance, in this study as shown in Figure 1, information dependencies of DPs are captured in DSM. These DPs can be sequenced using a partitioning algorithm (Mujumdar, 2015) to identify feedbacks or to form iteration blocks. Iteration is defined as repeating an already completed task to incorporate new information (Ulrich and Eppinger, 2000). So far, very few researchers had explored the iteration in construction projects (Austin et al., 2000; Fayez et al., 2004; Oloufa et al., 2004; Wang et al., 2006; Maheswari and Varghese, 2007).

MDM (Maurer, 2007) is identified as a potential and emerging approach to capture and model information exchanges across multiple elements. Typically, MDM is a combination of the DSM - along with the diagonal and DMM (Domain Mapping Matrix) - off-diagonal encapsulating the enriching features of the square and rectangular matrices (Maurer and Lindemann, 2008). As shown in Figure 1, in MDM, DSM captures relationships of the same element type and DMM models relationships between two element types. Few applications in construction projects reveal that MDM is an appropriate solution to schedule multiple elements at one instance (Kreimeyer et al., 2009; Furtmeier et al., 2010; Krinner et al., 2011; Mujumdar et al., 2014).

CASE STUDY

To investigate the usage of the five matrix-based methods, case study approach (Yin, 2014) is utilized. A case study on the design of the underground metro project is conducted. Qualitative data were collected from various sources such as documents (design reports, drawings), interviews (unstructured and semi-structured), direct observation (site visits, review meetings), archival records (past project performance reports over a period of three months.

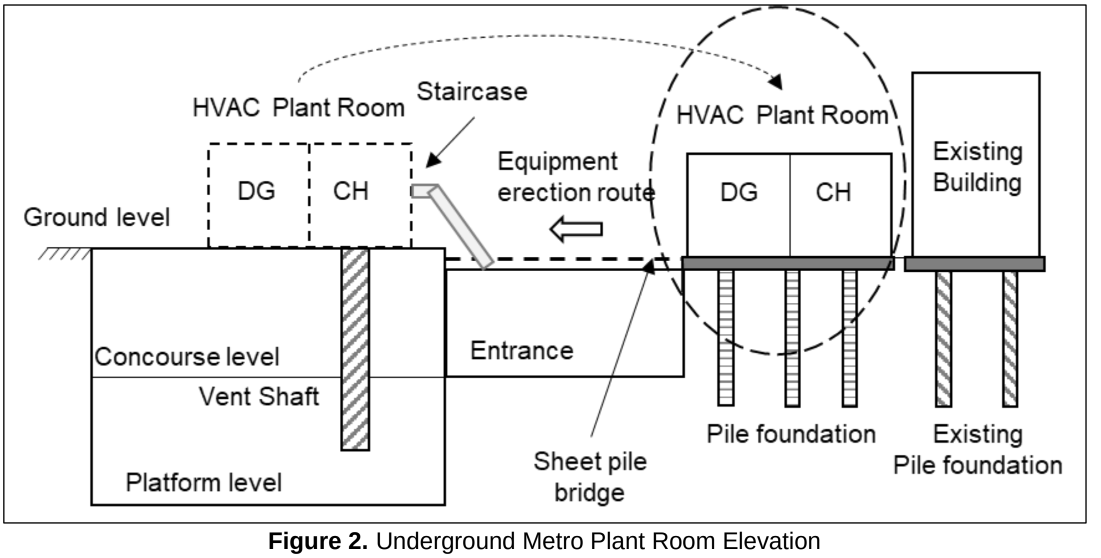

Figure 2. Underground Metro Plant Room Elevation

The case study involves the design of HVAC (Heat Ventilation and Air Conditioning) plant room of metro underground project as shown in Figure 2. Requirements briefing is the first and essential step in the design phase through which other project stages are derived. However, due to the improper briefing of metro project requirements such as smoke ventilation, plant room, equipment erection and cable trench structure erection, significant revisions or rework occurred at the construction stage. As shown in Figure 2, initially HVAC plant room was planned to build on the roof of the underground metro, and the drawings were also issued to the contractor. However, due to a change in railway requirements, HVAC plant room has to build in between entrance structure and existing building, leaving less space as shown in Figure 2. This constructability issue necessitated redesigning entire plant room. Additionally, to meet the project deadlines, few design activities of the plant room and entrance structure were carried out in parallel without considering their dependencies which further triggered redesigns. Analysing interdependencies of these decisions are one of the critical challenges for project planners. This HVAC plant room design is analyzed using five matrix-based methods, and perspectives of each method on dealing with this problem are discussed in further sections.

House of Quality (HoQ)

Figures 3 depict the HoQ of the proposed design. Proposed designs can be analyzed systematically by transferring CRs to TRs. Designs can be analyzed by quantifying the strengths of relationships between CRs and TRs. Strong relationships are more suspected to revisions and have a significant negative impact on the project as compared to weak relationships. One can calculate the importance rating and relative weights of TRs based on the strength of relationships (Akao, 1990; Luu, 2009) in the chosen design. Figure 3a shows relative weights of TRs of the proposed design. Based on relative weights, critical TRs can be chosen for further improvements or refinements in the chosen design. As shown in Figure 3a of the proposed design, TR1 to TR5 are chosen as critical TRs and revised their specifications. The main reason for high relative weights is due to conflict of HVAC plant room and smoke ventilation requirements that resulted into the shifting of plant room to a new location as shown in Figure 2 which further necessitated to provide additional pile foundation to support plant room. Further, as shown in Figure 3b, the revised relative weights of TRs are calculated for any further improvement of TRs.

HoQ	TR1	TR2	TR3	TR4	TR5	TR6	TR7	TR8
TR1	X							
TR2	X	X			X			X
TR3		X	X	X		X	X	X
TR4		X	X	X				
TR5				X	X			
TR6			X			X		
TR7	X	X	X			X	X	
TR8		X						X

		DI	TR1 Roofslab area	TR2 Plant room layout	TR3 Chiller slab dimension	TR4 DG slab dimensions	TR5 Vent Shaft area	TR6 Entrance area	TR7 Station Dwall width	TR8 cable trench area
Enclose metro	CR1	3	1							
Accomodate equipments	CR2	5	9	9	9	9	9			
Ventilate Smoke	CR3	5	3	9			1			
Access to concourse	CR4	2						1	1	
Electric supply	CR5	4								3
Importance rating			63	90	45	45	50	2	2	12
Relative weight (%)			16	23	12	12	13	1	1	3

Figure 3a. Original HoQ

HoQ	TR1	TR2	TR3	TR4	TR10	TR5	TR6	TR7	TR8	TR9
TR1	X									
TR2		X			X		X			
TR3		X	X							
TR4		X		X					X	
TR10		X			X		X			
TR5	X					X				
TR6		X					X		X	
TR7	X							X		
TR8	X	X					X		X	X
TR9		X							X	X

		DI	TR1 Roofslab area	TR2 Plant room layout	TR3 Chiller slab dimensions	TR4 DG slab dimensions	TR10 Pile foundation layout	TR5 Vent shaft area	TR6 Entrance width	TR7 Station Dwall width	TR8 cable trench area	TR9 erection dimensions
Enclose metro	CR1	3	1									
Accomodate equipments	CR2	5		9	9	9	9		3			9
Ventilate Smoke	CR3	5	3									
Access to concourse	CR4	2					9	1	1			
Electric supply	CR5	4								3	3	9
Importance rating			18	45	45	45	63	2	17	12	12	81
Relative weight (%)			4	9	9	9	13	0	3	2	12	17

Figure 3b. Revised HoQ

Figure 3. HoQ of the Underground Metro Plant Room

Axiomatic Design (AD)

In AD, FRs and DPs are considered to analyze the HVAC plant room design. Few FR-DP pairs are coupled as shown in Figure 4. These coupled designs are emerged due to the conflict in the FRs of plant room designs (refer Figure 2). For instance, FR2-DP1: FR4-DP3 are coupled due to the conflict in plant room foundation and smoke ventilation requirements. This coupled design can be decoupled or uncoupled by modifying DP1 and DP3. As shown in Figure 4, DP11 – pile foundation is considered in place of DP1- roof foundation to generate a decoupled design. For coupled design (FR6-DP4: FR7-DP5) in Figure 4, one new FR15-structural stability (erection structure) is added to decouple this coupled design as shown in Figure 5. That is, in the proposed design, entrance (after construction) was initially chosen for the erection of cable trench structure. However, erection requires a smooth and even passage which can be implemented only through providing separate erection platform over the entrance. So, new DP13-cable erection length was provided over the entrance (Refer Figure 2) which also necessitated to add new FR15 as shown in Figure 5.

AD		DP1 Roof slab thickness	DP2 Vent Shaft area	DP3 Plant room layout	DP4 Entrance width	DP5 Station Dwall width	DP6 Entrance depth	DP7 Cable trench length	DP8 Cable trench depth	DP9 Chiller slab thickness	DP10 DG base slab thickness
FR1	Support soil surcharge load	X									
FR2	Support plant structure load	X	X	X							
FR3	Extract heat released from train	X	X								
FR4	Provide structural stability	X		X							
FR5	Resist lateral earth pressure				X						
FR6	Support passengers load				X	X					
FR7	Support cable trench erection			X	X	X					
FR8	Support cable load				X	X	X	X			
FR9	Resist max soil pressure at base								X		
FR10	Support chiller erection				X					X	X
FR11	Support chiller load									X	
FR12	Support DG erection				X						X
FR13	Support DG load			X							X

Figure 4. Coupled Design - Underground Metro Plant Room

AD		DP1 Roof slab thickness	DP3 Plant room layout	DP2 Vent Shaft area	DP11 Pile foundation	DP12 Pile depth	DP6 Entrance depth	DP13 Cable erection length	DP5 Station Dwall width	DP4 Entrance width	DP7 Cable trench length	DP8 Cable trench depth	DP9 Chiller slab thickness	DP14 Chiller Erection area	DP15 DG Erection area	DP 10 DG Room slab thickness
FR1	Support soil surcharge load	X														
FR4	Provide structural stability	X	X													
FR3	Extract heat released from train	X		X												
FR2	Support plant structure load		X		X											
FR14	Resist shear and bending moments		X		X	X										
FR5	Resist lateral earth pressure						X									
FR15	Structural stability							X								
FR7	Support cable trench erection		X					X	X							
FR6	Support passengers load								X	X						
FR8	Support cable load		X						X	X	X					
FR9	Resist max soil pressure at base									X	X	X				
FR11	Support Chiller load		X		X	X							X			
FR10	Support chiller erection		X		X	X							X	X		
FR12	Support DG erection		X		X	X								X	X	
FR13	Support DG load		X		X	X									X	X

Figure 5. Decoupled Design - Underground Metro Plant Room

Affordance Structure Matrix (ASM)

In ASM, as mentioned earlier, components and affordances are considered and represented as shown in Figure 6. As can see in Figure 6a of the proposed design, all components of the underground metro plant room have a harmful impact, and it is essential to convert them into helpful relationships using ASM methodology. For instance, C2 - plant room and C5 - vent shaft has a harmful relationship with +AUA1 ventilate smoke. That is, when any fire accidents occur inside the underground metro station, vent shaft cannot ventilate smoke to outside due to clash with plant room structure (refer Figure 2). Thus, the relationships can be converted from harmful to helpful by shifting the location of the plant room out of the metro station as shown in Figures 2 and 6b. Still in the revised ASM as shown in Figure 6b, C2 – plant room has harmful relationships with –AUA1 - theft and –AAA1 - corrosion. The possible reason can be due to its location outside the metro station and its bad exposure with weather conditions, which can lead to theft of equipment and corrosion of structure. Thus, these negative relationships can be improved by providing security measures around the structure and by applying corrosive resistant external paint to all external walls of a plant room structure.

HoQ

	TR1	TR2	TR3	TR4	TR5	TR6	TR7	TR8
TR1	X							
TR2	X	X			X			X
TR3		X	X	X		X	X	X
TR4		X	X	X				
TR5				X	X			
TR6			X			X		
TR7	X	X	X			X	X	
TR8		X						X

		DI	TR1 Roof slab area	TR2 Plant room layout	TR3 Chiller slab dimension	TR4 DG slab dimensions	TR5 Vent Shaft area	TR6 Entrance area	TR7 Station Dwall width	TR8 cable trench area
Enclose metro	CR1	3	1							
Accomodate equipments	CR2	5	9	9	9	9	9			
Ventilate Smoke	CR3	5	3	9			1			
Access to concourse	CR4	2						1	1	
Electric supply	CR5	4								3
Importance rating			63	90	45	45	50	2	2	12
Relative weight (%)			16	23	12	12	13	1	1	3

Figure 6a. Original ASM

HoQ

	TR1	TR2	TR3	TR4	TR10	TR5	TR6	TR7	TR8	TR9
TR1	X									
TR2		X			X		X			
TR3		X	X							
TR4		X		X					X	
TR10		X			X		X			
TR5	X					X				
TR6		X					X		X	
TR7	X							X		
TR8	X	X					X		X	X
TR9		X							X	X

		DI	TR1 Roof slab area	TR2 Plant room layout	TR3 Chiller slab dimensions	TR4 DG slab dimensions	TR10 Pile foundation layout	TR5 Vent shaft area	TR6 Entrance width	TR7 Station Dwall width	TR8 cable trench area	TR9 erection dimensions
Enclose metro	CR1	3	1									
Accomodate equipments	CR2	5		9	9	9	9		3			9
Ventilate Smoke	CR3	5	3									
Access to concourse	CR4	2					9	1	1			
Electric supply	CR5	4								3	3	9
Importance rating			18	45	45	45	63	2	17	12	12	81
Relative weight (%)			4	9	9	9	13	0	3	2	12	17

Figure 6b. Revised ASM

Figure 6. ASM of the Underground Metro Plant Room

Design Structure Matrix (DSM)

Modeling relationships of decisions at parameter level increase the accuracy of scheduling analysis. The dependencies among parameters of the proposed design are represented in DSM as shown in Figure 7. Four iteration blocks (DP1-DP2, DP1-DP3, DP4-DP10, and DP4-DP5) are formed that are termed as negative iterations. For instance, change in DP2- vent shaft area will change DP3- plant room layout and vice versa, and it will never converge/improve the chosen design due to a clash of the plant room and vent shaft (refer

Figure 2). By changing the location of the plant room and considering the erection platform for the erection of cable trench structure, and equipment, negative iterations can be eliminated. However, iterations still exist in the revised DSM (refer Figure 8), and they are positive. For instance, in Figure 8, the iteration block (DP3 and DP4) also implies that the change in DP3- plant room layout changes DP4- entrance width and vice versa. However, after a few iterations, the design can be converged/repetitions can be stopped. That is, both teams - structural design (entrance) and HVAC design (plant room) can be collaborated to finalize the entrance width and plant room layout with few revisions as the requirements are not conflicting, or components are not clashing to each other.

DSM		DP1 Roof slab thickness	DP2 Vent Shaft area	DP3 Plant room layout	DP4 Entrance width	DP10 DG base slab thickness	DP5 Station Dwall width	DP6 Entrance depth	DP7 Cable trench length	DP8 Cable trench depth	DP9 Chiller slab thickness
DP1	Roof slab thickness	X	X	X							
DP2	Vent Shaft area	X	X								
DP3	Plant room layout	X	X	X		X		X	X		X
DP4	Entrance width			X	X	X	X			X	X
DP10	DG base slab thickness			X	X	X					
DP5	Station Dwall width				X		X				
DP6	Entrance depth							X			
DP7	Cable trench length	X		X	X		X		X		
DP8	Cable trench depth	X		X	X		X			X	
DP9	Chiller base slab thickness			X							X

Figure 7. Partitioned DSM - Underground Metro Plant Room (Negative Iterations)

DSM		DP1 Roof slab thickness	DP3 Plant room layout	DP11 Pile foundation area	DP4 Entrance width	DP12 Cable erection length	DP7 Cable trench length	DP5 Station Dwall width	DP8 Cable trench depth	DP9 Chiller slab thickness	DP13 Chiller Erection area	DP2 Vent Shaft area	DP14 Pile depth	DP6 Entrance depth	DP15 DG Erection area	DP 10 DG Room slab thickness
DP1	Roof slab thickness	X														
DP3	Plant room layout		X	X	X											
DP11	Pile foundation area		X	X	X											
DP4	Entrance width		X		X		X		X							
DP12	Cable erection length		X			X	X									
DP7	Cable trench length	X	X		X	X	X									
DP5	Station Dwall width	X						X								
DP8	Cable trench depth	X				X	X		X							
DP9	Chiller slab thickness		X							X	X					
DP13	Chiller Erection area		X		X	X				X	X					
DP2	Vent Shaft area	X										X				
DP14	Pile depth		X	X									X			
DP6	Entrance depth				X									X		
DP15	DG Erection area		X		X	X									X	
DP 10	DG Room slab thickness		X				X				X					X

Figure 8. Partitioned DSM - Underground Metro Plant Room (Positive Iterations)

Multiple Domain Matrix (MDM)

MDM		Structural T1	ECS T2	Electrical T3	Entrance C3	Cable trench C4	Staircase C5	Plant room C2	Roof slab C1	Vent Shaft C6	Roof slab thickness DP1	Vent Shaft area DP2	Plant room layout DP3	Entrance width DP4	DG base slab thickne DP10	Entrance depth DP5	Station Dwall width DP6	Cable trench length DP7	Cable trench depth DP8	Chiller slab thickness DP9
T1	Structural	X	X	X									X		X			X	X	X
T2	ECS	X	X	X							X	X		X		X				
T3	Electrical	X	X	X									X	X		X	X			
C3	Entrance				X	X	X	X					X					X	X	
C4	Cable trench				X	X	X	X					X	X		X	X			
C5	Staircase				X		X	X					X	X						
C2	Plant room					X	X	X	X		X							X		
C1	Roof slab							X	X	X		X			X					X
C6	Vent Shaft							X	X	X	X		X							
DP1	Roof slab thickness	X							X		X	X								
DP2	Vent Shaft area		X							X	X	X								
DP3	Plant room layout		X					X			X	X	X	X	X	X		X		X
DP4	Entrance width	X			X								X	X	X		X		X	X
DP10	DG base slab thickness		X					X					X	X	X					
DP5	Entrance depth	X			X											X				
DP6	Station Dwall width		X		X									X			X			
DP7	Cable trench length			X		X					X		X	X			X	X		
DP8	Cable trench depth			X		X					X		X	X			X		X	
DP9	Chiller slab thickness		X					X					X							X

Figure 9. MDM of Underground Metro Plant Room (Negative Iterations)

MDM		Structural T1	ECS T2	Electrical T3	Plant room C2	Pile C6	Entrance C3	Cable trench C4	Sheet Pile C7	Roof slab C1	Vent Shaft C5	Roof slab thickness DP1	Plant room layout DP2	Pile foundation area DP12	Entrance width DP4	Cable erection design DP7	Cable trench length DP7	Station Dwall width DP5	Cable trench depth DP8	Chiller slab thickness DP9	Chiller Erection design DP15	Vent Shaft area DP3	Pile depth DP13	Entrance depth DP6	DG Erection design DP16	DG Room slab thickness DP 10
T1	Structural	X	X	X									X				X		X	X						X
T2	ECS	X	X	X										X	X						X		X	X		
T3	Electrical	X	X	X								X				X		X				X		X	X	
C2	Plant room				X	X	X	X						X	X								X	X		
C6	Pile				X	X	X	X	X				X							X				X		X
C3	Entrance				X	X	X	X	X	X			X			X			X		X				X	
C4	Cable trench				X	X	X	X		X			X		X			X								
C7	Sheet Pile				X	X	X	X	X	X			X		X		X		X	X						X
C1	Roof slab									X	X											X				
C5	Vent Shaft									X	X	X														
DP1	Roof slab thickness	X								X		X														
DP2	Plant room layout		X		X								X	X	X											
DP12	Pile foundation area	X				X							X	X	X											
DP4	Entrance width	X					X						X		X		X		X							
DP7	Cable erection design	X			X			X	X				X			X	X									
DP7	Cable trench length			X				X				X	X		X	X	X									
DP5	Station Dwall width	X					X					X						X								
DP8	Cable trench depth			X				X				X				X	X		X							
DP9	Chiller slab thickness		X		X								X							X	X					
DP15	Chiller Erection design	X			X				X				X		X	X				X	X					
DP3	Vent Shaft area		X								X	X										X				
DP13	Pile depth	X				X							X	X									X			
DP6	Entrance depth	X					X								X									X		
DP16	DG Erection design	X			X				X				X		X	X									X	
DP 10	DG Room slab thickness		X		X								X				X				X					X

Figure 10. MDM of Underground Metro Plant Room (Positive Iterations)

In MDM, elements relationships can determine indirectly by capturing direct relationships of any one element type using a deduction of logic (Maurer and Lindemann 2008). Modeling different element types relationships individually in DSM is a time-consuming process and can generate errors. In this study as shown in Figures 9 and 10, parameter DSM is considered as native DSM, and other DSMs such as teams and components are derived from parameter DSM using MDM methodology. Parameters relationships in DSM are captured from experts while other DSMs are derived by matrix multiplication of respective DMMs. For instance, as shown in Figure 9, the relationships between elements in the team and component DSM can be obtained by multiplying team-parameter DMM, parameter-team DMM and parameter DSM (see logic 6 of Figure 6 in Maurer and Lindemann 2008). If the relationships among DPs are not available, then two DMMs can be multiplied to obtain team and component DSM (see logic 3 of Figure 6 in Maurer and Lindemann 2008). Similarly, other logic (Maurer and Lindemann, 2008) can be utilized to derive DSMs. Thus, iteration blocks - negative and positive as shown in Figures 9 and 10 are identified semi-automatically across team and components.

DISCUSSION

The findings of the case study are presented in Table 1. As can be seen from the table, these five matrix-based methods are classified into two groups – a) design-oriented methods: HoQ, AD, and ASM, and b) design-process methods: DSM and MDM. Each method considers different dependencies and algorithms to analyze the solutions. HoQ and ASM require expert ratings to analyze the requirements in the form of customer requirements and affordances, while AD evaluates the proposed design solutions using independent axiom. On the other hand, DSM uses a partitioning algorithm to resequence the elements to form iteration blocks, and MDM models indirect relationships of multiple elements using a deduction of logic principle.

Table 1. Matrix-Based Methods Classification

	Design-Oriented Methods			Design Process-Oriented Methods	
Characteristics	HoQ (Akao, 1900)	AD (Suh, 1990)	ASM (Maier et al., 2007)	DSM (Steward, 1981)	MDM (Maurer, 2007)
Element types	Two	Two	Two	One	Multiple
Dependency	Functional	Functional	Affordance	Informational	Informational
Aim	Identifies unnecessary specifications	Identifies good and bad designs	Identifies harmful relationships	Model and estimate iterations	Model and estimate iterations
Principle	Capture CRs and TRs relationships	Capture FRs and DPs relationships	Capture affordances and components relationships	Model information relationships	Model information relationships
Method	Independent/ weighted score method	Independent axiom	Weighted score method	Partitioning operation	Deduction of logics-indirect relationships
Analyse	Determine relative weights	Classify designs – coupled, decoupled and uncoupled	Harmful and helpful relationships (%)	Multiple design sequences (minimum and maximum duration)	Multiple design sequences (minimum and maximum duration)
Output	Critical TRs with high importance ratings	Functional decision-making sequence	Critical components with a high negative percentage difference	Choose an optimum path (least duration)	Choose an optimum path (least duration)

For proper usage of these methods, it is essential to understand in which phase of construction project these methods can be applied. As can see in Figure 11, AD and HoQ can be applied in the conceptual design phase as these methods focus on the finalization of technical concept through processing requirements systematically. ASM can analyze affordances in designs at the end of conceptual design after finalization of components specifications. Further, as shown in Figure 11, DSM and MDM can be used in the detailed design and construction phase to model the design iterations and execution rework. DSM and MDM cannot be applied in the conceptual design phase due to non-availability of components specifications. HoQ, AD, and ASM are ineffective if applied in detailed and construction phase as it delays the finalization of designs or deliverables to the construction phase.

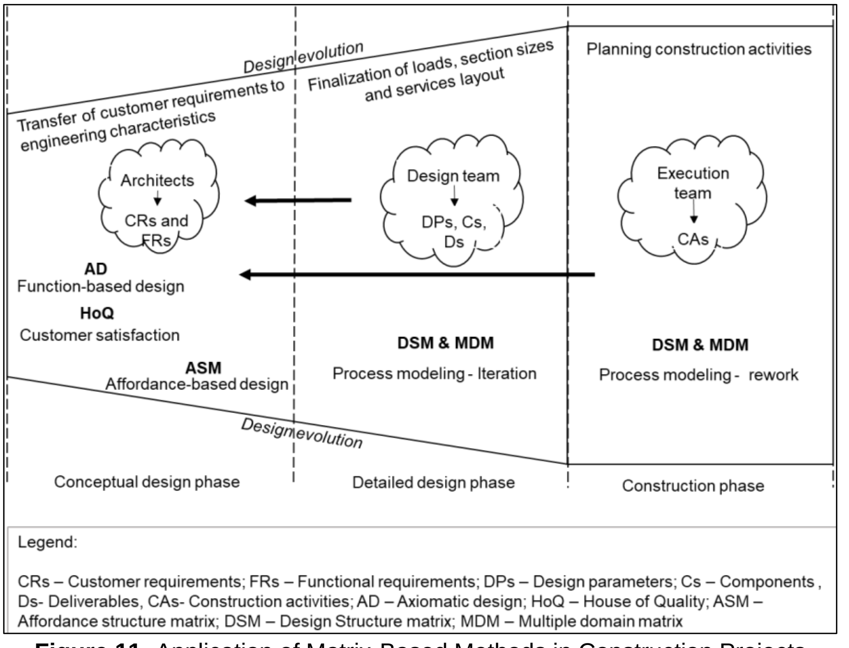

Figure 11. Application of Matrix-Based Methods in Construction Projects

On the basis of these findings, it can be stated that systematic planning of construction projects can be divided into three stages: (1) requirements generation and analysis; (2) solutions generation and analysis; (3) execution of decisions. In stage 1, HoQ can aid to identify project requirements by transferring CRs to TRs systematically. Stage 2 involves the analysis of proposed designs using the independent axiom of AD. AD systematically analyze conflicts among FR-DP pairs and converts coupled designs into decoupled or uncoupled designs to eliminate redesigns at later stages of a project. Further, ASM can aid to evaluate proposed designs by examining the harmful relationships of components with affordances. In stage 3, the decisions can be scheduled and implemented using DSM and MDM by modeling information relationships within and across multiple elements.

It is evident from this study that matrix-based methods complement each other with their unique advantages. It can suggest that the collective usage of matrix-based methods can aid project planners to solve multiple issues in construction projects. For instance, integrating AD and DSM (Tang et al., 2009) in the conceptual design stage can eliminate unnecessary rework or negative iterations at later stages of the project. Integration of HoQ and AD (Gilbert III et al., 2014) can aid planners to enhance customer satisfaction and achieve project requirements in a logical sequence. Integrating AD and MDM can enable to track and assess requirement change impacts across multiple elements such as parameters, teams, components, and deliverables. ASM (Maier et al., 2007) as discussed earlier integrates HoQ and DSM to analyze affordances in the designs. Since ASM can apply only after the finalization of components specifications, integrating with an AD can aid to analyze both functions and affordances of design solutions at the same time during the conceptual design stage.

There are other matrix-based methods which are derived from basic methods (refer Figure 1) and applicable for specific context are High Definition Design Structure Matrix - HHDSM (Tilstra et al., 2012), Modular Function Deployment - MFD (Erixon, 1998), and Change prediction method – CPM (Clarkson et al., 2001). HHDSM is developed on the basis of the DSM concept, and it can be applied to capture the different level of detail and interactions across the elements. MFD uses HoQ principles to achieve modularisation fulfilling project requirements and environmental drivers. CPM integrates DSM and risk management principles to predict high-risk change impacts through modeling components relationships. In this study, only five matrix-based methods as shown in Figures 1 and 11 are reviewed as these methods are generic and can apply to any problem related to the planning of construction projects.

CONCLUSIONS

This study set out to critically review the five matrix-based methods to enhance the planning of construction projects. Matrix-based methods have the capability to model and analyze interdependent decisions systematically to meet a diverse range of project requirements. Each method analyzes different types of relationships between same and different elements. HoQ and AD can systematically transfer project requirements into the technical concept using a functional approach. ASM captures affordances and components relationships to minimize harmful effects. DSM and MDM can aid to schedule the iterative decision-making process systematically. One significant observation in this study is that all five methods complement each other with distinctive advantages. This study provided a roadmap for proper usage of five matrix-based methods across different phases of a construction project. The findings can aid project planners to manage the designs and its process holistically and can minimize schedule and cost overruns. The present study has one limitation. The five matrix-based methods are reviewed using qualitative data. Future work will include the development of an integrated framework for the qualitative and quantitative analysis of design solutions for systematic planning of construction projects.

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A REVIEW ON THE COMPARATIVE STUDY BETWEEN THE PRECAST AND CONVENTIONAL BUILDING CONSTRUCTION

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Abstract
The precast building construction method emerged in Malaysia construction industry as an approach to accelerate the productivity. This paper aims to provide an overview on the critical elements used for the comparative studies in precast and conventional building construction methods. Previous research works are reviewed to identify the standardization in comparison between the chosen building systems and the critical elements contributing to the economic benefits. It is important to evaluate for the standard comparison between both construction methods in the assessment for better choice among the two-construction methods.

Keywords: *Precast construction method; Malaysia construction industry; productivity; conventional construction method; critical elements; comparative studies*

INTRODUCTION

The conventional construction method is the oldest method which has been practiced in the construction industries worldwide. Concept of conventional construction method is commonly referred to as structural components that are fabricated on construction site, on- site installation of steel reinforcements, and the use of timber or plywood formworks for the casting of components (Andres and Smith, 1998; Badir and Kadir, 1998; Haron et al., 2005; Lou, 2012; Aishah and Ali, 2012; Lou and Kamar, 2012; Rahim and Syazwan, 2013).

Andres and Smith (1998) defined conventional construction method as more expensive since it consumes more raw materials such as the timber formworks and steel reinforcements during the on-site fabrication of building components. It also uses more labours for the cast in-situ works. However, conventional buildings are mostly built from conventional construction method. Due to high labours consumption for site works and low speed construction, conventional construction method is more costly (Badir and Kadir, 1998).

On the other hand, precast construction method is specific to structural components which are standardized and prefabricated or produced off-site (factories or plants that are located away from the construction site). The components are then transported and assembled onsite (Rohana and Siti, 2013). Malaysia construction industry defines precast construction method as industrialised building system (IBS) as it involves mass production of components through industrial methods (Azhari et al., 2012). Precast construction method has been defined by various researchers as an alternative construction method towards the adoption of prefabricated and mass production of the building works which tends to improve the productivity, quality, time and cost saving (Junid, 1986; Khaiat and Qaddumi, 1989; Badir and Kadir, 1998; Sarja, 1998; Gibb, 1999; Trikha, 1999; Warswaki, 1999; Parid, 2003; Trika, 2004; Haron et al., 2005; Ekholm et al., 2005; Marsono et al., 2006; Omar and Rahman, 2006; Chung and Kadir, 2007; Abdullah et al., 2009; Ahmad et al., 2011; Abedi et al., 2011; Construction Industry Development Board, 2017).

Khaiat and Qaddumi (1989) stated that precast construction method reduced the amount of site labour involved in building operations since the elements are standardized and prefabricated in factory. Badir and Kadir (1998) described precast construction method can comprise all various site works such as temporary facilities, building frames, building finishes and equipment. It is based on the industrialization concept to produce the prefabricated components in factory and it integrates all the process of preassembly, organization and completion of project with well management (Gibb, 1999; Parid, 2003; Ekholm et al., 2005; Omar and Rahman, 2006; Marsano et al., 2006; Chung and Kadir, 2007; Ahmad et al., 2011).

In correspondence to those studies, Trika (2004) defined the precast construction method as the building system of which all the building components are erected and assembled through mechanized means and involved minimal site works. It is a set of interrelated activities between the managerial and technological for the production and installation of these elements (Junid, 1986; Sarja, 1998; Abdullah et al., 2009; Abedi et al., 2011).

As a summary, all the definitions from the researchers can be generalised into the significance of precast construction method to view as technological, process integrated, standardised, well-planned; organised; and high-prefabricated production.

To date, conventional construction method still cannot get rid of the problems of long construction time, low productivity, poor safety records, and large quantities of waste (Egan, 1998; Eastman, 2008; Azam et al., 2013). Instead, Malaysia construction industry worked a great attempt in the adoption of precast construction method. Precast construction method has restructured the entire conventional construction process in order to improve and speed up both the design phase and production planning. The precast construction method has emerged as a new fast track construction method to boost the growing economy. It raises the significant advantages in terms of shortened construction time, lower overall project cost as well as better quality. Besides, it also enhances occupational health and safety, more means for sustainability with less construction waste, less environmental emissions, and reduction of energy and water consumption (Ismail and Shaari, 2003; Lai, 2005; Dabhade et al., 2009; IEM, 2001; Chen et al., 2010; Yang and Yunus, 2011; Azam and Zanarita, 2012; Bari et al., 2011; Ismail et al., 2012; Shamsuddin et al., 2013; Jabar et al., 2013; Dineshkumar and Kathivel, 2015; Virendravyas, 2015; Construction Industry Development Board, 2017).

Ismail and Shaari (2003) interpreted precast construction method as not aimed to substitute the conventional construction method but an approach to decrease the reliance on labour, improve productivity with shorter construction time and maintain the quality. Lai (2005) indicated precast construction method as an attempt to show greater productivity, shorter construction period, improved quality and reduction in overall construction cost in large-scale precast buildings in Malaysia. Yang and Yunus (2011) and Shamsuddin et al. (2013) viewed that precast construction method is able to increase the profit in long-term for the stakeholders as the cost of the labour and materials can be reduced. In contrast, Azam and Zanarita (2012) stated that precast construction method does not have much difference in term of material saving as compared to conventional construction method but it has benefits in terms of quality and labour saving.

Precast construction method that is recognised as a fast-track construction method can offer time saving during construction which compensates the overall construction cost (Dineshkumar and Kathivel, 2015; Virendravyas, 2015). Kathivel (2015) explained that the rapid construction rate by adopting precast construction method because the method reduces unnecessary handling and equipment time. On the other hand, conventional construction method consumes a lot of time during the on-site hardening of concrete with the usual practice of at least of 7 days to achieve its concrete strength. In correspondence, Virendravyas (2015) conducted a comparative study between precast and conventional construction method and stated that precast construction method registered almost the whole saving on plastering and finishing works. Similarly, according to the previous data reported from Construction Industry Development Board (CIDB) (2017), it shows that the precast construction method gives rise to cut down the construction costs as much as 15% in some instances. So, the precast construction method that produced in mass production can build a large number of buildings in short time at low cost. This stimulates the development of domestic construction industry at the meantime.

The implementation of precast construction method in Malaysia has a very wide range, from the iconic buildings to the infrastructures; such as KLCC, Petronas Twin Towers, National Stadium Bukit Jalil, Kuala Lumpur’s Sentral station, KL’s new international airport, Putrajaya Bridge, Light Rail Transit, and also the Monarail (Idrus and Utomo, 2008; Phang, 2017). The precast industry receives great encouragement by the government with the increase in incentives to motivate the saleable area, quality and sustainability. Despite the adoption of precast construction method on those high-profile projects and current existing conventional construction method is deemed to be ‘3D’ (dirty, difficult and dangerous), besetting the perennial problems such as time delay, cost overrun and waste generation; the growth of the precast construction method is still slow. Therefore, it is essential to look at how the precast construction method is able to save cost and time for all the construction industry practitioners.

As in the year 2016, the total construction contracts in Malaysia are RM 124.96 billion. The public sector accounted for 23% and the private sector undertook the remaining 77 % of the contract values. The public sector took a total of RM29.07 billion involving the residential projects (RM 0.60 billion, 2 %); non-residential projects (RM 6.12 billion, 21 %); and infrastructure projects (RM 22.35 billion, 77 %). Comparatively, the private sector undertook the larger contract amounts with the total of RM 95.89 billion consisting residential projects (RM 28.62 billion, 30 %); non-residential projects (RM32.07 billion, 33 %); and infrastructure projects (RM 35.20 billion, 37 %) (Elias et al., 2017). From this statistic, it can be seen that the private sector is the major player in the construction industry but the adaptation of precast construction method in the private sector is extremely low at 14 %, as compared to 69 %in the public sector (Department of Statistic Malaysia, 2016). Thus, this clearly reveals that the private sector must take the lead to practice precast construction method in Malaysia.

Therefore, this paper intends to review previous research works carried out on the comparative study of conventional and precast construction methods with the focus on building projects. The types of structural components used for the comparative studies are addressed and critical elements involved in the comparative studies are also reviewed herein.

COMPONENTS OF PRECAST AND CONVENTIONAL CONSTRUCTION METHODS

Generally, the conventional construction method is divided into two major components. The first component is the structural system which is the cast-in-situ (cast in the construction site) of the structural frame such as column, beam, and slab. The second component involves the construction operations which are the erection of timber formwork and scaffolding, installation of steel bar, pouring of fresh concrete and disassembly of formwork and scaffolding (Asiah et al., 2012).

The precast construction method is the most popular IBS system practiced in Malaysia construction industry (Alinaitwe et al., 2006). Figure 1 shows the IBS manufacturers in Malaysia (not including Selangor) in the year 2014. According to the statistics obtained from IBS Centre (2014), the data shows the increase in precast manufacturers from 15 in the year 2009 to 53 in the year 2014.

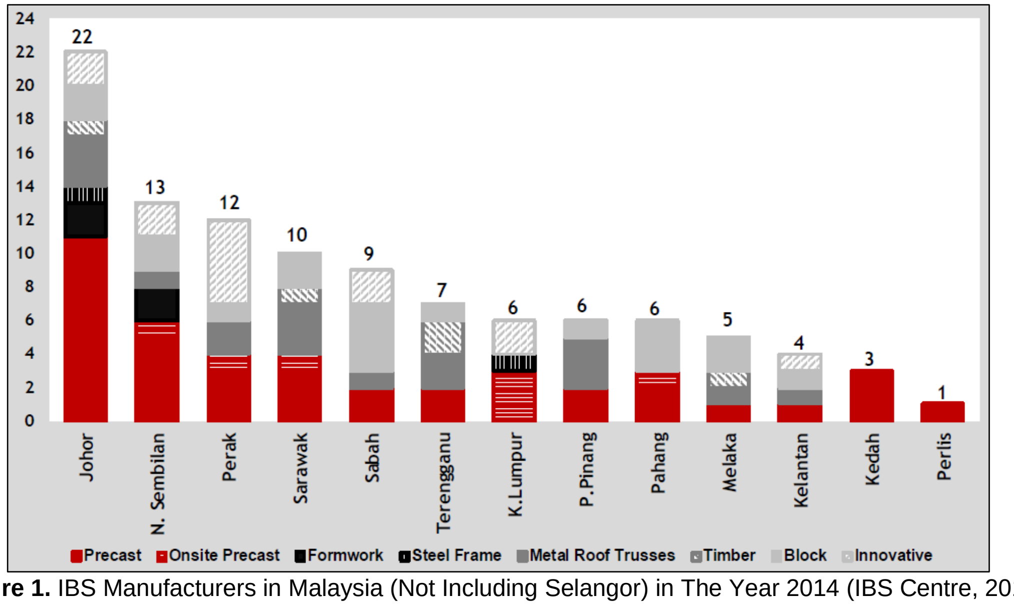

Figure 1. IBS Manufacturers in Malaysia (Not Including Selangor) in The Year 2014 (IBS Centre, 2014)

According to the Construction Industry Development Board (CIDB) (2013), there exists total numbers of 172 types of components listed as precast components. The precast components are further divided into precast building system and precast infrastructure system. The precast components must possess the six characteristics as following:

i. Production of prefabricated components through industrial process;
ii. Highly mechanized in-situ processes;
iii. Reduced labour during prefabrication of components and site works;
iv. Modern design and manufacturing methods such as utilisation of Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM);
v. Systematic Quality Control to fulfil ISO 9000 principles;
vi. Create Open Building Concept for permitting hybrid applications, adaptable to standardisation and modular coordination (MC).

According to Construction Research Institute of Malaysia (CREAM) (2017), 'precast components' are defined as structural precast components and are divided into seven main categories, namely beam, column, half slab, hollow core slab, prestressed planks, staircase and wall (load-bearing and non-load-bearing wall). For example, the components that are commonly installed in precast building system includes precast columns, precast wall panel, precast slab or half-slab, precast beam and precast staircase as shown in Figure 2. The principal of measure of precast construction method is through the use of standard prefabricate components from Malaysia Standard MS 1064 with repetition design.

Figure 2. Precast Building System (CIDB, 2013)

BARRIERS OF PRECAST CONSTRUCTION METHODS IN MALAYSIA

Although precast construction method is an ideal conceptualisation as compared to conventional construction method, it is still not able to cater the demand of the market. As summarised from CREAM in 2007, the barriers of adoption of precast construction method in Malaysia included lack of knowledge among designers; lack of standardisation; slow adoption from the private sector; monopoly of certain manufacturers, lack of special machinery and equipment; and lack of skilled workers.

Previous research studies have been carried out particularly to support the arguments. Researchers including Angela et al. (2013); Asmah et al. (2012); and Martinez et al. (2008) gave an overview regarding the problems on the knowledge among designers. According to Angela et al. (2013), lack of standardisation in design is a concerned technical issue that limit the practice of precast construction method. The project indirect cost will tend to increase and therefore it is not economical as compared to conventional construction method. Asmah et al. (2012) had conducted a research on the target group of G5-G7 contractors registered under CIDB within Sarawak region. It was concluded that most of the contractors are still lack of exposure and show limited application on precast construction method. The main constraint to the integration of the method in the local construction industry can be identified through the payment and investment method on precast components especially the weak level of implementation due to lack of knowledge and design standardisation which is still based on conventional practice. In addition, it is surely a gap and hard to decide on the precast construction method as it requires more coordination and planning during the design stage. It is necessary for the client and construction professionals to carry out two-way information to make earlier decisions and have better communication to avoid expensive changes and variations to the design once production has started (Martinez et al., 2008).

The adaptation of precast construction method in Malaysia experienced the problems with regards to the lack of precast manufacturers and supplier causing the price of precast components to increase when the demand increases faster than the supply and the existence of monopoly which is not beneficial. This is supported by Khalfan and McDermott (2009) which stated that Malaysia is lacking precast manufacturers and it became worse when the adoption from the construction industry practitioners is slow and demand for the precast components is low. In addition, the limitation for the adoption of precast construction method is due to the perception among the stakeholders that precast construction method is mechanised based and it involves high initial capital for investment. Precast manufacturers will charge for an initial payment or deposit from the contractors for the purchase and delivery of precast components. Subsequent delivery of precast components would also require immediate payments. This may create cash flow problems to contractors as the project owner are more used to practice payment methods based on conventional construction work (Kamar and Hamid, 2009).

The Construction Industry Master Plan (2007) identified the low level of implementation of precast construction method was due to shortage of skilled workers and the increase in cost of hiring skilled workers. In correspondence, Chan and Osei-Kyei (2015) mentioned that too much reliance on foreign workers with cheap labour rate is the root cause for current Malaysia construction industry to continue practicing the conventional construction method despite the precast construction method is able to shorten the construction time and lower down the construction cost when building components are mass produced.

The arguments for the construction industry to promote the precast construction method mainly embrace on the economic or monetary perspectives ranging from quality, construction time and cost savings. A numerous research studies which included Rozana et al. (2015), Azman (2013), Yang and Yunus (2011), Jaillon and Poon (2008), Ding (2008), Ali et al. (2006) and Goodier and Gibb (2007) have been done previously and showed the dispute regarding the cost performances of precast construction method as compared to conventional construction method.

Ali et al. (2006) collected the data from 100 residential projects through a questionnaire survey and summarised that there was negligible difference in structural cost between conventional and precast method. Therefore, it upholds the tendency where most of the construction industry practitioners tend to choose the conventional construction method over the precast construction method since there is no motivation in the cost factor.

Goodier and Gibb (2007) and Ding (2008) highlighted the shorter construction time in precast construction method, hence showing significant cost saving. These results were in agreement with the study carried out by Jaillon and Poon (2008) which proved that the reduction of 15% of total construction time in the construction resulted a cost saving of 16% as well as in labour requirement on-site due to the standardisation process in manufacturing the building components.

Yang and Yunus (2011) proved that the cost for labour and materials reduced significantly when adopting precast construction method but Azman (2013) stated that contractors are reluctant to involve in precast construction method due to high-cost consumptions on materials and skilled-labour. Correspondingly, the economic attribute of precast construction method may offer a remarkable profit margin from its overall cost saving rather than an individual cost perspective since it offers faster in return-on-investment (ROI) of a project (Rozana et al., 2015).

As evidence from the survey done by the CIDB regarding the advantages of precast construction method, as listed from the most beneficial to the least beneficial are (1) less wastage; (2) cleaner environment; (3) less site materials; (4) reduction of site labour; (5) controlled quality; (6) faster project completion; (7) neater and safer construction sites; and (8) lower total construction cost (Majid, 2011). Therefore, it should be noticed that the total construction cost still remains as the primary concern on the selection of construction methods.

Although it is generally on accepted fact that the use of repetitive precast components contributes to appreciable cost savings in a high-rise project, it is not clear if such cost advantages apply in a low-rise landed house environment. In the interest of investigating the technical feasibility of precast construction method for landed houses, there is a need for comparison of cost on precast construction method versus conventional construction method for low-rise housing.

According to the report from the Research Design and Standards Organisation (2014), there still exists the root problem on the variation in the cost of precast components, which differs according to the type and size of construction. For small scale project, the total cost will be higher due to no production of elements in bulk. Instead, it results in lower cost for bigger projects. This is supported by the study carried out by Dineshkumar and Kathivel (2015) in India where it was found that the cost of construction for a double-storey residential building using precast elements showed 13 % more expensive than the cost of conventional construction method. Akash and Venkateswarlu (2016) addressed the same limitation by noticing that the increase or decrease in costs as a result of one more or one less unit of output causing the cost increase is more marginal than substantial. But mass production of repetitive precast units will eventually lower down the cost to a level comparable to conventional construction.

According to Azman et al. (2011), precast construction method creates high buildability for high repetition building particularly for the high rise building but this benefit is limited for the low rise building since it has less repetition. Anecdotally, precast construction method offers fast in two cycled projects if the sequence of work is planned properly. Due to high initial investment for the precast technology, it usually consumes much maintenance cost and it requires a few projects to cover the initial cost of precast technology.

In Malaysia, precast construction method is usually integrated into high-rise governmental projects or projects with high repeatability in structures instead of a low-rise residential project (Jaafar et al., 2013). The private sector is reluctant to adopt precast construction method as it was found not economical for building projects of less than 100 units or 5-storeys (Amir et al., 2015).

Generally, the two factors to escalate the efficiency of practicing precast construction method includes:

i. Designing of the building layout with maximum repetition of precast unit.
ii. Designing construction details to maximise the number of standardised components.

The concrete issue for the precast construction method can be identified direct or indirectly. The direct issue is always related to the elements, system, production, handling, assembling, and connection and demounting. The indirect issue to consider precast construction method are the precast concrete materials, technology, structural analysis and equipment. Therefore, the selective use of precast components within conventional building system may have economic and managerial benefits even in the case of small and heterogeneous projects with less design repetition (Senthamilkumar et al., 2014). Bhavani (2014) explicitly explained the importance of the design and planning phase and in the division and specialisation of human workforce in order to complete the project on high speed.

Conclusively, the main barriers that should be overcome to persuade the continuous development of precast construction method is to ensure the considerable profit for the clients and stakeholders in long-term income and expenditure (Hao et al., 2007).

CRITICAL ELEMENTS FOR COMPARATIVE STUDY BETWEEN PRECAST AND CONVENTIONAL CONSTRUCTION METHODS

Cost is regarded as the main critical factor in determining the nature of business, not least in the construction industry. Construction cost is the factual data which consists of cost estimating till finished quantities of a building. It is the fundamental to predict and plan the total executing cost of a construction work. Therefore, it is the most rational criteria and vital for evaluating the choice on construction method (Norazmi, 2008).

In Malaysia, there still exists arguable comparison or simply describes as ‘apples’ are being compared to ‘oranges’ to give ambiguous information for the comparison study prior to selection between the conventional construction method and precast construction method. The way forward for the comparison of the construction methods is to compare “apple to apple” (Henk and Peter, 1999).

Normally, the building owners, contractors, and investors adopted the construction cost indices to allow for the comparison of the building construction cost across the countries, such as multi-nationally or major urban area domestically where the construction cost indices are used to estimate the cost by taking into consideration of the local currency (Davis, 2010). The way to compute the construction cost by adjusting the purchasing power parity as an approach to correlate it to a reasonably cost relativity between two distinct localities was also suggested by McCarthy (2011). Although building economists updated the construction cost indices regularly, it is, however, cost estimation of an equivalent building based on per square meter basis does not take into account the different construction methods and ignores broadly the location conditions such as labour force availability, weather and terrains. Significantly, it impacted on the cost overruns and limited the construction industry development with regards to the choice of construction methods (Stapel, 2002). Previous studies on the cost comparison between two localities by using the construction cost indices carried out by researchers such as Stapel (2002), Walsh and Sawhney (2004) and Davis (2010) have not relatively linked the choice of construction methods and location-specific conditions.

Therefore, the more accurate comparative methods have been widely discovered over the time in order to improve the accuracy and develop more reliable comparison method between the conventional and precast construction methods. Previous researchers (Bouwcentrum, 1995; Eurostat, 1996; Lim et al., 2017) including the government body (Jabatan Kerja Raya, 2017) have published the guidelines for the purpose of comparative study.

In the comparative study between precast construction method and conventional construction method, there exist five types of key comparative methods for the estimation on construction project total cost. These include the cubic content estimation; floor area; unit valuation; bill of quantities; and approximate quantities. Cubic content estimation is the most simplified method used to obtain the project total cost of which the volume of a building is obtained through the product of dimension of the building (height × length × width) and assume the construction cost per unit volume. The floor area estimation method is based on the assumption of the area on the particular slab by multiplying its width and length and cost is counted by per square metre. Unit valuation method estimates the quantity of certain equipment of occupants that is constantly occupying the building based on unit cost.

Bill of quantities is the regular method practiced by the construction industry of which refer to the estimation on project total cost by referring to the cost calculated by the quantity surveyor on each of the materials and components used for the building. Approximate quantities are the most accurate method for estimating project total cost. It estimates cost by listing out all the components of the building in detail based on the construction drawing and calculates based on its typical unit cost of the respective component (Jabatan Kerja Raya, 2017).

The precast construction method is a concept to develop a prototype module that can be replicated and customised to suit varying needs and situations. Study on precast construction projects can be divided into 3 categories which are the fully precast project, partially precast projects, and selected components precast projects. The fully precast project integrates highly standardised and repeated precast components throughout the building design and construction. Partially precast projects combine both the use of conventional structural components and precast components in a building project while selected components precast projects refer to the building project that involves only a particular type of selected precast components in the building projects which aims for creative and aesthetic requirements (Lim et al., 2017).

In addition, Bouwcentrum (1995) and Eurostat (1996) suggested 3 methods for comparing costs of building projects which include the comparison of standardised identical buildings; comparison of standardised identical buildings with local modifications; and comparison of standardised identical buildings with similar functionality. Comparison of standardised identical buildings is about the comparison on the identical buildings based on the same drawing and specifications but this comparison method does not take into consider on the local modifications, codes, standards, and specifications. Instead, comparison of standard buildings with local modifications is more accurate as the cost is correlated to its local modifications, codes and specification levels. The third method, comparison of functionally similar buildings comparison of standardised identical is an approach where it includes the types of building as well as its functionality and aesthetic value fulfil the client’s expectations.

Construction cost has all the complex and complicated elements. Ambiguity in the interpretation of cost performance in construction projects has become a major concern for both contractors and clients (Proverbs and Xiao, 2002). It is necessary to address the project- related determinants and its effect (Proverbs and Xiao, 2002 and Elhag et al., 2005). According to Elhag et al. (2005), a reliable cost-estimating technique is delivered when the cost-determinants is fully considered. The cost-determinants included all the direct and indirect costs. Previous research studies carried out by Bubshait and Al-Juwairah (2002), Chan and Park (2005), Elhag et al. (2005), Stoy and Schalcher, (2007), Memon et al. (2010), Aini et al. (2012), Rohana and Siti (2013) focused on factors that affect the overall cost in construction starting from project estimation to completion. These studies affirmed that construction cost is directly affected by the competence in managing cost, technologies, economic as well as government policies.

Bubshait and Al-Juwairah (2002) carried out a survey from the group of contractors, consultants and owners had concluded that improper planning and managing in direct cost such as material cost has led to the financial-control problem which resulted in high construction cost. Similarly, Memon et al. (2010) had gathered research data for general construction project despite the selection on construction methods through questionnaire and statistical tools. This study concluded that poorly managed project scheduling especially in large government construction projects has generally influenced the construction cost in construction project. From those studies, it should be realised that the proper project management must be practiced in order to control the flow of construction cost. Besides that, labour cost is another crucial element in determining the selection of building construction method since the highly skilled labours implement in the precast building construction method always caused higher rate than the labours in conventional building construction method. Manufacture of precast components require a number of skilled works but these numbers are still in shortage and therefore must be hired in higher wage rates. This argument was supported by the study carried out by Chan and Park (2005). The study has randomly picked the sample study of Singapore's building projects valued at more than US$5 million and identified the crucial component caused the construction industry to facing problem in construction cost is the high-technologies and high-skilled worker requirement which tends to increase the cost, which is out of the cost estimation.

In addition, Aini et al. (2012) carried out a study towards IBS in Malaysia. The study was conducted through questionnaire survey to extract the views on determining the cost-influencing factors of IBS projects in Malaysia from IBS contractors' and manufacturers' perspectives. This study concluded that construction cost is impacted by economic and market condition which may cause the risk in cost overruns. Apart from that, Rohana and Siti (2013) gathered data from the ten samples of interviewers and emphasised that it is important to address the inter-relationship of cost factors which include labour, material and production cost in order to sustain the implementation of precast construction method in Malaysia construction industry.

Extensive studies have been done to identify the factors that affect the overall cost of construction projects. The research outcome suggests that various elements, ranging from project estimation to completion, will significantly affect the project cost (Memon et al., 2010; Elhag et al., 2005; Chan and Park, 2005). It is important to address all the project-related determinants and its magnitude in order to control the project cash flow. A representative comparison must take into account all the relevant elements which can be further classified into time-dependent and quantity-dependent cost components and contributed towards the direct and indirect cost such as labour, material, investment, general expenses, transportation and overhead.

It is however, as supported by CIDB (2016) and Lim et al. (2017), the relationship between the time, labour, materials and costs are always interrelated and cannot be analysed separately. It should be evaluated in its overall context. According to CIDB (2016), the method of costing by material quantities with a fixed factor for labour cost usually practiced by the local construction industry. But it should be realised that this method can lead to incorrect estimation. For instance, the labour usage in precast construction method is usually half of the conventional construction method. However, precast construction method may compensate for a 10% increase in material cost, but there is saving in time. Also, if properly designed and executed, precast construction method can lead to a much better capacity of work. The overall cost impact of precast construction method has, therefore, to take all these factors into consideration. Resulted from the less consumption of time and labour cost, the trend is that precast construction method become increasingly competitive compared to conventional construction method. Concurrently, in the research study from Lim et al. (2017), it was identified that material cost is a significant part of the precast construction method but it should not be evaluated independently of other cost-related factors. For example, by using more expensive precast construction method, direct labour cost is reduced. This is a significant consideration in a market like Singapore where labour cost has been expensive and are expected to continue to rise. Time-saving is another important factor, and this translates directly into lower preliminaries and faster project turnover. Thus, it will be easier to cater for the benefit of each construction method, either conventional or precast by considering the critical elements through the three main stages: design, production and construction.

During the design stage, the nature of the construction project can be used to decide the more favourable construction method. The main consideration is the project characteristics. Project characteristic tends to figure out the flow of project management and coordination (Stoy and Schalcher, 2007; Aini et al., 2012; Azman et al., 2012; CIDB, 2017). Somehow, precast construction method with repetitive components must be created with high buildability and ensure the competence of the heavy precast components to be stiff and rigid for handing and installation.

Aini et al. (2012) have conducted a questionnaire survey to study the factors affecting precast construction costs in the Malaysian construction industry. The survey comprised a total number of 44 contractors and manufacturers to look into the critical factors which include the project characteristics, contract procedure and procurement method, consultant, and design parameters, contractor’s attributes, economic and market conditions, external factors and government’s requirements. The results analysed from the relative importance index (RII) showed that factors related to project characteristic (88.18%), contractor’s attributes (82.73%), economic and market conditions (80.45%) are common factors that can influence the construction cost of precast construction project.

It should be noted that the project cost is also influenced by the project characteristics such as project size; project type involving speed of construction, either fast-track or urgency for completion; and also, the repeatability and standardisation with typical floor plans in a multi-story building project. Adequacy of project management may also lead to the good level of coordination and control on the project cost overrun (Stoy and Schalcher, 2007).

Azman et al. (2012) carried out a study of precast concrete in Malaysia by applying a qualitative approach through a series of interviews and observations on 15 decision makers from precast manufacturers with 5-year experience in precast system works and reported that about 33% determined the design-and-build as one of the four main themes in practicing precast building construction method. The best practice tender award for the precast system with design-and-build is able to control the whole project flow, especially during the construction period, with less change in the design stage.

In Malaysia, precast construction method is not a solution for certain construction works. For example, the method cannot be practiced in the construction of structures with unique designs. This is due to lack of design standardisation code in precast project design. Most precast manufacturers have their own respective design system which differs from the other in terms of size, type and installation method. The lack of consistency in design will complicate the installation process. (CIDB, 2017). Therefore, the design of the building layout is prior for the selection of building construction method.

At the production line, the quality control system is another vital element used to supervise throughout the production and manufacturing process to ensure the precast products have achieved higher quality and better finishes. On the other hand, the benefit of improved quality is appreciable but difficult to measure. Better quality means lower subsequent defect rectification costs, but its direct cost benefit is not as easily quantifiable. Therefore, during the production process, it is another concern to take up the initial investment and machinery cost for the precast construction method (Rozana et al., 2013; Rohana, 2016) and to consider the waste generated from both construction methods (Badir et al., 1998; Begum et al., 2006; Dani et al., 2014; Phang, 2017).

Precast construction method has the possibility to reduce the construction project total cost, in the long run, to overcome its high investment of the machinery at the start if it is widely adopted locally. As stated in Rohana (2016) study on the framework in term of process considerations of precast building construction system through semi-structured interviews targeted at construction industry players involved in the precast system at multi-levels, the results have shown that 80.2% of the respondents agreed that initial investment cost is the most important aspects of involving and producing the precast structural components and it must have comprehensive information and knowledge with regards to the construction method prior to control the project total cost in long-run. In addition, Rozana et al. (2013) carried out a study on economic attributes of precast construction method in Malaysia and found out that the method offers long-term monitoring mechanism by using life cycle costing in cost development (about 5%), the thoughts of environmental-related products are always involving huge financial burden up-front in term of financial investment (about 6%), but it offers faster ROI of a project (about 3%).

Conventional construction method consumes more wooden formwork and many numbers of labour and raw material. The long construction time is the main critical constituent toward higher construction cost. However, conventional construction method is suitable for those country where skilled labour is limited since this method does not integrate heavy machines and high-skilled technical works, where labour can be trained easily to perform the construction works such as erecting the moulds and placing the steel reinforcement. Therefore, conventional construction method is technically applicable to almost all types of building construction works since it requires low skills with easy adaptation and simple construction (Badir et al., 1998).

Waste is another serious scenario created from conventional construction method. The continuous increase in material waste has directly impacted on the operational management on site. The material loss greatly affects the productivity and causes the project to lose considerable amount of revenue. According to Begum et al. (2006), almost at least 10% of materials in the construction site is wasted in conventional design, documentaries, materials and site management. As a result, there is an increase in total construction cost of a building. In Malaysia, the precast construction method has been proven that it is better in reuse and recycle around 73% of the construction wastage. As the demand for residential development keeps on increasing, a large amount of construction waste is being produced. For instance, a typical home constructed by using the conventional construction method normally creates between 20%-30% of wastage in terms of production cost. It is estimated that 2.5 to 4 tons (about 1.5 to 2.5 kg per square foot) waste is generated. The largest component of waste material consists mainly of lumber and manufactured wood products, drywall, masonry materials, steel, and cardboard. The remainder is a mix of roofing materials, metals, plaster, plastics, foam, insulation, textiles, glass, and packaging (Dani et al., 2014). On the other hand, precast construction method optimises the use of materials which in turn causes the reduction in waste and increases site safety due to better site management and neatness (Phang, 2017).

During the construction process on site, time consumption must be well controlled to avoid the cost overhead and it is also important to consider the general expenses especially in precast construction method. It is important to supervise on crane planning and coordination on delivery to ensure no consequential delay in the onsite installation process. It is realised that the current construction industry still cannot fully surmount the significant effects on time delay. According to Akintoye et al. (2002) in the study on cost and time overruns of projects in Malaysia, it was discovered that among 359 construction projects in Malaysia, only 18.2% of the public sector projects and 29.5% of private sector projects were completed on time with an average percentage of 49.7% projects suffering time overrun and delay. It might be realised that the projects suffering delay were due to some inevitable reasons which include the problems of financing such as late payment for completed works or poor contract management; sudden changes in site conditions and design; shortage of materials supply and the most unavoidable weather conditions. In addition, a study in Hong Kong also addressed that at least 15-20% of a sample of 67 civil engineering projects suffered extra time consumption and overrun due to inclement weather on site (Miller et al., 2000). As the concept of time is money is the nature of the local construction industry, therefore, it is important to select the alternate construction method so as to minimise the root cause of the time delay such as the issue of inclement weather for site works. Phang (2017) observed that precast construction method is better in cost saving as it consumes less construction time since the construction operation is less affected by bad weather.

Construction method also affects the choice of ‘materials and methods’ used in construction. Total building cost will be affected significantly by the choice of construction methods. Chan (2011) conducted a study on the comparison of construction cost and choice of methods through a quantitative framework study on the construction material, labour and capital cost indices for evaluating the framework structure of the construction industry. It was found that the life-cycle cost of buildings can be reduced if the construction method is easily adopted; the involvement from large numbers of cheap labour forces; availability of abundant construction materials without the added transportation cost; inexpensive maintenance cost and lower investments on the methods used. On the matter of transportation cost, Warszawski

(1999) mentioned that transportation is the main barrier that has limited the design considerations on the size and weight of the completed precast structural components in Malaysia. The length of a volumetric structural component should not exceed 12 m. The precast component should not exceed the maximum height and weight of 4.5 m and 7 tonnes, respectively, when loaded on the trailer. The components could not enter the highway system if they exceed a height limit ranging from 4.8 to 5.1 m. Mobile cranes commonly with 20- ton, 50-ton, or 70-ton capacity maybe required for the hoisting to install the precast structural components. This may somehow increase the operational cost of the construction project. In addition, the construction development area to the fabrication plant should be within the distance of 50 to 100 km for economical transportation cost.

As for the wage rate, is the direct cost per hour paid to the workmen whereas the indirect labour costs are the payments made by a contractor on the behalf of employee. Therefore, the labour rate is the total of direct and indirect cost per hour (Davis, 2010). According to Haron et al. (2013), conventional construction method will cost more in the whole construction project cost due to the cost for labour, raw material and longer time duration of the construction project. According to Zarim (2017), the factors that determined the benefits of the precast construction method includes the labour, of which the number of labours can be reduced, easier coordination, less raids by authorities, less social problems and create more profit. Precast construction method also creates less accident, less disruption to construction time which brings more profit, offers faster construction period, faster delivery to purchasers and less interest payments to the bank. Precast components also minimise defects and gain reputation for delivering fast and high-quality products.

Lim et al. (2017) also noticed that conventional construction method is very labour intensive and unproductive. Wet works such as the fabrication of steels on site have higher wastage, creates housekeeping problems and lead to potential spalling due to poor workmanship. Quality pertaining to bulging formwork and honeycombing problems, result in abortive works like hacking and patching. Advantages of precast construction method includes self-supporting ready-made components are being used, so the need for formwork, and scaffolding is greatly reduced. Construction time is reduced and buildings are completed sooner, allowing an earlier ROI. On-site construction and site congestion are minimised. Quality control can be easier for high-precision components manufactured in the factory. Time spent in bad weather environments at the construction site is minimised. Less waste may be generated and hence more sustainable. On the other hand, challenges of precast construction method include careful handling of precast components such as concrete panels. Attention has to be paid on the strength and corrosion-resistance and leaks of the joining of precast sections to avoid failure of the joint. Transportation cost may be higher for precast components. Large precast components require heavy-duty cranes and precision measurement and handling to place in position.

As a summary, the comparative study between the conventional construction method and precast construction method has to begin with identifying the type and nature of the construction project. Next, the selection of comparative method such as cubic content estimation, floor area, and unit valuation, bill of quantities or approximate quantities depends on the level of accuracy required for the comparison. The critical elements for the comparative study include time, labour, equipment, machinery and material cost. These can be further evaluated from its design, production and construction phases. It is also necessary to break down the critical elements further into fixed cost, time-related cost and quantity- proportional cost.

In general, the construction project total cost is determined from its project direct cost and indirect cost. Despite the investment in the precast may return on its revenue over the long term as more components are produced but many of the local contractors are still not able to adopt the precast construction method due to limited local technology and high investment capital. Time delay is a major reason for escalating project cost. Delay in the completion of a project will likely incur provision for the liquidated and ascertain damages (LAD) payment of a specified amount in breach of contract. The longer the delay, the higher the provision will be.

As mentioned in the preceding discussion, precast construction method reduces the costs on labour and wastage. The profit margin of the method will be less volatile and visible if the cost elements are combined with better project delivery in term of time. The adoption of precast construction method enables better management of building material and hence overcome the supply shortage problem in building material such as sand, aggregates, and ready-mixed concrete. As the increase in demand over supply can raise the construction cost which can burden builders, precast construction method can also stabilise the building material prices by reducing construction materials used. The critical problems on choosing precast construction method greatly depend on the availability and standardisation of precast components. With the availability of standard components, it will further develop a standard and more competitive price and quality products and hence make it more affordable. Apart from that, the ISO certification of precast manufacturers will boost buyers' confidence in the quality of the product.

SUMMARIZE OF PROBLEMS OF IMPLEMENTATION OF PRECAST BUILDING CONSTRUCTION METHOD

To date, conventional construction method still remains the primary choice of construction method as compared to precast building construction method. Conventional building construction method is widely adopted among the construction practitioners especially the private sector in small scale housing project. It is due to the nature of project total cost is the primary concern for the choice on construction method of which aims to raise the profit turnover.

According to the statistics recorded in year 2016, the total construction contracts in Malaysia is RM124.96 billion. The public sector accounted for 23% of contracts values and the private sector undertook the remaining 77% of the contract values. The public sector took a total of RM29.07 billion involving the residential projects (RM0.60 billion, 2%); non-residential projects (RM6.12 billion, 21%); and infrastructure projects (RM22.35 billion, 77%). Comparatively, the private sector undertook the larger contract amounts with the total of RM95.89 billion consisting residential projects (RM28.62 billion, 30%); non-residential projects (RM32.07 billion, 33%); and infrastructure projects (RM35.20 billion, 37%) (Elias et al., 2017). Hence, the private sector is the major player in the construction industry especially in housing projects. However, the adaptation of precast construction method in the private sector is extremely low at 14%, as compared to 69% in the public sector achieved in the same year (Department of Statistic Malaysia, 2016).

The precast building construction method remains lukewarm since there still exists the ambiguity in term of the interpretation of project total costs. Research findings from previous researchers have polarized on this issue. Most of the research works done previously were focused on comparative study on particular types of structural components and considered the single component for cost-determinants. For instance, the research done by Yong (2010) to compare the material costs on slab and beams constructed by using conventional and precast construction methods cannot fully used to compare the economic performances between both construction methods. In addition, the comparison methods on which to breakdown the project total costs also highlight the extent of accuracy of the comparative results and to ensure the parameters of the comparative study are consistent and obtain homologous comparison. Therefore, previous research findings obtained from Hafiz (2016) on the comparison of material costs between precast half slab and conventional suspended slab tackled from unit cost per floor gross area can be presented into more delicate way. Regarding on this, Jabatan Kerja Raya (2017) stated that approximate quantities is the most accurate method for estimating the project total costs. In between, the cost-determinants have to include all the direct and indirect costs.

In addition, it is hard to convince the construction practitioner to practice the precast building construction method in low rise building project mainly on housing project since there remain disputes findings on the cost effectiveness of precast building construction method in low-rise housing project. As the previous research findings stated that precast building construction method only raises the costs effectiveness in large scale project with building projects more than 5 storey (Research Design and Standards Organisation, 2014; Akash et al., 2016).

COMPARATIVE STUDIES ON CONVENTIONAL AND PRECAST BUILDING CONSTRUCTION METHODS

This section reviews the comparative case studies between the conventional and precast construction methods in building projects. The outcomes of each of the comparative studies are also presented in this section.

Overview on Precast Building Construction Methods Worldwide

The precast construction method is recognised worldwide. According to Jaillon and Poon (2009), the precast construction method has been widely utilised in the developed countries such as Japan, United States, United Kingdom, Sweden, Netherlands, Australia, Singapore, and Hong Kong in the early of 1970’s to fulfil the high housing demand due to rapid increase in population.

In Asian countries, for instance, the precast industry in Japan started in the 1960’s since the usage of precast components and succeeded to represent about 20% of the housing projects in the year 1999. Majority of the precast component being used is the steel framing system (73%), the wood framing system (18%) and reinforced concrete framing (9%). In Singapore, the development of the precast construction industry encountered failure at the early stage when the first precast construction method was launched in 1963 using precast panels and other precast systems to construct 10 blocks of standard 16-storey flats. The project experienced numerous technical and management problems and had to be solved by the conventional method. However, the precast construction industry reincarnated in year 1979 and yet introduced many types of precast systems with spectacular growth. The precast construction industry in Thailand developed rapidly due to labour shortage and high interest rate (Jaafar et al., 2003).

In United Kingdom, about 165,000 precast concrete dwelling units had been built ranging from single storey bungalow to large high-rise buildings in year 1960. Precast concrete represents about 25% of the market for cement product. The precast 'tilt slab' was first introduced in Australia in the early of 1950s to afford the number of accommodations in Canberra. Germany is well recognized for the area of precast internal and external wall as well as roof panel since year 1998. In United State of America, precast construction method emerged in the early of 1930's through the construction of prefabricated steel house by General Homes, Inc. However, the method faded in the early of 1930's due to uncompetitive price, high capital and inconsistent local codes. Fortunately, the trend reversed after the Second World War due to the need to resolve critical shortage of houses. In 1999, prefabricated housing gained substantial market share with 30% of housings using this construction method. Although most low-rise housing uses timber frame, concrete precast system is being used intensively, particularly in areas that are vulnerable to environmental hazards such as hurricanes and tornados (Jaafar et al., 2003).

In Malaysia, precast concrete beams and columns were first introduced in 1960's in a high-rise apartment project of 17 floors. Within year 1995 to 1998, the success of practicing precast construction method in Malaysia can be traced back from the symbolised structures, including the Petronas Twin Tower, the Light Rail Transit, and the Bukit Jalil National Sports Complex. Despite the fact that precast construction method has been introduced in the Malaysia construction industry in the past five decades ago, the method still receives relatively low adoption particularly in the private sector as compared to the developed countries. In terms of technology, while Malaysia is still using mechanical machines, Japan has advanced to robotics in the production of the precast components. Although statistics are not readily available, in 2002, most precast components in Malaysia were found to have originated from the U.S., Germany and Australia with market share of approximately 25%, 17% and 17% respectively. Malaysia-owned precast manufacturers accounted for only 12%. This indicates that there is a considerable room for improvement in the area of research and development of precast construction method in Malaysia (Malaysia Equity Research, 2014).

Cost Comparative Case Studies on Fully Precast Building System and Conventional Construction Methods

In India, Aakash et al. (2016) had carried out a comparative case study on a double storey residential building with precast and conventional building construction methods to review on the role of time, cost, quality and productivity of the precast system. The total duration for both conventional and precast construction methods were divided into substructure, superstructure and finishing works whereas the cost comparison for the structural components was done by categorising it into conventional reinforced concrete components or precast structural components. Results have shown that precast construction method came out to be 23.1% lesser in costs and saved construction time up to 50% compared with the conventional method. The economic aspects in terms of lower cost and shorter time improve the productivity and the quality is secured through the precast products. The particular saving in construction costs may be owing to the design of the building layout with high repetition and standardised precast components.

According to Amir et al. (2015) on economic comparison of industrialised building system and conventional construction system with the same initial investment and time by using building information modelling, the case study for single-story building was modelled by using the Revit Architecture 2013 into two types of plans, one is for precast construction method and the other one is for conventional construction method. The data were collected based on Malaysian rules and reasonable assumptions on unit price of materials. Based on the two modelling, the quantity take-off was calculated and the work breakdown structure (WBS) was created to estimate the project total cost. Microsoft Excel software was employed by using the visual graph based on the break-even point (BEP) analysis, ROI and profitability of each project. The results show that building cost in precast method is more expensive as compared to conventional method by 41%. However, precast construction method can save up to 26% on materials (less wastage) as compared to conventional construction method. These findings indicate that precast construction method is only more economical compared with conventional construction method when more than 200 units of precast structural components are implemented in the projects.

A separate study was conducted by Yong (2010) on the cost comparisons for conventional and precast building construction methods in Malaysia to determine the effects of wages and material costs on the price of the selected method. The materials or components costs were obtained from the precast manufacturers and the costing rate can become the reference costs for precast construction projects in the states of Selangor, Perak and Federal Territory of Kuala Lumpur. The case study focused on proposed hostel blocks for an institution of higher learning in the state of Perak, Malaysia. The builder was obligated to construct 4 blocks with implementation of the precast construction method and the remaining blocks were constructed by using conventional method. Each hostel block had the same total floor area. The cost estimates were done based on each respective set of construction drawings for the two construction methods. The conventional construction method used the cast-in-situ reinforced concrete structural frame with slab and beam arrangement whereas the proposed precast construction method used precast columns, precast inverted T beams supporting hollow-core precast prestressed planks of which the planks were eventually topped up with an 80 mm structural screed. The comparison of the structural material costs showed that the precast structural components are 64% more expensive than the conventional cast-in-situ reinforced concrete structures. In contrast, the wage for precast labour is 39% cheaper than conventional on-site labour. Therefore, it can be concluded that the lower labour costs consumed in the precast method still cannot substitute the conventional method due to higher precast material costs.

In a case study on a residential building in Melbourne with utilised precast prestressed hollow core planks with precast prestressed inverted T beams, Yong (2010) identified a number of significant cost differences between precast and conventional building construction methods. This case study on the building at Octavia Street in the suburb of St. Kilda includes a single level basement and two above ground levels providing a total built-up area of 1,154 m^2. The walls were also precast concrete panels. A cost estimate of the structure was obtained from the builder for the supply and installation of all the precast components. In order to compare the two construction methods, an alternative post-tensioned slab and beam system was worked out.

The purpose of adopting a post-tensioned band beam and slab methods was to ensure that the same column and beam layout could be used for both the precast and post- tensioned systems. The results have shown that the post-tensioned conventional cast-in situ slab and beam option costed approximately 30% more than the precast construction method. This was mainly due to higher material costs and doubling of the conventional method labour cost. The cost for crane rental was similar due to the requirement of higher capacity cranes for lifting of the precast components compared with lower capacity cranes for longer time duration for the conventional construction method.

From the above case studies by Aakash et al. (2016) and Amir et al. (2015), it can be seen that designing the building layout with maximum number of repetition and standardised precast structural components can help in lowering the precast construction costs. While the cost differences in the two case studies in Australia and Malaysia by Yong (2010) can be interpreted as the vast difference in wage structure in the two countries. The conventional construction labour force in Australia usually involves predominantly local and highly skilled labour, therefore attracting premium wages. In contrast, the conventional construction labour in Malaysia consisted of foreign workers with lower wages. In conclusion, construction players in a developed country with high labour wage rates usually switch to higher capital inputs such as precast construction method in order to decrease labour input to minimise costs as opposed to conventional construction method. On the other hand, construction players in a developing country refuse to practice precast construction method because of easier access to cheap foreign labour in conventional construction method. As a conclusion, the practice of precast construction method is still considered as localised since it is always limited by the local practice's norm and regulations. Besides, it may be affected by the location factors such as the transportation cost, availability of raw materials and labour force. Therefore, future studies regarding on the comparative study between the conventional and precast building construction methods should probe into these parameters particularly on the building design specifications and labour costs.

Cost Comparative Case Studies for Precast Slab and Conventional Building Construction

Time is another crucial element in the discussion on comparative studies between building construction method. As stated in the study of Hafiz et al. (2016), the study was focusing on the cost comparison of precast half slab and conventional suspended slab for a school construction project based on technical data collection and analysis on material costs. Two school projects which are SMK Idris Shah at Kinta in Perak and SMK Tinggi Klang in Selangor had been selected for the case study. The method to calculate the floor gross area with only the ground floor was used for the comparative study. The cost was estimated based on the floor area by multiplying its width and length and computed by using the cost per square metre by taking the assumption on material cost from the bill of quantities. Comparison was carried out through the construction drawings and work programme. The results have shown that precast construction method came in overall lower technical price at about 11.9% as compared to conventional construction method but it has shown higher price particularly on precast half-slab components as compared to conventional slab concrete. Besides, the study also aimed to determine the perception from a total number of 110 industrial players on precast and conventional construction methods through questionnaire surveys. Most respondents gave feedback that precast method can reduce the construction cost and time. The results obtained also suggested the correlated relationship between the time factor and overall construction costs.

Construction Method – Comparative Case Studies on Precast Wall Panel and Conventional Building Construction

This part reviewed some research studies which were focused on the integration of precast wall panel in building construction and the advantages raised form its usage. According to Rajendra and Vivek (2015) on the case study on conventional and fast track construction techniques, it was found that precast and cast-in situ formwork construction methods resulted in cost saving of 37% for monolithic construction and 53% for precast construction method due to early completion of project. The study was conducted based on the investigations on a police quarters at Mysure, India with aspects such as quantity of materials required, cost and time duration with cast-in situ formwork construction, precast panel system and conventional construction method.

Sivapriya and Senthamilkumar (2014) had carried out a building cost comparison study on precast and conventional building construction through a case study on school project with total built up area of 18,800 m2 with only the ground and the seventh floor constructed with the precast wall panel components. It was concluded that the project overall cost needed for precast panel building construction was reduced by 20% as compared to conventional method. This was mainly due to the reductions in formwork by 75%, access scaffolding by 75% and reliance on wet trades by 90%. Besides, the total cost of an architectural precast concrete wall has been lowered by taking full advantage of precast concrete portion.

Asiah et al. (2012) had carried out a study on adaptable housing of precast panel system in Malaysia. The methodology for data collection used in this research was by case study and questionnaire survey. The paper identifies the potential solutions to deliver quality housing for Malaysians as well as to solve and ever harmonising the architectural design with the innovation of precast panel system in construction. The questionnaires were distributed to the tenants of teachers' quarters in the urban, suburban and rural area of Selangor and Perak. The teacher's quarters which were constructed during 1998 to 2002 remain as the biggest housing in Malaysia constructed using precast panel system. The research examined the needs and satisfaction of residents for every internal space of the quarters such as the living area, dining area, kitchen, bedroom, and bathroom. The outcomes of the study showed that there are two innovations in the project which are the Plug and Play or Support and Infill. As a conclusion, the application of precast building construction method allowed flexibility in architecture facilitated renovation in the building.

Kow (2017) reviewed on a case study of 10 storey apartment, Residential Seri Jati Apartment in Setia Alam with 948 units of 6 blocks in a single-phase development as shown in Figure 3. The construction system for the building project is shown in Figure 4 of which the building project involved the conventional construction method with foundation, ground floor, transfer beam, and reinforced concrete slab. The precast construction components included prefabricated steel roof trusses, precast walls for roof, precast load bearing walls, precast non-bearing walls, precast staircases and landing slabs, precast lift core walls, precast bathroom slab and precast air-conditioner ledges. Scoring point is the use of precast structural frames with in-situ concrete floor using reusable system formwork and use of precast walls following MS1064 vertical and horizontal repetition. The advantage on the choice of construction method in this project is that the project has high degree of repetitions for both horizontal and vertical plan. Architectural and structural designs with precast intention to capitalise on precast advantages as it gives high economy turnover of scale with more than 900 units of apartment with a single unit layout. Construction logistic is fully considered at planning stage such as the wall layout, work sequencing, crane's capacity and movement. The disadvantages of the project are brickwork and plastering in stand-alone amenities building, box-out for M&E services and kitchen or yard walls as it is non-compliance in Modular Coordination for structural elements and architectural design input. As a conclusion, an exciting external facade with different architecture features reduces the monotonicity of the internal repetitive layout. Steel moulds provide consistent quality in architecture features. No columns and projected beams provide consistent square in shape and consistent quality.

Figure 3. Residential Seri Jati Appartment, Setia Alam

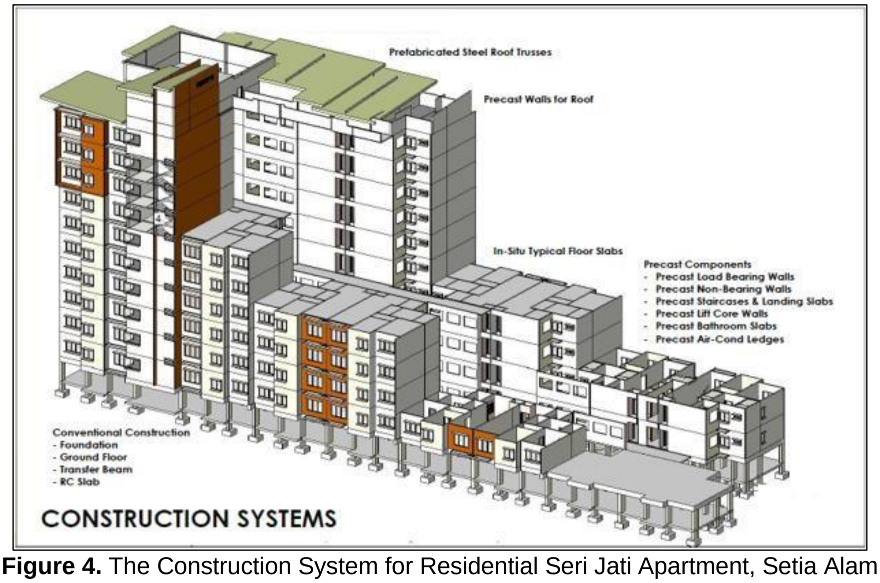

Figure 4. The Construction System for Residential Seri Jati Apartment, Setia Alam

Based on the research studies done on the comparative case studies on precast wall panel and conventional construction method, it was found that result outcomes have shown the ability of the precast construction method to overcome the technical issues and make renovation works feasible, but it still has deficiency in term of its design input. The use of precast components is proven to lower the project cost as it shortens construction time and saves wet works such as the fabrication and installation of formwork and steel reinforcement. It is, however, the cost saving gives rise to ambiguity as the cost elements for comparison of precast components is not fully described and explained especially the transportation and installation costs.

Summary of Previous Research Findings

Table 1 analyse the summary of research findings in case studies, building projects or components which have been compared in the previous studies.

From the analyse, it is crucial to understand thoroughly the comparison components prior to obtain the desired level of accuracy of anticipated comparative studies between the conventional and precast construction methods especially in its overall total cost of construction. This is to assess both the general perspective overview on the growth and cost-influencing factors and the particular comparison between the conventional and precast systems used in the case studies.

The comparative study on the general perspective overview on both the precast and conventional methods are extensively done by the researchers. The complexity of the practices in the local construction industry is dealt with customising onsite production and resources as well as schedule driven. Precast construction method is viewed as an alternate method to improve the quality and productivity of the projects through better or less machinery, equipment, materials and extensive project planning. Factors including design, construction materials, safety and risks, project total time, environmental impacts and availability of local skills will ultimately translate into construction project total cost directly or indirectly. Therefore, the critical elements to identify the comparison between the pros and cons of both construction methods can be summarised into the comparison on time consumption, operational management, and technical feasibility which can significantly influence the project total cost consumption.

From the extract of comparative case studies done by the researchers, it can be concluded that the precast construction method is still in concern for its higher direct cost for small-scale projects and the precast construction method in Malaysia is at a standstill while most project implemented the precast construction method by selecting only a particular system or partial-precast such as precast slab, wall-panel or beams instead of fully-precast construction.

Table 1. Summary of Literature Reviews

Author	Research Topic	Research Methodology	Findings
Yong (2010)	Effects of wages and material costs on the price of the selected method	Case studies -Compared on slab and beam	Precast were 64% more expensive in materials but 39% cheaper in labour costs but still higher for precast in overall.
Asmah et al. (2012)	Level of awareness of the Contractors (Grade 5-7) on IBS In Sarawak Construction Industry	Questionnaire Survey	56.1% never involved in precast project.
Lou and Kamar (2012)	Adoption of precast in Malaysia construction industry	Case Studies - Critical success factors	Key Factors: Efficiency
Amir et al. (2015)	Economic comparison of precast and conventional construction methods	Modelling - Revit architecture 2013 into two types of plans, one is precast with another one is conventional, assumptions on unit price of materials.	Precast more expensive by 41% and economical when more than 200 units of precast structural components were implemented in the projects.
Hafiz (2016)	Cost Comparison for Precast Half Slab and Conventional Suspended Slab in term of Material Costs.	Case studies -Method to calculate floor gross area with only the ground floor was used for the comparative study.	Higher price particularly on precast half-slab components as compared to conventional slab concrete.
Construction Industry Development Board (2016)	Critical Elements for Comparative Study between Precast and Conventional Construction Methods	Case studies on project management on precast construction projects	The relationship between the time, labour, materials and costs are always interrelated and cannot be analysed separately
Jabatan Kerja Raya (2017)	Critical Elements for Comparative Study between Precast and Conventional Construction Methods	Case studies on comparative studies between conventional and precast building construction method	Approximate quantities is the most accurate method for estimating project total cost.
Lim et al. (2017)	Critical Elements for Comparative Study between Precast and Conventional Construction Methods	Case studies on types of precast construction projects	Study on precast construction projects can be divided into 3 categories which are the fully precast project, partially precast projects, and selected components precast projects.
Kow (2017)	The advantages of choosing the Precast Building Construction Method	Case study of 10 storey apartment, Residential Seri Jati Apartment in Setia Alam with 948 units of 6 blocks in a single phase	Architectural and structural designs with precast intention to capitalise on precast advantages as it gives high economy turnover of scale with more than 900 units of apartment with a single unit layout.

FUTURE PERSPECTIVE OF THE PRECAST BUILDING CONSTRUCTION INDUSTRY IN MALAYSIA

Regardless of the varied cost influencing factors identified in literature, to date, there is still no literature available to clearly figure out and break down the detailed comparison between a fully-precast and fully-conventional construction project in Malaysian construction industry as prior research focused on the cost breakdown involving the precast and conventional construction methods. As for the stated case studies reviewed on other countries, they can only be used as supportive proves or relevant causal relationships. In fact, the construction project total cost is influenced by the difference in local practices and regulations such as the government and construction industry policies, availability of local resources such as the raw materials, labour and capital.

This paper suggests that the comparative study between the conventional and precast construction methods should be carried out through a clearer prototype module or otherwise a fully-precast project by comparing its economic aspects among both the precast and conventional construction methods. Therefore, stakeholders in multinational projects which include the contractors, investors, designers, financial and government organisations should be equipped with enough knowledge on the choice of construction method during the planning of projects in different environments so as to give advice on project total cost at the feasibility stage and prior to bidding and construction.

CONCLUSION

It is crucial to understand thoroughly the comparison components prior to obtain the desired level of accuracy of anticipated comparative studies between the conventional and precast construction methods especially in its overall total cost of construction. This review paper assesses both the general perspective overview on the growth and cost-influencing factors and the particular comparison between the conventional and precast systems used in the case studies.

The comparative study on the general perspective overview on both the precast and conventional methods are extensively done by the researchers. The complexity of the practices in the local construction industry is dealt with customising onsite production and resources as well as schedule driven. Precast construction method is viewed as an alternate method to improve the quality and productivity of the projects through better or less machinery, equipment, materials and extensive project planning. Factors including design, construction materials, safety and risks, project total time, environmental impacts and availability of local skills will ultimately translate into construction project total cost directly or indirectly. Therefore, the critical elements to identify the comparison between the pros and cons of both construction methods can be summarised into the comparison on time consumption, operational management, and technical feasibility which can significantly influence the project total cost consumption.

From the extract of comparative case studies done by the researchers, it can be concluded that the precast construction method is still in concern for its higher direct cost for small-scale projects and the precast construction method in Malaysia is at a standstill while most project implemented the precast construction method by selecting only a particular system or partial-precast such as precast slab, wall-panel or beams instead of fully-precast construction.

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PROJECT RISK MANAGEMENT THROUGH ALTERNATIVE DISPUTE RESOLUTION (ADR) PROMOTES FEASIBLE MEANS OF SETTLING CONSTRUCTION DISPUTES THAN VIA TRADITIONAL LITIGATION

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Abstract
A variety of strategies and initiatives of dispute settlements have been introduced as a project risk management tool to resolve disputes in the construction field, which has been found to be the most dispute ridden industry. Alternative Dispute Resolution (ADR) is notably a mechanism of resolving disputes outside the courtroom and is usually used as an alternative to traditional litigation. Due to ADR being quick, amicable and economic in its approach, it is seen as a feasible means of settling disputes in comparison to arduous litigation that is perceived to be a lengthy, costly and inflexible method. However, it is necessary to study the ADR implementation in Malaysia so that it can satisfy the needs of the industry for a feasible resolution of disputes. The aim of this paper is to promote ADR and its function as an alternative method to traditional besides emphasizes ADR as a feasible means of resolving construction disputes. This is achieved through the collection from secondary data sources.

Keywords: *Dispute settlement; project risk management; construction industry; Alternative Dispute Resolution (ADR); traditional litigation; feasible resolution.*

INTRODUCTION

The Malaysian construction sector constitutes an important element in the Malaysian economy, as well as being a significant contributor to Malaysia's gross domestic product (GDP). Based on the current trends in the past few years, the Malaysian Country Report by the Construction Industry Development Board Malaysia (CIDB, 2017) reported that the growth in GDP in 2017 was once again led by the construction sector, and this is expected to grow by 8.0%.

Furthermore, although the construction sector accounted for a moderate growth at only 7.4% in 2016, the value of construction projects has increased by 57.5% from RM141.8 billion in 2015 which could prove to be a sustainable demand of this sector (CIDB, 2017). According to Sundaraj (2006), the existence of demand in construction is due to the creation of wealth and demand in quality of life which require developments to happen. Thus, the construction sector is seen as a major productive sector in Malaysia that contributes significantly to the national economic development besides being a valuable customer for other existing industries in Malaysia (CIDB, 2016; Dwikojuliardi, 2016).

Due to the rapid growth of the construction sector, there is a continuously expanding complexity of this industry which leads to complications and disputes at any stage of the project lifecycle (Alaloul, Liew, Zawawi & Mohammed, 2018). In addition, the abundance of involvement of parties in a particular construction project creates numerous points at which disputes can occur. Thus, disputes are an almost inevitable phenomenon in construction projects (Love, Davis, London & Jasper, 2008; Pétursson, 2015).

The fragmented nature of the industry, adversarial nature of contracts, improper contract documentation and administration, vexatious tendering policy and system, payment default issues and ineffective communication are some of the various factors that contribute to the development of disputes in construction projects (Tayeh, Alaloul & Al-Hallaq, 2018). Despite the list, the Global Construction Disputes Report 2018 by Arcadis highlights that the root cause for disputes in construction projects for the last five (5) years in a row was due to improper contract administration.

When the factors that lead to a dispute continuously happen, it can give a serious impact on the whole life cycle of a project. In order for a project to continue, any disputes that arise have to be resolved to avoid a halt in the construction process (Koutsogiannis, 2017). Hence, the methodologies used for dispute settlement are the most important elements to be contemplated in terms of their impacts to the overall project prior their implementation (Alaloul, Liew & Zawawi, 2015).

Problem Statement

The construction sector is synonymous with being a dispute ridden industry due to its characteristic mix of complex contractual and project relationships, with large sums of money at stake and rigid time pressures (Holtham, Russell, Hird & Stevenson, 1999); (Mackie, Miles, Marsh & Allen, 2000). Thus traditionally, parties would enter into litigation (Gad et al., 2015); (Alaloul et al., 2019) although a lengthy time and high cost are often the means of resolving a dispute (Harmon, 2003); (Martin, 2007); (RCT, 2012); (Worthington, 2014); (Cook, 2016). In addition, the study by Tazelaar & Snijders (2010) claims that dispute resolution in the construction industry by litigation continues to proliferate and Chong (2013) added that there is an inclination for people to resolve their disputes in court. As the consequence to this trend, litigation has been the preferred form of dispute resolution in construction projects (Raji, Ali Mohamed & Oseni, 2015).

Unfortunately, the shortcomings of litigation have echoed for the last few decades and this has resulted in multiple attempts on finding other immediate means for dispute resolution in construction (Raji et al., 2015). Other than that, the disappointment from the failure of litigation in addressing the dispute with its growing challenges and demands, has invoked the industry to look for other alternative methods (Pĕna-Mora, Sosa & McCone, 2003).

Consequently, in spite of having litigation as the main mechanism for dispute settlement, Alternative Dispute Resolution (ADR) has emerged as an alternative to court litigation for resolving disputes alongside providing confidentiality, choice of neutral parties and flexibility in procedure (Love, 2011). Moreover, based on Cheung (2006), ADR is a generic term used to indicate a wide range of dispute settlement mechanisms that aim to resolve dispute efficiently in terms of time and cost consumption. Similarly, Worthington (2014) and Cook (2016) share the same view that ADR has the advantage to avoid a lengthy process and costly traditional litigation. Therefore, various methods of ADR have been introduced into this industry to avoid the arduous approach of litigation.

However, the recent data as per the Construction Law Report by CIDB (2018) shows that the total number of construction cases registered at the High Court in 2017 has risen by 92.57% in comparison to only 377 registered cases in 2016. Although Cheung (2006) claimed that ADR is rapidly spreading around the globe due to its wide implementation in the developed countries' construction industries, the number of cases that were registered in the third fiscal year for dispute resolution via ADR method in Malaysia as per based on the CIPAA Conference 2017 by Kuala Lumpur Regional Centre for Arbitration (KLRCA, 2017) were only 547 cases which was less than the cases registered through litigation settlement which were 726 cases in 2017 of Construction Law Report (CIDB, 2018).

On top of that, although there were several attempts to introduce mediation as an alternative to traditional litigation in the construction industry through a few standard forms of contracts, its implementation is surprisingly low (Ameer Ali, 2010). Similarly, according to recent studies by Lee (2017) and Oii (2017), the actual implementation and appreciation of ADR in the Malaysian Construction Industry was understandably low as some of the alternative methods in ADR have not yet been widely accepted.

As a result of these sets of circumstances, ADR which is an alternative to traditional litigation and is very well-known for its benefits by many scholars, (Allison, 1990), (Treacy, 1995), (Cheung, 2006), (Love, 2011), (Worthington, 2014), (Cook, 2016), (Harbans Singh, 2017), (Ayupp & Abdul Latif, 2017) & (Raes, 2019) needs to reveal its feasible resolution to encourage and increase the preference for it in order to impede the high statistics of dispute resolution in the courthouse. It should be noted that having ADR allows either early settlement of disputes or an intervention particularly at the pre-litigation stage of dispute resolution, which could reduce the caseload in the court (Markowitz, 2016); (Rooney, 2016).

Research Objectives

Previous studies reported that disputes in the construction sector have become a typical event (Chan & Suen, 2005); (Jannadia, Assaf, Bubshait & Naji, 2000). At present, Ratna (2018) has reported that the situation is no different in Malaysia where the disputes in the Malaysian construction sector have increased to the total value of disputed claims at almost RM1.4 billion. Thus, this study has its significance and is timely discussed. A variety of technical issues are being recognized as the dominant factors in construction disputes that limit the capacity of litigation to resolve these types of disputes (Cheung, 2006). Hence, ADR is considered to be the most felicitous method in resolving construction disputes as its existence is constantly expanding, evolving and offering less limitation to the types of dispute resolution processes (Zuhairah, Azlinor & Rozina, 2010).

This study is intended to reveal that ADR has features that could offer a feasible resolution to incurring disputes particularly in the Malaysian construction industry. At the end of this research, the results are expected to increase the preference on ADR as the means of resolving construction disputes, and to benefit all the stakeholders in the construction industry, especially the CIDB G7 Contractors who were found to be the most affected group in construction disputes as per listed in the current Malaysian Construction Law Report (CIDB, 2018).

LITERATURE REVIEW

This section will give a review on relevant literature by previous researchers of which have been critically evaluated to ensure only the following relevant issues and concepts are emphasized. This includes the issue of disputes in the construction industry, an overview of the concept of project management, the two different methodologies available for dispute settlement and an overview of the concept of ADR that contributes to the perspective of key players in the construction industry.

Construction Disputes

Construction projects have been found to be incessantly bombarded with disputes by many researchers including recent studies such as Pétursson (2015), Cook (2016) and Hayati, Latief & Achmad Jaka (2019). Dispute in the construction projects is also an endemic problem in the industry as described by Cheung (1999). Hence, conflicts are inherent in construction projects whilst disputes are pervasive and inescapable (Zack, 1995). There is no absolute definition for a dispute as its existence is usually unpredictable and subjective besides requiring a good sense of judgement, experience, availability of facts and consideration of the law and policy (Reid & Ellis, 2007). Moreover, the definition and the conceptual distinction between conflict and dispute are often found to be perplexed. In order to clarify the meaning of these terms, Acharya & Lee (2006) came up with the following continuum model containing risks, conflicts, claims and dispute: -

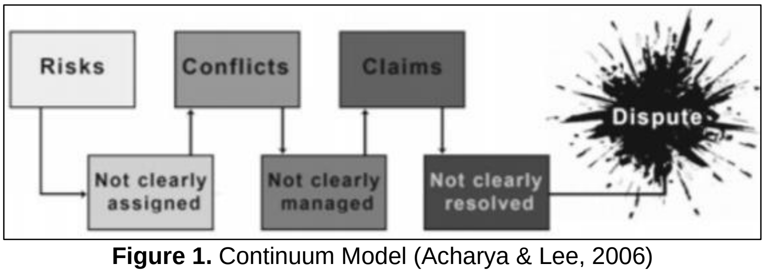

Figure 1. Continuum Model (Acharya & Lee, 2006)

The construction industry that includes the engineering, construction and procurement phases is very well-known for its complex, fragmented multi-tasks, huge sums of money at stake and relentless time (Holtham et al., 1999); (Mackie et al., 2000); (Kabirifar & Mojtahedi, 2019). Owing to the diversity of parties involved such as engineers, architects, contractors, developers and many more, there is bound to be inevitable conflicts which in a blink of an eye, can turn into disputes (Cakmak & Cakmak, 2014). Moreover, based on Mackie et al. (2000), disputes have the capacity to impoverish the strongest entity of the industry due to its reputation in a tough and aggressive world. Hence, projects within the construction industry are always claimed by many ‘a dispute waiting to happen’ (Patterson & Seabolt, 2001).

Love et al. (2008) postulated that it is impossible to identify the root of dispute as the causes of disputes in construction are innumerable. Based on Global Construction Disputes 2018 Report by Arcadis (2018) and Wright & Greenhill (2017), disputes in construction mainly arise from the failure to properly administer contracts, poorly drafted or incomplete claims, and the failure of involved parties such as employer/contractor/sub-contractor to understand and comply with the contractual obligations. Whilst Cheung & Yiu (2006) posit, the occurrence of dispute is the indication of underlying conflicts due to the differences in human beings in their agenda, perspectives and interests. Mitropoulos & Howell (2001) also added that project uncertainties, contractual problems and opportunistic behaviours have greatly contributed to the development of dispute in construction projects.

Disputes in construction could be due to a single or a combination of multiple reasons (Mahamid, 2016) which are always related to time, money and quality (Okoronkwo, 2015). Therefore, there is a possibility of difficulty in quantifying cost escalation if disputes are not immediately resolved (Abdul Ghadas, Mohd Zafian & Mohamed, 2019). Meanwhile based on Cheung (2006), the proceeding of resolution to disputes which includes the fees of legal representatives and expert witnesses are the anticipated visible expenses. Other visible costs that could incur are the resources of the organization allocated for the settlement of disputes and lost business opportunities. Whereas the invisible costs would be the damaged of good working relationships and values lost due to inefficient dispute settlements (Farooqui, Masood & Saleem, 2012).

Arising disputes are usually resolved by third parties (Alaloul, Liew & Zawawi, 2016) and this is concurred by many authors dealing with the construction industry as they are in the opinion that the relationship among the construction parties is usually harsh and has a tendency for conflicts and litigation (Tazelaar & Snijders, 2010). Since the components of construction disputes consist of technical and legal dimensions, the litigation approach may not be the best medium in resolving disputes in this industry (Cheung, 2006). Therefore, Harmon (2003) and Alaloul, Liew & Zawawi (2015) agree that the methodologies applied in resolving disputes as they emerge in the construction industry are important factors to be addressed. According to Vallerand (2018), intelligible planning of project procedure is essential to avoid disputes along with the ability to identify and promptly manage the disputes. These are needed as a barrier to construction disputes, which involve the deployment of project management processes.

Project Risk Management

Plan risk management, risk identification, perform qualitative risk analysis, plan risk responses, implement risk responses and monitoring risks are the six project risk management processes which lead to the realization of project risk management, which optimizes the possibilities for a successful project by improving and reducing the impact of positive and negative risks respectively (PMI, 2017). In addition, according to Ba Hamid & Shu Ing (2017), risk management is defined as a method that is organized and comprehensive that leads the risk factors towards ‘organizing’, ‘identifying’ and ‘responding’ characters for project goals achievement.

Risks in projects are uncertain events (Aven & Renn, 2009; IPMA, 2015; ISO, 2018; PMI, 2017; APM, 2019) as the most carefully planned project could also cause a dispute (Greene & Stellman, 2013). Therefore, in the context of this study, the promotion is focused on the use of project risk management through its plan risk responses which must be aligned with the most feasible methodologies of dispute settlement for an amicable approach whilst dealing with major construction disputes.

The processes of plan risk responses involve the options of development, strategies selection and actions agreement to identify the most suitable approaches in addressing the overall and individual projected risks (PMI, 2017; Rehacek, 2018). This process involves the establishment of a strategy to maximize the potential opportunities and minimize the potential threats (PMI, 2017). According to Kerzner (2003), Loosemore, Raftery, Reilly & Higgon (2006) and PMI (2017), the typical risk responses are to avoid, transfer, mitigate and accept.

Disputes Settlement Methodologies

The construction field is found to be the most conflict and dispute ridden industry, which has resulted in an unavoidable frequency of claims (Ewa, Haytham, Okon, Enang & Emir, 2018). Many countries have their own ways of approach to appropriately resolve the disputes in order to maintain the unity of their nations and the economies and political stabilities of the states (Owasanoye, 2001). Therefore, a variety of methods are introduced to resolve disputes arising among the parties (Agarwal, 2001). Richter (2000) has invented a dispute resolution management system as shown below in Figure 2 which is based on the observation of the management of risks or disputes within the construction field which have been frequently utilized.

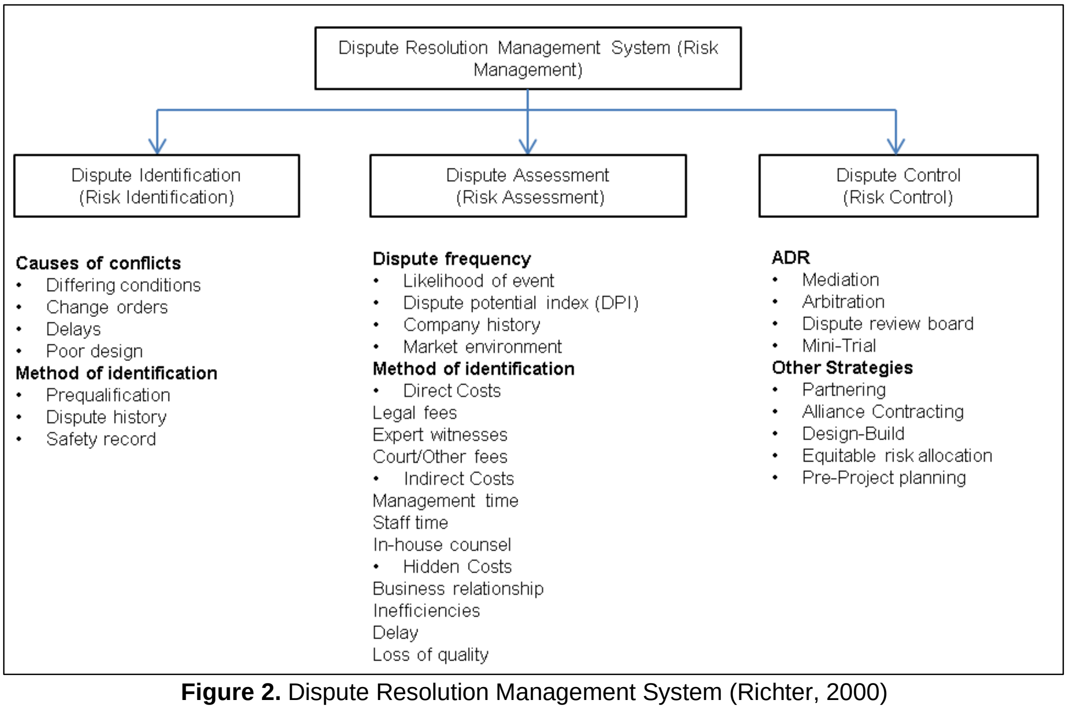

Figure 2. Dispute Resolution Management System (Richter, 2000)

Table 1. Typical Types of Disputes Resolutions

Methodology of Disputes Settlement	Traditional Disputes Resolution	Alternative Disputes Resolution (ADR)	Source
Litigation	√		(Hughes, Champion & Murdoch, 2015; Gad et al., 2015; Raji et al., 2015; Alaloul et al., 2019).
Negotiation		√	(Mackie et al.,1995; Ritcher, 2000; Gad et al., 2015; Harbans Singh, 2017; Alaloul et al., 2019;
Mediation		√	(Pétursson, 2015; Gad et al., 2015; Rooney, 2016; Cook, 2016; Harbans Singh, 2017; Oii, 2017; Alaloul et al., 2019; Abdul Ghadas et al., 2019).
Adjudication		√	(Mackie et al.,1995; Cook, 2016; Lee et al., 2016; Harbans Singh, 2017; Abdul Ghadas et al., 2019)
Arbitration		√	(Pétursson, 2015; Gad et al., 2015; Cook, 2016; Alaloul et al., 2019; Abdul Ghadas et al., 2019)

Since both litigation and arbitration were available in the construction industry long before the existence of any methods of dispute resolution, El-Adaway & Ezeldin (2007) have classified dispute resolution into three (3) categories which are litigation, arbitration, and alternative dispute resolution (ADR). Nonetheless, some scholars have considered arbitration to be part of ADR (Battersby, 2003). Hence, based on thorough review of the literature, Table 1 as tabulated below categorizes the dispute resolution methods into two typical types which are traditional and ADR.

Traditional Dispute Resolution

Opting for trial is the most traditional and common method to resolve disputes within the construction industry (Hughes, Champion & Murdoch, 2015). According to Alaloul et al., (2019), litigation in construction is a way of resolving disputes in the court by engaging in legal action. In litigation, the plaintiff files a lawsuit against the defendant for his/her wrongdoings which following this proceeding could allow the court to determine a binding judicial of the party's rights or guilt (McKenzie, 2011). Alas, the decision in court is done by the judge or jury who probably have limited knowledge in construction (Tolle, Barton & Mountain 1990) and parties involved could possibly get agitated about going to trial due being fully aware of the drawback of litigation which usually means for extended time of disclosure, inflexible procedure and delayed of process (Tolle et al., 1990); (Zuckerman, 1995); (Rendell, 2000).

It is believed by Pinnel (1999) and Howick (2003) that the practitioners in the construction industry will normally opt for litigation as the method to resolve disputes in complex projects. However, litigation approach is not advisable in resolving disputes that arise in the construction industry according to many construction experts since the sustainability and survival of this field is dependent on amicable relationships between the parties involved (Alaloul et al., 2019). Based on Cheng, Tsai & Chiu (2009), the action of bringing the dispute to court would usually lead to serious harm to the disputant’s reputation which consequently could affect the quality and progress of ongoing works.

Stipanowich (1998) also added that the efficiency of the trial process could normally be affected whilst resolving the dispute associated with an ongoing construction project due to its financial and technical complexities. Since litigation may cause an irreparable damage in relationships and work (Allison, 1990), this approach should always be taken as the last option in resolving disputes (Weese, 2018).

On the other hand, the resolution of disputes through the court system may help to achieve the objectives of parties engaged in the dispute. However, at times where confidentiality, privilege and privacy are at stake, this approach would not be favourable. According to Bristow & Vasilopoulos (1995) and Dore (2006), traditional litigation can expose the disputants to the media as all civil court proceedings and legal document filings are disclosed to the public. Furthermore, since every party in dispute as based on Cheng et al. (2009) is aimed to achieve ‘a win-win situation’, Alaloul et al. (2019) doubts that is almost impossible to be accomplished if the resolution is done in court as the outcome will be either a ‘lose-win’ or it could also lead to a ‘lose-lose’ situation as the process is often time consuming and involves a lot of expenses.

Therefore, since the process of litigation is always owing to time demands and rising costs (Harmon, 2003); (Martin, 2007); (RCT, 2012); (Worthington, 2014); (Cook, 2016); (Hayati et al., 2019), the industry of construction has put a continuous effort to resolve disputes in ways that could save more time and money (Cheng et al., 2009). The practitioners have also realized that traditional litigation approach is often synonymous with uncertainties and vulnerabilities in its processes hence the needs for a reformation towards more amicable approaches and feasible ways to resolve disputes (Henriod & Masurier, 2002).

Alternative Disputes Resolution

ADR is notably the mechanism of resolving disputes outside the courtroom (Love, 2011); (Aggarwal, 2017). ADR methods as based on Katz (1993) are early neutral evaluations, mini-trials, summary jury trials and expert fact-finding. Notwithstanding suggested ADR, the negotiation, mediation, adjudication and arbitration are listed as the type of ADR that is commonly used in Malaysia (Abdul Ghadas et al., 2019). In order to encourage ADR' utilization, the local standard forms of contract such as CIDB Standard Form of Contract for Building Works Edition 2000, PAM Contract 2006, PWD Form 203A (Rev. 2007) and IEM Standard Form of Contract 2003 have introduced arbitration, mediation and/or adjudication as the mechanism to resolve dispute with prior reference to judicial dispute resolution i.e. litigation (Mohd Danuri et al., 2012).

A high burden in cost and time has resulted in the discovery of other methods other than litigation to resolve construction disputes quickly (Treacy, 1995). Therefore, ADR is now an integral part of the very mechanism in dispute settlement that seeks to replace the traditional litigation (Mohd Danuri et al., 2012). According to Mackie et al. (2000), the United States witnessed the existence of ADR in early 1980s due to the disappointment of the shortcomings of the traditional litigation. Despite gaining a preference starting in the late of 1980s, ADR with its advantages of resolving dispute in a more economical and time-saving ways has pushed the system further allowing it to be grown widely in the construction industries of many countries such as the United Kingdom, Australia and Canada (Mackie et al., 2000; Holtham et al., 1999).

ADR has been defined in numerous ways to fit with preferred outcomes such as Additional Dispute Resolution, Assisted Dispute Resolution, Alternative Dispute Resolution, Appropriate Dispute Resolution and Amicable Dispute Resolution (Mackie et al., 2000; Cheung, 2006). Through ADR, a final settlement could be obtained despite the fact that most of the methods in ADR do not assure the final outcome during the process (Mackie et al., 2000). As according to Eisenberg (2002), the utilization of ADR has achieved high settlement rates ranging between 50% and 90%. However, ADR is only a successful method if the disputants work together to form a mutually accepted agreement as this approach requires the process of collaboration (Holtham et al., 1999). Thus, according to Abdul Ghadas et al. (2019), the most important elements for an effective ADR are to understand, collaborate and agree on a consensus in order to achieve a successful outcome.

Some methods in ADR allow the parties to have full control of the process as they could determine the parameters of the agreement such as involving the development of settlement with a neutral third party and having the right to stop the process at any point (Pẽna-Mora et al., 2003). Therefore, according to Zuhairah et al. (2010), parties who opted for this alternative method to resolve their dispute were more satisfied because they had control in determining the terms of the agreement that corresponded to their needs. Despite the prevailing concept of having a full control in the whole process, there are also other methods in ADR in which the power of decision-making lies with the neutral third party and having to undergo formal procedures (Katz, 1993); (Uff, 2005). This shows that dispute resolution has a variable range of control to fit the disputant's preference from the methods that have the least control to those with the most control (Brown & Marriot, 1999). Figure 3 below by Cheung (1999) depicts it in the form of rising steps to show the escalation of hostility and costs for different methods in dispute resolution.

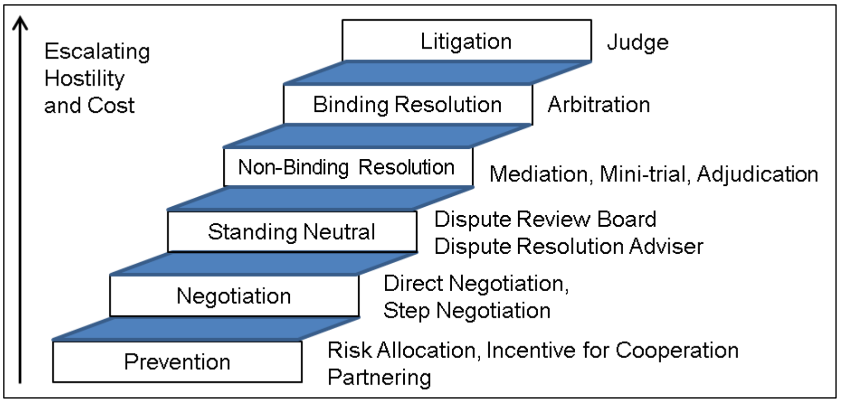

Figure 3. Construction Dispute Resolution Steps (Cheung, 1999)

Table 2. ADR's Feasible Features for Dispute Resolution

S/No.	Features of ADR	Source
1	Maintains a business relationship	(Treacy, 1995; Harbans Singh, 2017; Ayupp & Abdul Latif, 2017; Moniz, 2017; Alaloul et al., 2019; Abdul Ghadas et al., 2019).
2	Speed	(Treacy, 1995; Agarwal, 2000; Mackie et al., 2000; Cheung, 2006; Love, 2011; Worthington, 2014; Cook, 2016; Harbans Singh, 2017; Moniz, 2017; Alaloul et al., 2019).
3	Lower cost	(Treacy, 1995; Agarwal, 2000; Mackie et al., 2000; Netzley, 2001; Cheung, 2006; Love, 2011; Worthington, 2014; Cook, 2016; Harbans Singh, 2017; Moniz, 2017; Alaloul et al., 2019).
4	Confidentiality	Treacy, 1995; Love, 2011; Harbans Singh, 2017; Moniz, 2017; Abdul Ghadas et al., 2019).
5	Flexibility	(Treacy, 1995; Agarwal, 2000; Love, 2011; Harbans Singh, 2017; Moniz, 2017; Abdul Ghadas et al., 2019).
6	Greater satisfaction	(Love, 2011; Moniz, 2017).
7	Minimal resources	(Netzley, 2001; Harbans Singh, 2017; Moniz, 2017).
8	Non-Formal procedure	(Agarwal, 2000; Harbans Singh, 2017; Moniz, 2017; Alaloul et al., 2019).
9	Direct control	(Treacy, 1995; Pẽna-Mora et al., 2003; Harbans Singh, 2017; Abdul Ghadas et al., 2019).
10	Responsive system	(EPA, 2000; Braithwaite, 2002)

According to Zuhairah et al. (2010), ADR also has evolved into some hybrid methods such as expert determination, med-arbitration, dispute review board and court-annexed ADR. Thus, ADR is very flexible as it offers many options which all have advantages of their own to specifically suit the situation (NADRAC, 2012). According to Coleman (2013), ADR allows the parties in dispute to switch from one process to another without any issues. Since

ADR is pertinent for a wide range of resolution processes, Mackie et al. (2000) and Cheung (2006) have the same opinion that this method should be adopted as a solution for construction disputes with the aim to resolve disputes efficiently especially in terms of time and cost. Table 2 below lists several practical features of ADR obtained from the previous scholars that contribute for feasible means of settling disputes.

Notwithstanding the benefits of ADR, Kumaraswamy (1998) believes that the expert's advice at certain times is also required in guiding towards the most suitable dispute resolution method to avoid incurring unresolved disputes.

ADR within the Malaysian Construction Industry

The year 2020 marks the waiting of Vision 2020 and the Eleventh ("11th") Malaysia Plan to take the plunge. With an increase of 16% from the previous plan under development expenditure of the 11th Malaysia Plan, it certainly brings great hope for the growth trajectory of the construction industry (Ratings, 2016). Despite the projection of slower growth for the construction industry in 2019 (Bernama, 2018), Malaysia is moving forward while preparing for post-2020. A total of RM45 billion was expected to have been spent by the Government of Malaysia in 2019 on development projects to ensure sustained economic growth. The formulation has been set for national development (Yusof, 2019). Since the construction industry in Malaysia is expected to continue to grow, and the growth in construction sector usually owes to increasing of disputes, Malaysia, without doubt, needs to head towards reforming the applicable dispute resolutions and exploring feasible ways to provide justice in a shorter period, fewer expenses and without the need for court intervention.

Almost a decade ago, the courts in Malaysia had started to acknowledge the existence of ADR and its contribution particularly in mediation. The evidence could be seen through a few efforts which were made by the courts to promote mediation in the Malaysia legal system. According to a local newspaper published on 14 February 2010, it reported a statement by the Chief Justice, Tun Zaki bin Tun Azmi, that the judiciary and the Bar Council have cooperated in drafting a Practice Direction to encourage the disputing parties to opt for mediation instead of going to trial since this approach would be the "preferred" way to resolve disputes in Malaysian courts (Koshy, 2010). The fifth ("5th") Practice Direction of 2010 (Practice Direction on Mediation) finally came into force on 16 August 2010.

Furthermore, the Malaysian Bar Council has made an effort to request support from the judiciary as well as the lawyers to put Malaysia as an international hub for mediation and arbitration (Ravendran, 2011). Besides, apart from the establishment of the Malaysian Mediation Centre (MMC) by the Malaysian Bar in 1999 to encourage the utilization of mediation as a means of alternative dispute resolution (Bukhari, 2011), based on Mediation Rule by KLRCA (2014), the parliament has also introduced the Mediation Act 2012 to ensure a fair, speedy and cost-effective dispute resolution. Pursuant to this, the Malaysian Mediation Act 2012 is seen to act as a channel which is proposed to provide a court mandated mediation system that would help to clear the backlog in the courts (Bernama, 2008); (Ali Mohamed, 2018).

Whilst in the form of adjudication, Construction Industry Payment and Adjudication Act 2012 ("CIPAA") that came into force on 15 April 2014 is also seen to be an innovative step for Malaysia (Zuhairah et al., 2010). Provisions that lie under CIPAA according to Ameer Ali (2006) and Fong (2012) are said to be comprehensive in facilitating the payment procedure, resolving cash flow issues and expediting dispute resolution. In addition, Abraham (2012) and Mohd Majid (2013) also highlighted that Clause 13, Part II of CIPAA allows the disputing parties to refer to other dispute resolutions, which means that adjudication provides flexibility.

As for arbitration, a series of revisions have been made by the Government and the International Organization to improve arbitration in Malaysia. According to Lim (2009), the revisions include amendments to the Arbitration Act 2005 ("the 2005 Act") as well as upgrading the role of the KLRCA. In 2011, the Arbitration (Amendment) Act 2011 ("the 2011 Act") replaced the 2005 Act (AGC, 2011b) and the revision continued in 2018 with the imposition of Arbitration (Amendment) (No. 2) Act 2018 (the "Amendment Act") to replace the previous Act (AIAC, 2018c). Besides that, the initiative by AIAC to replace the previous KLRCA Arbitration Rule to AIAC Arbitration Rules 2018 effective on 9 March 2018 (AIAC, 2018b) is also another extensive commitment to promote arbitration in Malaysia. Through the adoption of the AIAC Arbitration Rules, it allows a great deal of flexibility in the conduct of arbitration proceedings in regard to the choice of the arbitrators and applicability of the procedural rules to ensure its efficiency (Celniker, Blakely, Levison, Yip, Thomas, Hambrick & Steel, 2018).

METHODOLOGY

This section explains the research methodology that was adopted to produce this paper. Data collection is one of the most essential stages to gather and measure information from wide variety of sources. There are several ways to collect data, but it can be mainly obtained from two sources which are either via primary or secondary data collection. Figure 4 shows and lists the sources of the two types of data collection process.

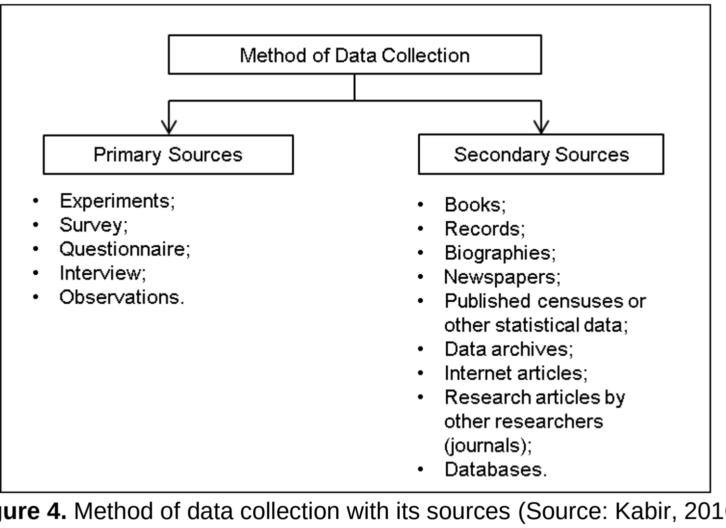

Figure 4. Method of data collection with its sources (Source: Kabir, 2016)

The data collection process utilized in this paper was through collection from secondary data sources. Secondary data collection involves an in-depth literature review of the areas of interest from pre-existing sources which come from previous and current work of experts in the field. A review of the literature for over 100 sources of information from journal articles, conference proceedings, published case studies, press releases, professional presentations and online articles was performed to analyse relevant information available with regards to ADR, with the aim 1) to determine the issues of disputes in the construction industry; 2) to provide the proper explanation of resolution management system within construction field; and 3) to determine the two different methodologies available for dispute settlement specifically within Malaysian construction industry.

CONCLUSIONS

From the review of related literature, it appears that the Alternative Dispute Resolution ("ADR") method is believed to be a feasible approach in resolving construction disputes unlike the intractable formalities of the traditional litigation system. Besides markedly reducing the backlog of cases in the courts, ADR is also described by most scholars as a method that embraces flexibility, amicability, informality, confidentiality, overall satisfaction, direct control, optimization of minimal resources, responsiveness, speed and is low in cost in resolving disputes. ADR is not a new phenomenon in this society but its implementation particularly in the civil process is still immature (Mohd Majid, 2019). This brings the author to conclude that there is insufficient research being done to highlight the perks of ADR's feasible features upon implementation particularly in the construction industry. Hence, in order to facilitate ADR's implementation in the construction industry, the Malaysian government and academicians need to work side-by-side to promote the advantages of ADR in resolving disputes concerning the construction sector which has always been a complex, fragmented and dynamic industry.

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MICROSTRUCTURE OF AMORPHOUS TROPICAL PEAT

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Abstract
The estimation of peat strength and compressibility properties is complex due to continuous changes in microstructure caused by decomposition. Decomposition significantly alters the fibre content and structural fabric arrangement in peat and is a significant factor towards establishing the strength and compressibility characteristics. The present study assessed the microstructure of amorphous peat through scanning electron microscope (SEM) and relate it to the index propertiessuch as moisture content, specific gravity, pH, liquid limit, organic and fibre content test. The micrographs of amorphous peat show colloidal amorphous-granular particles with no visible evidence of hollow cellular connections. The measured index properties reflect the effect of decomposition and are somewhat different from that of fibrous peat. The influence of fabric composition on the geotechnical properties of peat is discussed. This paper contributes to improving the characterisation of amorphous peat through microstructural study.

Keywords: *Amorphous peat; microstructure; index properties; decomposition*

INTRODUCTION

Peat is a geotechnical material that is composed of high organic content as a product of partial to full decomposition of plant remains. The organic solids range from woody coarse-fibres (fibrous)to fine-fibres (hemic) and amorphous matter (sapric). The state at which these organic solids existhighly depend on the parent plant, environmental condition and degree of decomposition (Pichan & O'Kelly, 2012). Southeastern Asia experiences high rainfall and hot temperature concurrently throughout the year. Therefore, tropical peatlands are formed from the forest and decompose considerably. Peat deposits in the tropics are rapidly decomposed because of the influence of penetrating air and the combination of large heat with humidity (Joosten, 2015). Unlike peatlands in the temperate region which are covered by moss and sedge that are slow in decomposition. Also, the microbes (fungi, bacteria and microflora) activities of breaking down accumulated plant remain occur more rapidly in aerobic condition while the accumulation of plant remains intensified during anaerobic condition (Pichan & O'Kelly, 2012). Oxygen is reduced in a water-saturated environment. Therefore, an anaerobic condition exists andvice versa. Temperature, acidity and nitrogen level also affect the rate of decomposition (Joosten, 2015).

Whatever form peat exist, it is generally considered a geotechnical material that is unstable in geotechnical character, and often cause excessive settlement, long-term creeps and unexpected failures (Al-Ani et al., 2013; Huat et al., 2011). The heterogeneity of peat is as a result of its organic origin which enables continuous decomposition with time. Therefore, the physical and mechanical properties of peat seem to depend on the level of decomposition and microstructural arrangement (Long & Boylan, 2013; O’Kelly & Pichan, 2013). However, avoidance of construction on peat may not be realistic in areas where it occurs in abundant and coincides with developments. Therefore, an extensive study of the geotechnical properties of peat is required for predicting settlement, estimation of shear strength and save construction on peat.

The study of microstructure and decomposition effects is limited. Hence, high-quality data are unavailable for the complementary study of peat settlement and strength behaviour, unlike other index properties such as moisture content, specific gravity, organic and fibre content. A precise observation from the record of unexpected settlement and stability failures in the literature is thatthe study of microstructure has not been used to complement other peat characterisation studies (Long & Jennings, 2006; McInerney et al., 2006; Zwanenburg et al., 2012). Most researchers probably assume that decomposition does not occur fast enough to change the microstructure within the design life of a geotechnical structure, however, tropical peat is contrary to this assumption (Pichan & O'Kelly, 2012). The knowledge of peat morphology and microstructure is as essential as the knowledge of geology in inorganic soils (Hobbs, 1986).

This paper presents the results of a complementary study of index properties and microstructure of decomposed amorphous tropical peat conducted in the laboratory. The index properties includemoisture content, specific gravity, pH, liquid limit, organic and fibre content test. The microstructure of amorphous peat was studied through scanning electron microscope (SEM) and it was related to the basic geotechnical properties of peat investigated in the laboratory. The resultsof these tests were correlated from an engineering perspective with the aim of providing a base formore appropriate prediction of engineering behaviour.

PEAT SAMPLING

The peat samples were collected from Kampung Endap, Kota Samarahan (KEP), Sarawak, Malaysia (1°25'37.2"N, 110°27'32.3"E) as shown in Figure 1. The site is about 3.5km away from the Samarahan campus of Universiti Teknologi MARA and 8km away from Universiti Malaysia Sarawak. The undisturbed samples were collected with thin-walled PVC sampler at 1.2m depth. The PVC sampler measures 100 mm in diameter and 250 mm in height with a cutting-edge angle of about 20º to reduce sample disturbance. Figure 2 shows the collection of undisturbed sampling. Reconstituted test samples were scooped into plastic containers for reconstitution in the laboratory. The containers were sealed with silicone sealant to avoid loss of moisture.

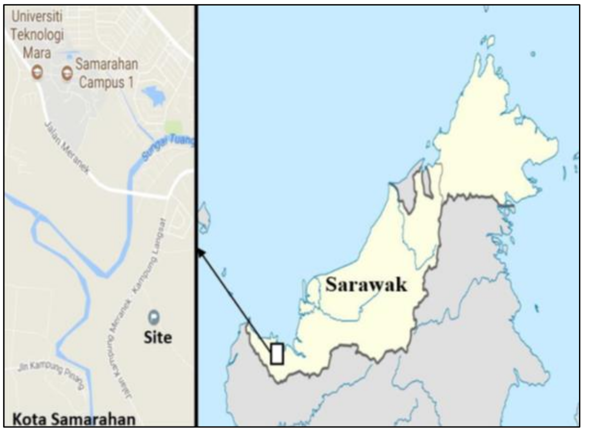

Figure 1. Map Showing the Location of KEP Site (1°25'37.2"N, 110°27'32.3"E)

Figure 2. Picture of Showing the Undisturbed Sampling Method

INDEX PROPERTIES

A series of tests were carried out on the natural peat samples in order to determine the index properties, which include the moisture content, specific gravity, pH, liquid limit, organic and fibre content test. The peat sample was visually examined on site, and the visual examination indicates a dark brown coloured organic material with a smooth texture. The Von-Post squeeze test (Von Post & E. Granlund, 1926) was also conducted on site to visually examine any material escaping between the fingers when the sample is squeezed by hand. It was observed that the peat is in a reasonably uniform paste and it is practically fully decomposed with unrecognisable plant structure. Almost all the peat escaped through the fingers except for few scattered undecomposed fibres. Therefore, the KEP peat is classified as a Sapric Peat. The loss of ignition test was conducted by combusting peat samples at a temperature of 450OC until there was no significant change in mass (usually about 5 hours) as suggested by ASTM D2794 (2007). The organic content in the samples shows that the soil can be classified as peat. Landva et al. (1983) classified geotechnical material with >80% organic content at peat. The fibre content of the peat sample is determined by the ratio of the weight of fibres retained on ASTM sieve No. 100 to the weight of the total oven-dried sample in accordance with the ASTM D1997-13 (2013) standard. The range of fibre content measured indicates that the peat is highly humified. The result of classification tests conducted on the samples in this study is in agreement with the specifications of peat in the classification chart of the Public Works Department, Malaysia (Zainorabidin & Wijeyesekera, 2007; Zulkifley et al., 2013). Table 1 shows the Extended Malaysian Soil Classification System (MSCS) for peat which improves on the various existing classification works in the literature, especially for tropical peats.

For the specific gravity tests, kerosene was used instead of distilled water recommended in ASTM D854-02 (2014) because water may be denser than the peat sample. The moisture content was determined in the laboratory by oven-drying the undisturbed peat samples at a temperature of 800C until there was no further change in mass. The water content for KEP is in the range of 394% to 614%.

Table 1. Malaysian Soil Classification Systems (MSCS) for Peat (Adapted from Zulkifley et al., 2013)

Soil Group	Organic Content	Group Symbol	Subgroup Symbol	Degree of Humification	Subgroup Name	Field Identification
Peat	> 75%	Pt	Ptf	H1-H3	Fibric or Fibrous	Dark brown to black in color. Material has low density so seems light. Majority of mass is organic, so if peat is fibrous, the whole mass will be recognizable plant remains. If highly humified, the peat will be more likely to smell strongly.
			Pth	H4-H6	Hemic or Moderately Decomposed Peat	
			Pta	H7-H10	Sapric or Amorphous	

The pH test was conducted according to the procedure mentioned in ASTM D4972 (2001). 75 ml of distilled water was added to a 30 gm of dried, sieved peat and stirred evenly for a few minutes. The solution was left standing overnight in an incubator to maintain temperature, humidity and other conditions. A digital meter with a glass electrode was used to measure the pH value of the suspension after 24 hours. Lastly, the peat liquid limit was determined from the cone penetrometer method as according to BS Standard (1990). The range of the basic geotechnical properties of the peat calculated from the numerous samples that were tested are presented in Table 2. The peat samples used in this study can be classified as highly humified with less fibre based on the chart in Table 1 and index tests results in Table 2.

Table 2. Index Properties of Kampung Endap Peat

Index Properties	Value Range	Technique and Device
Von Post	H8-H9	Hand squeezing
Organic Content (%)	92 - 96	High-temperature oxidation method (ASTM D2974)
Fibre Content (%)	3.5 - 6.2	Oven drying (ASTM D1997-91)
Moisture Content (%)	394 - 614	Oven drying (ASTM D2216)
Specific Gravity	1.69-1.73	Pycnometer using the kerosene (ASTM D854-02)
Liquid Limit (%)	540 - 602	Fall cone (BS 1377-2)
Colour	Dark Brown	Visual Examination

MICROSTRUCTURAL STUDY AND ANALYSIS

The micrographs of peat samples have been taken with the Hitachi TM 3000 Tabletop scanning electron microscope (SEM) to study morphology and spatial arrangement of the peat constituents. The setup of the electron microscope is shown in Figure 3. The peat samples were initially air dried at room temperature for two weeks. The air-drying technique was adopted to prevent the organic material from charring when oven dried at high temperature. The air-dried sample was pulverised using a rubber hammer and stored in an airtight polythene bag. Then the pulverised sample was sprinkled on a 5 mm aluminium stubs (sample holder), which are overlaid with double-sided carbon tape as a form of adhesive to gum the sample to the stubs. Then the sample was coated with thin layer of gold in a sputtering diode system for 10 minutes to allow repulsion of the scattered electron that hits the surface of the sample when it is placed into the Scanning Electron Microscope (SEM). Various samples were prepared according to the explained method and examined with the SEM.

Figure 3. The UNIMAS Hitachi TM 3000 Tabletop Scanning Electron Microscope

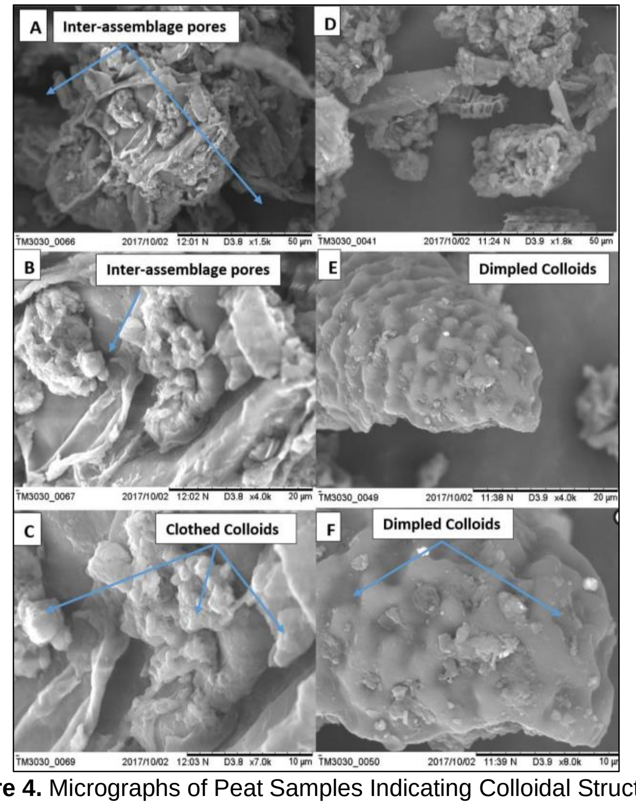

Figure 4. Micrographs of Peat Samples Indicating Colloidal Structures

The images from SEM studies of the peat samples that were taken at different magnifications are presented in Figure 4. Most of the viewed microstructure are homogeneous non- crystalline micro-particles that are colloidal in structure and jelly-like in texture. Samples magnified at different scale are shown in Figs 4a to 4c and 4d to 4f. The colloidal structure as clearly shown in figs 4b, 4c, 4e and 4f do not indicate any intra-assemblage pore space, but surfaces seem to be bounded by pore water. Colloidal microstructure in peat is evidence of highly humified granular material which is in the range of H8 to H10 in the Von-Post classification (Von Post & Granlund, 1926). Organic colloids are very small in size (less than 2μm) because it is formed from humified peat with fewer fibres (Huat et al., 2014; Kazemian et al., 2011). They are the product of secondary synthesis of peat and are chemically active due to their small sizes and high electrical surface charge (Santagata et al., 2008).

There is no evidence of hollow perforated cellular structure as can be found in fibrous peat from the SEM micrographs. Invariably, the intraparticle space of the peat is reduced, and the water storage capacity is hindered because water can only be stored in between the interparticle voids. Thus, the moisture content in amorphous peat is lower than that of fibrous peat (Huat et al., 2011). Note that two- thirds of the water content in fibrous peat are mostly stored within the hollow cellular fibres while one- third is stored in the interparticle voids between the fibres (Landva & Pheeney, 1980; Mesri & Ajlouni, 2007; O'Kelly, 2014). Also, the peat particles could become more gelatinous, compact and relatively high specific gravity (Hobbs, 1986; Boylan, 2008).

CONCLUSION

The peat tested is this experiment is dominated by high organic contents that are highly decomposed. The specific gravity of 1.7 is relatively higher than what is obtainable in other types of peat, and the reduction in water content also indicates a reduction in fibrosity. The SEM results complement the data of the index properties. The SEM micrograph shows that the hollow perforated cellular structure of fibrous peat has been lost and particles are colloidal in texture. Hence peat becomes more gelatinous, compact and relatively high specific gravity. Since there are no significant cavities for storage of water in the intraparticle spatial arrangement of the peat samples, the moisture content seems to be lower than that of fibrous peat.

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SIMULATION AND FORECASTING OF PRECIPITATION IN KUCHING CITY BY USING SALP SWARM OPTIMIZATION NEURAL NETWORK

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Abstract
There are significant changes in precipitation recently which leads to continuously occurrence of floods. For this reason, it is necessary to forecast precipitation accurately that can be used to directly apply for hydraulic engineering design as well as water-resources management. Not only that, but long-term forecast of precipitation is also important for the local authorities to confront and mitigate the adverse consequences. Thus, this paper is aimed to explore and develop new novel neural network that can be used to forecast long term precipitation (rainfall) accurately at Kuching. In this paper, annual mean monthly precipitations for year 2020, 2050 and 2080 are generated using Salp Swarm Optimization Neural Network (SSONN). For the evaluation of the results, appropriate statistical indexes such as root mean square error (RMSE), coefficient of determination (R^2) and index of agreement (IA) are applied. The results from the simulation of SSONN are acceptable with 3.95mm, 0.48 and 0.831 for RMSE, R^2 and IA respectively. The forecasting results can still be further improved by trying out different combinations of appropriate Global Climate Model (GCM) predictors. Moreover, more investigation works for input determination are needed in order to obtain more accurate results for predicting precipitation.

Keywords: *Precipitation forecasting; Salp swarm optimization neural network; artificial neural network; Kuching.*

INTRODUCTION

Due to the climate change, the rainfall intensity is increasing from year to year and thus lead to continuously occurrence offloods even though the drainage system is strictly designed according to design guidelines in Malaysia. These unpredictable flood events, especially during Northeast Monsoon Season, from November until March, had brought significant damage to properties, transportation system and communication disruption. Accurate precipitation forecasting brings significant impacts in the field of food production, securing water supplies for major towns and minimizing flood risks (Abbot & Marohasy, 2012).

Therefore, many research efforts have been put into the application of ANNs to solve different types of problems and case studies from year 1999 until year 2007 (Maier et al., 2010). Not only that, many hydrologists and engineers had put in a lot of efforts to forecast precipitation using Artificial Neural Network (ANN) (Nair et al., 2018; Kueh & Kuok, 2018; Abbot & Marohasy, 2017; Kuok et al., 2016; Montazerolghaem et al., 2016; Mekanik et al., 2013; Kuok et al., 2010; Kuok & Naib Bessaih, 2007). In Malaysia, the production of oil palm is one of the major sources of income. In fact, one of the factors that affecting the yield of oil palm is precipitation. High intensity of precipitation will cause poor pollination and less photosynthesis of oil palm (Haniff et al., 2014). As a result, the reduced yield of oil palm which affected by increasing trend in precipitation and precipitation extremes may severely affect oil palm-based economy in Sarawak. As Sarawak has high concentrations of species per unit area due to high species diversity, the increasing of precipitation may significantly affect the microenvironment of species and reduce biological diversity (Kang et al., 2015). It is also stated that the health of the forest and the ecological systems could be affected by small changes in precipitation characteristics (Zulfaqar Sa'adi et al., 2017).

Currently, researchers have considered and included the output data, which also known as predictors, from Global Climate Models (GCM) in order to forecast long term precipitation. However, the prediction of long-term precipitation for that specific study area is usually inaccurate due to the large uncertainties at regional and decadal scales of coverage areas. Therefore, it is recommended that researchers need to carry out as many researches as possible and explore more possibility of uncertainty reduction through higher resolution global climate models and statistical or dynamical downscaling in order to improve the understanding of precipitation extremes processes (Kao & Ganguly, 2011). As a result, accurate forecasting of precipitation can be used to directly apply for hydraulic engineering design as well as water-resources management.

Based on the analysis of Global Circulation Model (GCM) outputs, the characteristics of precipitation extremes will be affected by the future warmer temperature. The increasing sea surface temperature due to climate change has brought the substantial changes in precipitation and precipitation extremes (Trenberth, 2011). Not only that, the results from the comparison of observed and simulated climate model shows that the models may underestimate the expected severity of precipitation extremes under the impact of climate change (Liu et al., 2009).

Over the last decades, there are many researches have been done on the application of Artificial Neural Network (ANN) in different areas of water related activities because ANN models are suitable to cope with the natural behaviour of hydrological processes, which is known as complex, non-linear and dynamic systems that generally gives large amount of noisy data (Kuok, 2010). Furthermore, meta-heuristic techniques, one type of the training algorithms to solve optimization problems, have become very popular due to its flexibility, gradient-free mechanism, and local optima avoidance of the algorithms (Mirjalili et al., 2017). Hence, this study focuses on the development of new novel neural network, Salp Swarm Optimization Neural Network (SSONN) which can forecast precipitation accurately at Kuching by using historical precipitation data (year 1961 until year 2010) obtained from Department of Irrigation and Drainage (DID) Sarawak. Moreover, the developed SSONN will be used to forecast monthly precipitation at Kuching in long term period with the consideration of climate change variables.

The significance of this study is to provide valuable guidelines for the development of novel neural network, SSONN, to simulate and forecast precipitation at Kuching. SSONN which trained with meta-heuristic algorithms offer effective behaviours in finding the optimal solutions for optimization problems by only looking at the inputs and outputs (Mirjalili et al., 2017). In addition to that, novel SSONN offers faster convergence rate and minimal chance of getting local optima trapping. Furthermore, the reliability and accuracy of the forecasting result from the developed SSONN is important as the result of the developed model provides early warning signal to the local authorities for necessary flood preventive measures to minimise the loss or damage of Kuching city.

STUDY AREA

Malaysia, which comprises of Peninsular Malaysia on the West, and Sabah and Sarawak on the East, has the total area of approximately 329,750km^2 (Kueh, 2016). Recently, there are some climate change issues in coastal community of Malaysia (Hayrol Azril et al., 2015; Ercan et al., 2013; Hartmann et al., 2013; Muzathik et al., 2011; Suhaila et al., 2010; Wan Azli, 2010; Wai et al., 2005). The study area of this study, Kuching as shown in Figure 1, is located in Sarawak, Malaysia and it has a tropical rainforest climate with no dry season. One of rainfall gauging stations is located at Kuching Airport, rainfall gauging station ID 1403001, which was established by Department of Irrigation and Drainage (DID) Sarawak since year 1951 (Kuok et al., 2016). [6]. However, the rainfall station is currently moved to Kuching Regional Weather Forecasting office, Malaysia Meteorological Department, Sarawak Branch (Kuok et al., 2016). The main purposes of this office are to manage and provide weather forecast for aviation, mass media, private sector and general public of Sarawak. Furthermore, the actual weather information, issuance of severe weather warnings and alerts are provided to Air Traffic Control Centre (ATC) from this office.

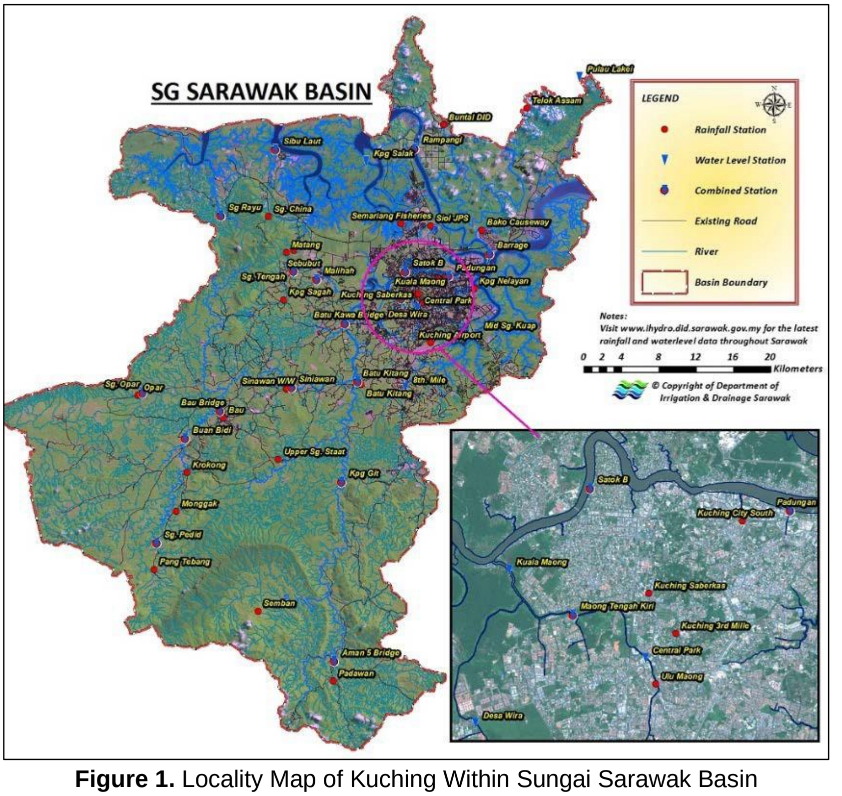

Figure 1. Locality Map of Kuching Within Sungai Sarawak Basin

Moreover, Kuching Regional Weather Forecasting Office provides several meteorological data such as temperature, sunlight, cloud cover, relative humidity, wind speed and directions (Kuok et al., 2016). Not only that, monthly report provided by this office covers daily average low and high temperature, the median of cloud cover, probability and types of precipitation, relative humidity, average daily minimum, maximum and average wind speed as well as wind directions and number of hours in which the sun is visible with various degrees of daylight, twilight and night.

SALP SWARM OPTIMIZATION NEURAL NETWORK

Salps belong to the family of Salpidae (Mirjalili et al., 2017). They have the transparent barrel-shaped body and their body tissues and movement are similar to jelly fishes as shown in Figure 2. They move their body by pumping the water through the body as propulsion to move forward. The living environments of this creature are extremely difficult to access and difficult to keep them in laboratory environments (Mirjalili et al., 2017).

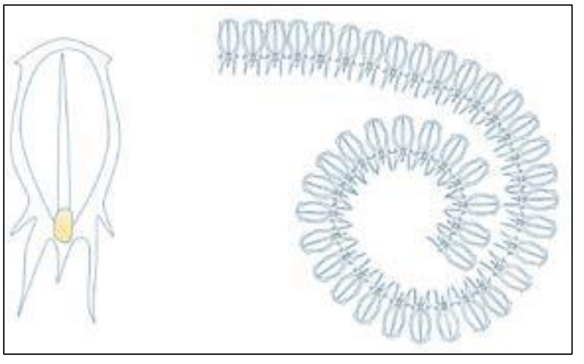

Figure 2. Appearance of Salp and Salp Swarm

One of the most interesting behaviour of salps is their swarming behaviour. They will form a swarm called salp chains in deep oceans and the main reason of this behaviour is not clear yet (Mirjalili et al., 2017). However, some researchers believe that this is done for achieving better locomotion using rapid coordinated changes and foraging in the ocean. This novel optimization algorithm is the first model of salp chains for solving optimization problem (Mirjalili et al., 2017).

One of the challenges when solving optimization problems is the presence of local solutions (Mirjalili et al., 2017). There is only one best return solution, which also known as global optimum, in a single-objective search space (Mirjalili et al., 2017). However, many other solutions, in term of return values that close to the objective value are shown up in every part of search space. This kind of return values which close to the objective value located in particular search space are called local solutions (Mirjalili et al., 2017). This is because they are locally the best solution in their vicinity, but not the best solution globally when consider the entire search space. As a result, the presence of these local solutions leads to the local optima stagnation (Mirjalili et al., 2017). In other words, local optima stagnation refers to the situation where an optimization algorithm finds a local solution and mistakenly assumes it as the global optimum. Therefore, efficient optimization algorithms should be capable of avoiding local optima stagnation (Mirjalili et al., 2017).

In addition, an optimization algorithm, which capable of avoiding local solutions, may not be able to converge effectively towards the global optimum. This term refers to the convergence speed of an optimization algorithm and this becomes another challenge for algorithms when solving optimization problems. Generally, quick convergence leads to local optima stagnation as local solutions are taken as global optimum quickly whereas the slow convergence happens when there are sudden changes in the solutions due to local optima avoidance. Therefore, these two trade-offs are the main challenges for algorithms when solving real problems (Mirjalili et al., 2017).

In the mathematical model, the salp population is divided into two groups: leader and followers. The leader salp is located at the front of the chain and guides the swarm to search and chase for food while the rest of salps are considered as followers and follow the leader salp directly or indirectly [18]. In order words, the follower salps follow the leading salp while the leading salp moves towards the food source (global optimum).

The model of salp chain movement can explore and exploit the space around both stationary and mobile food sources (local optimum and global optimum) (Mirjalili et al., 2017). From the outcome of the developed algorithm, SSA can improve the initial random solutions effectively and converge towards the optimum (Mirjalili et al., 2017). Therefore, SSA is chosen to be trained the feedforward neural network for inflow forecasting in this study.

METHODOLOGY

The overall methodology schematic diagram is shown in Figure 3.

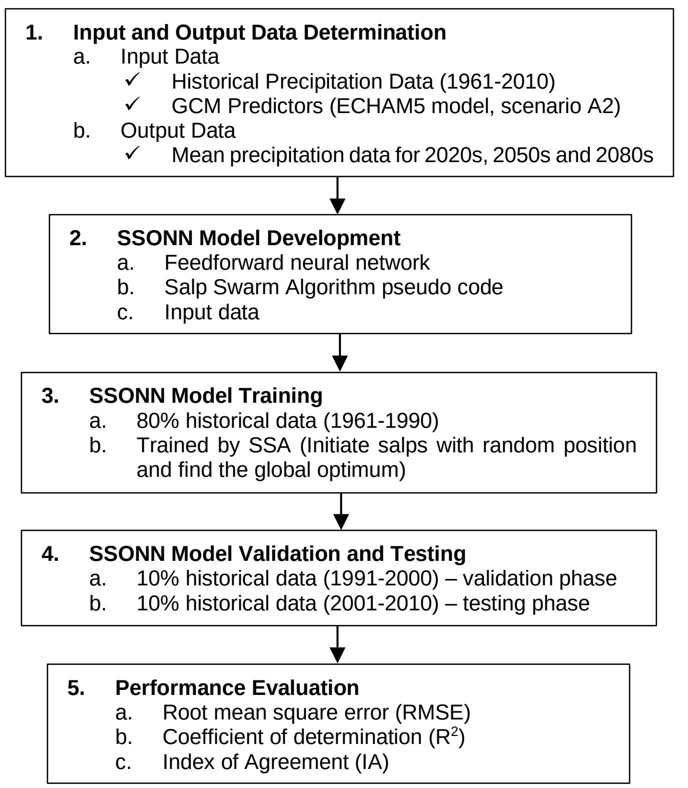

Figure 3. Methodology Schematic Diagram

Input and Output Data Determination

The first step for the model development is the choice of appropriate model output, such as the variables to be predicted, and a set of potential model input variables from the available historical data (Maier et al., 2010).

In this study, the input data for this model are historical precipitation data from DID and climate variables data (GCM predictors) from global circulation model or global climate model (GCM). Local data are obtained from historical observed data from local authorities and it can be used for simulation. Available precipitation data that are obtained from DID Sarawak contain long historical precipitation data from 1961 until 2010. In this study, historical precipitation data from 1961 until 1990 are used for model training, data from 1991 until 2000 are used for model validation and data from 2001 until 2010 are used for model testing.

GCM shows the mathematical terms of past, current and future climate. Through the usage of this model, climate scientists can predict on the weather and investigate on the interactions between climate processes. This is because GCM can show future climate projections under different hypothetical climate scenarios.

However, the misrepresentation of the local extremes and variability for coastal areas or mountainous regions under that particular region (Lu et al., 2013). The major drawback of the simulations of GCMs for policy-making decisions is its coarse spatial resolution which is inadequate in providing consistently agreeable information on climate below 200km (Meehl et al., 2007). In other words, GCM data can only provide coarse resolution of the map up to 200km but it can be used for future projection.

In this study, GCM predictors are obtained from ECHAM5 model generated by Max-Planck-Institut for Meteorology (MPI-M), Germany under scenario A2 with the resolution of 1.9o x 1.9o, or 140 x 210 km (IPCC, 2011). The GCM predictors which are found to be the best combinations to adapt for this study are monthly mean relative humidity at 200hPa (hur200), monthly mean relative humidity at 500hPa (hur500), monthly mean relative humidity at 850hPa (hur850), monthly mean air temperature at 200hPa (ta200), monthly mean air temperature at 500hPa (ta500), monthly mean air temperature at 850hPa (ta850), monthly mean sea-level pressure (psl), total precipitation (pr), monthly mean 2m surface air temperature (tas), monthly mean surface skin air temperature (ts), monthly mean Zonal surface wind speed (uas), monthly mean Zonal wind component at 200hPa (ua200), monthly mean Zonal wind component at 500hPa (ua500), monthly mean Zonal wind component at 850hPa (ua850), monthly mean Meridional surface wind speed (vas) and Meridional wind component at 200hPa (va200), Meridional wind component at 500hPa (va500), Meridional wind component at 850hPa (va850) (Kueh & Kuok, 2014). The output data for this model is mean precipitation data for three-time frames (2020s, 2050s and 2080s).

Salp Swarm Optimization Neural Network (SSONN)

In this study, Salp Swarm Algorithm (SSA) will be adopted for SSONN model development and used to carry out the simulation and forecasting of precipitation at Kuching. In order to train feedforward neural network by using SSA, some tweaks will be needed to determine the global optimum for SSONN. At the beginning, SSONN starts to approximate the global optimum by initiating multiple salps with random position (exploration phase) and then calculates the fitness of each salp while searching for food. When the salp obtained the best fitness for searching the food, it will be assigned as leader salp and the position of the best leader salp will be updated to the remaining salps. The remaining salps will form salps chain and follow the leader salp to move towards the food source (exploitation phase) (Mirjalili et al., 2017).

After SSA is integrated into Feedforward neural network, SSONN is then used for forecasting future long-term precipitation data for three-time frames (2020s, 2050s and 2080s) by using Matlab, 2017. During model training, 80% of historical data (1961-1990) will be input to Feedforward Neural Network and trained by SSA. After that, 10% of historical data (1991-2000) will be used for validation phase and another 10% of historical data (2001-2010) will be used for testing phase of the model.

After that, the performance evaluation of the developed SSONN model such as Root Mean Square Error (RMSE), coefficient of determination (R^2) and Index of Agreement (IA) are adopted as statistical indices. The use of statistical indices can establish the credibility of the trained ANNs (Seo et al., 2015; Nastos et al., 2014; Moustris et al., 2011).

RMSE can be calculated using the equation:

$$\mathrm{RMSE} = \left(\frac{1}{n}\sum_{i=1}^{n}(P_i - O_i)^2\right)^{\frac{1}{2}} \tag{1}$$

where n is the number of observations, O_i is the observed value and P_i is the predicted value (Nastos et al., 2014).

R^2 can be calculated using the equation:

$$R^2 = \left[\frac{\sum_{i=1}^{n}(O_i - O_{ave}) \times (P_i - P_{ave})}{\sqrt{\sum_{i=1}^{n}(O_i - O_{ave})^2} \times \sqrt{\sum_{i=1}^{n}(P_i - P_{ave})^2}}\right]^2 \tag{2}$$

where n is the number of observations, O_i is the observed value, O_{ave} is the average value of all the observed values, P_i is the predicted value and P_{ave} is the average value of all the predicted values (Nastos et al., 2014).

IA can be calculated using the equation:

$$IA = 1 - \frac{\sum_{i=1}^{n}(P_i - O_i)^2}{\sum_{i=1}^{n}(|P_i - O_{ave}| + |O_i - O_{ave}|)^2} \tag{3}$$

where n is the number of observations, O_i is the observed value, O_{ave} is the average value of all the observed values, P_i is the predicted value and P_{ave} is the average value of all the predicted values (Willmott et al., 1985).

RESULTS AND DISCUSSION

Table 1 shows the values of the statistical indices of reliability for SSONN model. It is worthy to remark that the results are satisfactory and encouraging as the random and extreme events are taken into consideration. The result of the evaluation seems satisfactory with RMSE = 3.95mm which means that the value of 3.95mm for RMSE is considered as typical magnitude for an error in estimation in this study (Wardah et al., 2008). Therefore, if the mean precipitation prediction is 25mm, an error of 16% is expected in the prediction.

Table 1. Statistical Indices for Evaluation of SSONN Model

RMSE (mm)	R^2	IA
3.95	0.480	0.831

Results also revealed that coefficient of determination (R^2) is 0.480 as shown in Table 1. In addition to that, the relationship between the predicted and observed values of mean monthly precipitation at Kuching for the forecasting period (1961-2010) in term of R^2 is clearly demonstrated in Figure 4.

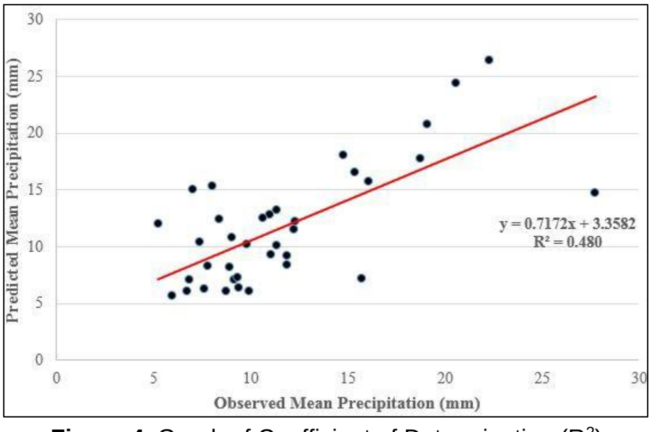

Figure 4. Graph of Coefficient of Determination (R^2)

R^2 = 0.480 indicates that 48.0% of the total variation in *y* during period (1961-2010) can be explained by the linear relationship between *x* and *y*:

$$y = 0.7172x + 3.3582 \tag{4}$$

where *y* represents the predicted values of mean monthly precipitation by developed SSONN model and *x* represents the observed values of mean monthly precipitation (Nastos et al., 2014; Moustris et al., 2011).

Other than that, the index of agreement (IA = 0.831) indicates that the forecasted values of mean monthly precipitation are very close to that of the observed values.

As shown in Table 2, the highest value of mean precipitation over the forecasting period 1961-2010 gives 24.16mm/month during January (1991-2010) whereas the lowest value of mean precipitation gives 5.94mm/month during July (1961-1990).

Table 2. Tabular Results of Mean Monthly Precipitation for Year 1961-2100

Years	Mean Precipitation (mm)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Observed (1961-1990)	22.28	19.08	11.88	8.90	7.62	6.74	5.94	6.82	9.16	10.97	12.27	15.38
Observed (1991-2010)	24.16	17.23	11.48	9.59	8.71	8.38	6.51	8.18	8.64	11.44	11.35	15.42
Predicted (2011-2040)	22.17	8.77	12.80	10.10	10.19	9.25	8.89	7.98	7.44	10.06	9.67	14.16
Predicted (2041-2070)	20.93	14.26	8.40	8.47	6.44	6.46	6.56	8.95	10.43	8.43	14.35	15.10
Predicted (2071-2100)	20.88	15.83	10.45	10.36	9.23	9.34	8.70	8.76	6.85	10.82	18.42	19.66

Figure 5 presents the projected mean monthly precipitation for 2020s, 2050s and 2080s at Kuching. The pattern of the annual precipitation at Kuching is clearly demonstrated in Figure 5. Northeast monsoon usually occurs from November to March with daily maximum precipitation of 350mm to 480mm and thus, the mean precipitation starts to increase gradually after October and reach its peak on January (Kueh, 2016). After that, mean precipitation begins to decrease gradually until March. The mean precipitation continues to drop, due to Southwest monsoon, until it reaches bottom in July and starts to increase gradually until September.

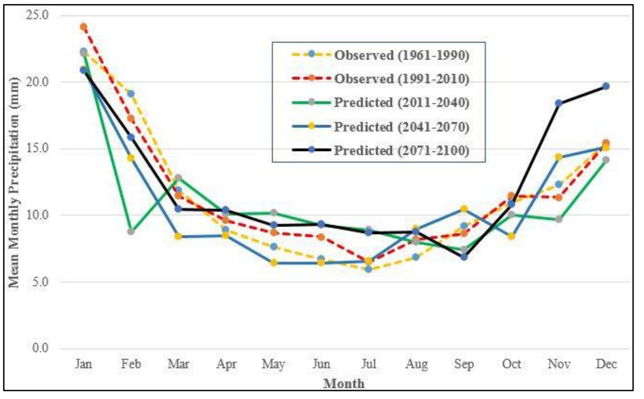

Figure 5. Prediction of Mean Monthly Precipitation for 2020s, 2050s and 2080s

One of the limitations of this study is that the proposed SSONN model need more particular historical precipitation data for model training. ANNs could not gain necessary experience for accurate and precise prediction of the variables if the historical data is insufficient because those extreme precipitation cases often occur with low frequency (Moustris et al., 2011). Furthermore, one limitation of this developed model is the appropriate determination of the input variables for an appropriate training. The inclusion of either too few or too many model inputs are undesirable and there is no standard guideline currently (Maier et al., 2010). As a result, the developed model with too few or too many model inputs might not be able to develop the best possible input-output relationship (Maier et al., 2010).

Despite of the limitations, the proposed SSONN model is easy to cope with complex, non-linear and dynamic systems that generally gives large amount of noisy data. With the inclusion of GCM predictors, SSONN can forecast precipitation in long term (2020s, 2050s and 2080s) with reasonable and acceptable forecasting results.

CONCLUSION AND FUTURE WORKS

In this study, novel neural network – Salp Swarm Optimization Neural Network (SSONN) is developed to forecast long term mean precipitation at Kuching for 2020s, 2050s and 2080s with the inclusion of GCM predictors such as relative humidity (hur), total precipitation (pr), monthly mean sea-level pressure (psl), monthly mean 2m surface air temperature (tas), monthly mean air temperature (ta), monthly mean surface skin air temperature (ts), monthly mean Zonal surface wind speed (uas), monthly mean Zonal wind component (ua), monthly mean Meridional surface wind speed (vas) and Meridional wind component (va). This study aims to provide accurate long-term forecasting of annual mean precipitation by using newly developed SSONN model. After carrying out the simulation and forecasting of precipitation using newly developed SSONN, the results are very satisfactory and encouraging with 3.95mm, 0.48 and 0.831 for RMSE, R^2 and IA respectively. The pattern of the annual precipitation at Kuching is also clearly demonstrated in Figure 5 which is very convincing.

Currently, most of ANN models are constructed on the basis of trial-and-error procedure with different architecture, different optimization algorithms or different combination of GCM predictors for long term forecasting of precipitation (when applicable). Thus, there may always exist better models for different field of expertise and hence, it is encouraged to try out new models which can really provide great performance and great consistency in forecasting water resources variables.

In addition, increasing the variability reduces the performance of ANN models as there are too many noisy data that influence the accuracy of results. Therefore, several combinations of the input data can be attempted and the input data with low coefficient of correlation can be eliminated in order to achieve more accurate and convincing forecasting results.

Lastly, further comprehensive work is required for the improvement on the accuracy and robustness of the developed model – SSONN as a reliable forecasting tool. Furthermore, SSONN could be adopted to explore more on other field of interest such as forecasting of dam inflow, river flow and water quality parameters.

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A PRELIMINARY STUDY ON BUILDING CONDITION OF HERITAGE BUILDINGS AT THE KUALA LUMPUR POLICE TRAINING CENTRE (PULAPOL), MALAYSIA

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Abstract
The Kuala Lumpur Police Training Centre or also known as PULAPOL Kuala Lumpur is the largest and oldest police academy in Malaysia. Established in the year 1904 by the British, its architectural design with the colonial influence is still maintained until now. With a total area of 249.5 acres, this academy hosts 27 heritage buildings and a monument that has been gazetted in 2004. Just like any other heritage buildings in this country, the heritage buildings at PULAPOL Kuala Lumpur are also vulnerable to damages and threats. Such damages and threats do not only affect the daily affairs of the academy but also induce bad impressions on the image of the historical buildings in Malaysia. Therefore, this study aims to identify the type of damages and threats in the heritage buildings at PULAPOL Kuala Lumpur as well as analyze those particular damages and threats. This study was carried out using qualitative approach with a case study research strategy. The instrumental aspects of the study involved field observation method and in-depth interview with the staff at the Facilities Management Unit of PULAPOL. The data were then analyzed using the content analysis. The study has found that the heritage buildings at PULAPOL Kuala Lumpur face some damages and threats in the drainage and piping system, paint exfoliation, moss and rust formation, structural damage, attack from hitchhiker plants, and also attack by insects. These damages and threats do not only impact the buildings' image but is also affect their occupants. Thus, these buildings require proper maintenance because the buildings implicitly represent the image of the criminal justice system in Malaysia.

Keywords: *Heritage building; building conservation; PULAPOL; building damage; British colonial building.*

INTRODUCTION

The architecture of heritage buildings in Malaysia has gone through a long history starting from the colonial periods of the Portuguese, Dutch and British. The influence of colonial architecture makes the heritage buildings in Malaysia unique because the European architecture needs to be adapted to hot and humid local weather throughout the year (Adam Che Yusof & Ahmad, 2018). Old buildings need to be preserved regardless of their location whether in a city or a small town because their presence is important in maintaining the history, identity of an area, architecture uniqueness, and to educate the next generation (Harun, 2020). As at 2019, 313 buildings have been declared as National Heritage Sites and Heritage Sites in Malaysia (Jabatan Warisan Negara, 2020). The majority of those declared buildings are from masonry buildings that have strong colonial influences. The Kuala Lumpur Police Training Centre or better known as PULAPOL Kuala Lumpur is an area occupied mostly by heritage buildings since the British colonial period. In total, there are 28 heritage properties in the academy which includes 27 buildings and a monument. Generally, PULAPOL Kuala Lumpur is the oldest police academy in Malaysia covering an area of 249.5 acres.

The academy was established on 20 November 1904 which was founded by Captain Graham, who was the contingent officer of the Malay Peninsular at the time. The academy recorded an important historical event to the country when the Japanese military attacked the Malay Peninsular in 1941 and turned the academy into a Japanese Competent Headquarters. Subsequently, after the defeat of Japan in August 1945, the academy was taken over and restructured by the British and it was made the largest police training center in the country. Thus, from 1946 to 1957, all commanders of the center were British (Abu Bakar, 2017). These buildings have been used for various occasions with their own assigned functions such as administrative buildings, religious buildings, training grounds, accommodation buildings and dining buildings which were officially gazetted in 2004. The management of these buildings is handled by the Management and Facilities Unit which includes the scope of repairing damage, landscaping, and building maintenance management. This unit comprises of two (2) supervisors, an assistant supervisor from the police department and is assisted by 26 civil servants. Malaysia's Department of National Heritage (JWN) is the organization responsible for declaring any location or building as national heritage site. However, the management and maintenance are the responsibilities of the building owner. Therefore, all heritage buildings in Malaysia have their own ways and this includes PULAPOL Kuala Lumpur.

Managing a heritage building is not an easy task because of the age factor of the buildings, that are usually hundreds of years old, causing the building to be susceptible to damage (Adam Che Yusof & Ahmad, 2018; Awang et al., 2020). Modernization is also a contributing factor to the damage caused by the inappropriate modification and insensitivity of the parties involved (Lukito & Rizky, 2018). Usually, the damage occurs on structures like basic structures, outer walls, pillars, beams, windows, doors, stairs, outer floors, and building apron (Hanafi et al., 2018). Buildings also suffer from defects due to external attacks such as local weather conditions, traffic vibration, high water level and plants that are too close to the building (Ahmad, 2018). Moisture attacks due to drainage system problems and groundwater cause serious damage to buildings in the form of wall cracks, exfoliation, cracked surfaces and the presence of moss (Harun, 2020). In addition, there are some defects to heritage buildings that are often found after conducting dilapidation survey such as termite attacks and salt crystallization due to no Damp Proof Course (DPC) on old buildings (Azree et al., 2017). Preservation of heritage buildings is one of the ways to improve the sector's history and culture-themed tourist (Choy, 2017). The lack of maintenance is one of the main factors that causes damages to heritage buildings (Alauddin et al., 2016). As the academy has a great number of heritage buildings in the area, the maintenance and management work is seen as something difficult and very challenging. Academic research and study on heritage buildings in PULAPOL Kuala Lumpur are also seen as insufficient thus, there is a need for more studies to be conducted to ensure that its existence as one of the most important heritage sites in the country is well preserved and made known to the public.

OBJECTIVES AND METHODS OF STUDY

Based on the issues mentioned above, this study aims to identify the types of damages and threats on heritage buildings at PULAPOL as well as to analyse those damages and threats. The study was carried out using qualitative approach through the case study method. PULAPOL Kuala Lumpur was selected because this academy is the only area that has a high number of heritage buildings in a single area, which is 27 buildings in total. The study instrument employed was field observation method and deep interview with the representatives from the Facilities and Management Unit. The observation method was applied to all buildings listed as heritage sites by JWN. Meanwhile, the interview method was carried out as purposive sampling with the assistant supervisor, who has been working at PULAPOL Kuala Lumpur for 30 years, where he was assigned to regulate and handle the building maintenance as well as to manage the landscape. The study data were analysed through content analysis based on both study instruments used. The study data have then be sent to the Office of Administration Deputy Commander (General police) PULAPOL Kuala Lumpur as a procedure requirement for government building and then to be reviewed for data validity as well as getting permission to be published to the public.

RESULT AND DISCUSSION

Types of Building Damages and Threats in PULAPOL Kuala Lumpur

Table 1. Type of Damage Identified on the Heritage Buildings at PULAPOL Kuala Lumpur

NO.	BUILDING CODE	BUILDING	TYPE OF DAMAGE AND THREAT						
			Drainage System	Piping System	Paint Exfoliation	Moss & Stain Formation	Structure / Finishing	Hitchhiker Plants	Insect Attack
1	JKR 1874	Building Of The Martial Art (SMD)		/	/	/	/	/	
2	JKR 1875	Physical Intelligence Test Building (UKF)	/	/		/	/	/	
3	JKR 1876	Cyberpool Building				/			
4	JKR 1877	Sports Building (Gymnasium)	/	/		/	/	/	
5	JKR 1878	Marching Band Building				/	/	/	
6	JKR 1879	Diner Building	/			/	/	/	
7	JKR 1786	Commander's Office Building (Guard Hall)	/	/			/	/	
8	JKR 2004	Finance Office Building				/		/	
9	JKR 2019	Commander's Office Building			/	/		/	
10	JKR 2006	Batu Lama School Building			/	/			/
11	JKR 2006	Hall One			/	/			/
12	JKR 1896	KEMAS Kindergarten Building			/	/	/		/
13	JKR 2076	Sports Building Complex	/	/	/	/		/	/
14	JKR 2005	PULAPOL Central Weapons and Armament Workshop	/			/		/	
15	JKR 341	Male Barrack		/		/		/	
16	JKR 342	Male Barrack		/		/		/	
17	JKR 394	Male Barrack		/		/		/	
18	JKR 386	Female Barrack		/		/		/	
19	JKR 2078	Gurdwara Sahib PULAPOL				/		/	
20	JKR 1331	Adjutant Residence			/				
21	JKR 817	Commander's Residence				/		/	
22	JKR 1332	Deputy Commander's Residence (Training)				/		/	/
23	JKR 1333	Residential Deputy Commandant (Administration & Garage)				/		/	/
24	JKR 1541-1544	Class F Family House	/	/		/	/	/	/
25	JKR 2085	Surau PULAPOL							
26	JKR 2003	Male Police's Children Dormitory	/	/	/	/		/	
27	JKR 1744-1755	Female Police's Children Dormitory			/	/	/		

(Source: Author, 2021)

Just like other heritage buildings, the buildings that have been declared and gazetted as heritage buildings in the academy can not escape from damages and threats. The damages identified were sedimentations on drainage systems, roof leakage, piping drainage, paint exfoliation, the formation of moss and stain, as well as structural damage, hitchhiker plant invasion, and attack from insects (Table 1). The study found that almost all heritage buildings here suffer damage, either minor or major damage. Minor damage is identified as the damage that does not harm the residents of the buildings such as the small damage on the finishing elements of the buildings, or delicate fractures on the structures. Meanwhile, major damage is a damage that occurs on the main structure such as roofs, columns, walls, and damage that affects the strength and stability of the building.

Based on the observation done on the field, only the Surau at PULAPOL was found to have no sign of damage as the building's upgrading works were in progress. Subsequently, Cyberpool Building, Marching Band Building, Adjutant Residences, Commandant Office, Finance Office, KEMAS Kindergarten, Batu Lama School Buildings, Hall One, Central Weapons and Armament Workshop, Gurdwara Sahib, and the Commandant Camp Office Building (Guard Hall) were found to be in good condition and only experience minor damages. While some buildings such as the Martial Arts Office (SMD), Physical Intelligence Testing building (UKF), Sports Building (Gymnasium), Male Police's Children Dormitory, Women Police's Children Dormitory, Marching Band building, Canteen Building, Sports Building Complex, Single Men's barrack are still in good condition but more attention is needed as some damages could potentially become serious if left unattended. Several buildings need special attention due to severe structural damage and they are found to be unsafe to live in such as Class F Family House, Deputy Commandant Residence (Training), and Deputy Commandant Residence (Administration & Garage).

As for problems in the drainage system, there are eight (8) buildings involved such as the male hostel for police children, Physical Intelligence Test Building, Sports Building, Central Weapons & Armament Workshop, Class F Family House, and Guard Hall. Among the problems identified were the accumulation of sand and soil, weed growth, clogged drain, accumulation of plants remains, and waste from maintenance works (Table 2). This situation makes the drainage system condition poor and unable to function properly.

Table 2. Problems Related to the Drainage System in Heritage Buildings in PULAPOL Kuala Lumpur

NO.	BUILDING CODE	BUILDING	DRAINAGE SYSTEM PROBLEMS				
			Sediments Accumulation	Weed Growth	Clogged Drain	Plant Remains	Maintenance Work Waste
1	JKR 2003	Police's Children Dormitory	/	/			
2	JKR 1875	Physical Intelligence Test Building (UKF)			/		
3	JKR 2076	Sports Building complex	/	/		/	
4	JKR 2005	Weapons and Weaponry Workshop				/	
5	JKR 1541-1544	Class F Family House	/	/			/
6	JKR 1877	Sports Building (Gymnasium)				/	
7	JKR 1879	Diner Building				/	
8	JKR 1786	Guard Hall				/	

(Source: Author, 2021)

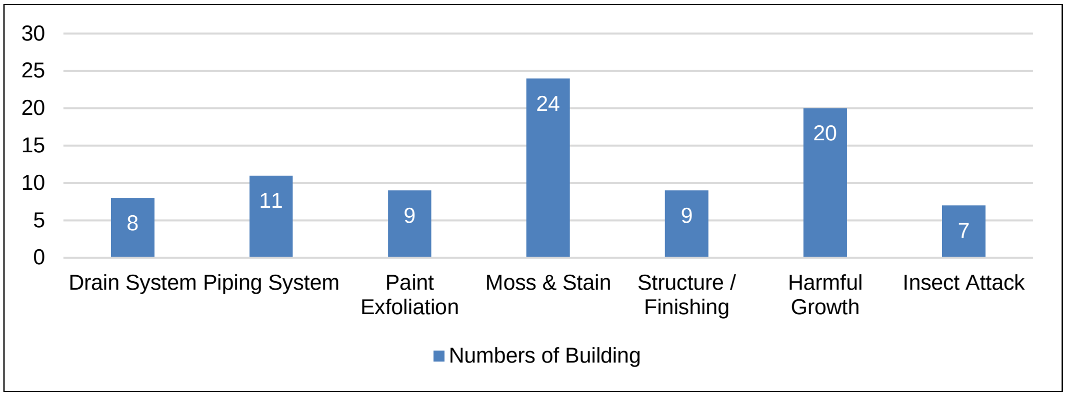

Figure 1. The Number of Heritage Buildings in PULAPOL Kuala Lumpur that are Categorized According to the Damages and Threats Faced

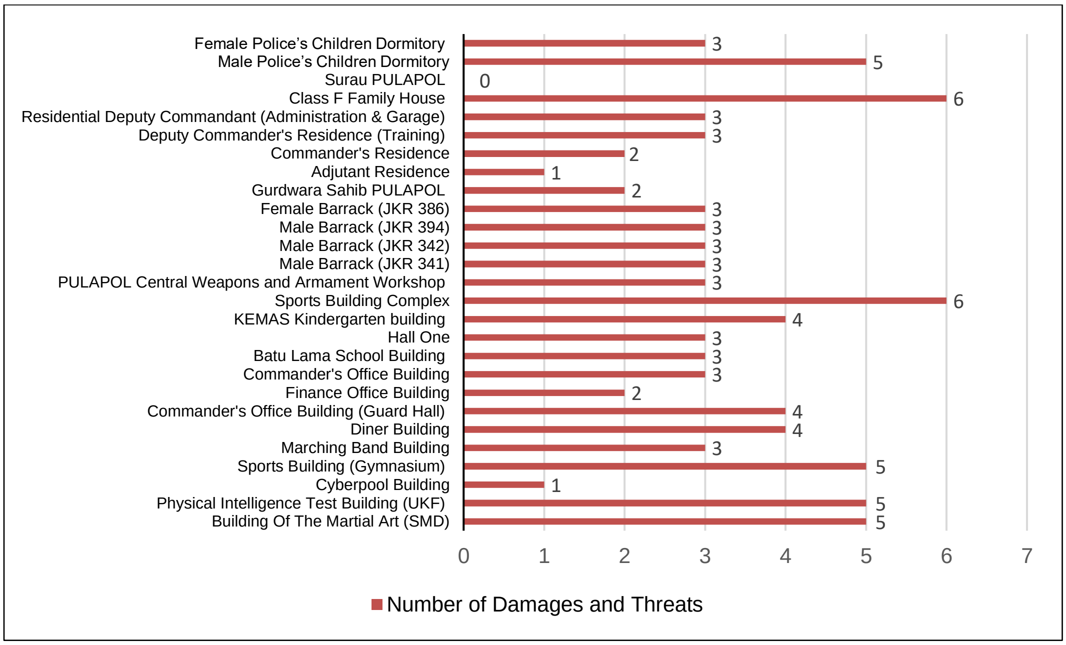

Figure 2. The Type of Heritage Buildings in PULAPOL Kuala Lumpur and the Number of Damages and Threats Encountered

a) Sediments and weed growth | b) Water stagnant in drainage system | c) Leaves in drainage system | d) Remaining of maintenance works

Figure 3. Types of Problems Related to Drainage in the Heritage Buildings of PULAPOL Kuala Lumpur

Leaking and piping system problems can be seen in ten (10) buildings such as the male hostel for police children, Financial Office, Commandant Office, Gurdwara Sahib, Martial Arts Office Building, Sports Building Complex, Sports Building (Gymnasium), Men's

Barracks and Guard Hall. The identified problems are vertical tunnel leakage from the gutter, sanitary tunnel leakage, damage to vertical drainage systems connecting gutter and drainage, and leakage of piping systems that supply clean water (Table 3). These problems cause buildings to have high humidity at all times (Zahari, 2020).

Table 3. Leaks and Piping Problems in the PULAPOL Kuala Lumpur Heritage Buildings

NO.	BUILDING CODE	BUILDING	LEAKAGE AND PIPING DRAINAGE PROBLEMS			
			Gutter damage	Vertical drainage leakage	Sanitary drainage leak	Water pipe leakage
1	JKR 2003	Male Hostel for Police Children		/		/
2	JKR 2004	Finance Office	/			
3	JKR 2019	Commandant's Office	/			
4	JKR 2078	Gurdwara Sahib		/		
5	JKR 1875	Physical Intelligence Test Building (UKF)			/	
6	JKR 2076	Sports Building complex	/	/		
7	JKR 1874	Martial Art Office Building				/
8	JKR 1877	Sports Building (Gymnasium)			/	
9	JKR 341, 342, 394 & 386	Male Barrack				/
10	JKR 1786	Guard Hall	/			

(Source: Author, 2021)

a) Vertical drainage leakage b) Gutter damage c) Leakage of sanitary channel d) Water pipe leakage

Figure 4. Types of Leakage and Piping Drainage Problems in the Heritage Buildings of PULAPOL Kuala Lumpur

Paint exfoliation is often associated with the presence of moisture. While most of the buildings at the academy use facing brick type of material, it was identified that some parts of the building have been plastered, and paint was employed on the walls. The involved section was observed to be frequently exposed to damage as these paints were typically applied at the bottom such as plinth parts, on wooden surfaces such as windows, walls, and poles. This problem can be seen in 10 buildings specifically on the plinth ,pillars, wooden structures such as fascia, door panels, windows, and ceilings (Table 4). Since the use of paint is not applied to the whole building, paint exfoliation is not very serious and thus not categorized as major damage. However, the exfoliating paint will make the buildings look less attractive and should be taken seriously to maintain the image of heritage buildings and academy institutions.

Table 4. List of Heritage Building Parts that Experience Paint Exfoliation, PULAPOL Kuala Lumpur

NO.	BUILDING CODE	BUILDING	PAINT EXFOLIATION PARTS						
			Plinth	Beam	Pillar	Rooftops	Door	Window	Fascia
1	JKR 1744-1755	Male Dormitory for Women Police children			/		/	/	/
2	JKR 1874	Martial Art Office Building (SMD)		/					
3	JKR 2019	Commandant's Office				/			
4	JKR 2006	Batu Lama School Building	/						
5	JKR 1896	KEMAS Kindergarten Building							/
6	JKR 2076	Sports Building Complex	/	/					
7	JKR 2003	Police Children's Male Dormitory	/						
8	JKR 1331	Adjutant Residence			/				
9	JKR 341, 342, 394 & 386	Male Barrack	/	/		/			
10	JKR 1333	Deputy Commandant Residence (Administration & Garage)					/	/	/

(Source: Author, 2021)

Table 5. Structures and Finishing Elements' Fractures on Heritage Buildings at PULAPOL Kuala Lumpur

NO.	BUILDING CODE	BUILDING	STRUCTURAL FRACTURES & DAMAGE OR FINISHING				
			Apron Fracture	Decaying of Finishing elements	Roof Damage	Wall Fracture	Pillar Fracture
1	JKR 1874	Martial Art Ofice Building (SMD)	/				
2	JKR 1875	Physical Intelligence Test Building (UKF)	/				
3	JKR 1877	Sports Building (Gymnasium)	/				
4	JKR 1878	Marching Band Building				/	/
5	JKR 1879	Diner Building	/				
6	JKR 2076	Sports Building Complex		/			
7	JKR 1896	KEMAS Kindergarten Building	/				
8	JKR 1541-1544	Class F Family House		/	/		
9	JKR 1744-1755	Women's Police Children's Dormitory		/	/		
10	JKR 341, 342, 394 & 386	Barrack Building for Single Male Police		/	/		
11	JKR 1333	Deputy Commandant Residence (Administration & Garage)		/	/	/	

(Source: Author, 2021)

The damage on the structures or finishing elements can also be observed at 11 buildings which are the Martial Art Office building, Physical Intelligence Exam Building, Sport Building (Gymnasium), Marching Band building, Canteen building, Sports Building Complex, KEMAS Kindergarten Building, Class F Family House, Dormitory for Women Police's Children, Barrack for Single Males and Deputy Commander Residence (Administration and Garage). The damages can be categorized into five categories (Table 5) which are fractures on the building apron, decaying on the finishing elements such as fascia, ceiling and others, structure damage on rooftops, and fractures on walls and columns. Fracture problem in the structures and finishing elements is not the main problem of the buildings because typically, most of the fracturing issue only occur on the building apron. Serious fracturing issues can be viewed in the marching band building in which the fractures occurr on the walls and columns.

a) Exfoliation of paint on beam; b) Exfoliation on plinth; c) Exfoliation on wooden structure such as window, door and column; d) Exfoliation on concrete column

Figure 5. Types of Paint Exfoliation Parts in the Heritage Building of PULAPOL Kuala Lumpur

a) Cracks on building apron; b) Damage on ceiling; c) Damage on roof structures; d) Vertical crack on toilet wall

Figure 6. Types of Structural Fractures and Damage of Finishing in the Heritage Building of PULAPOL Kuala Lumpur

For moss and stain formation, almost all buildings were found to have suffered these issue except the Commandant Camp Office (Guard Hall), Adjutant Residence and Surau PULAPOL. The most serious moss and stain formation is seen in the building of School Batu Lama, Male Police Children's Hostel, Single Men Barrack, Finance Office building, Deputy Commandant Residence (Administration & Garage) and Marching Brand building. Meanwhile, the buildings that are not mentioned here only suffer common moss and stain formation that can easily be managed through common maintenance work.

a) White stain on wall; b) White stain on toilet wall at Male Barrack; c) Moss and black stain; d) Black stain on flat roof

Figure 7. Types of Moss and Stain in the Heritage Building of PULAPOL Kuala Lumpur

Threats from hitchhiker plants can be seen occurring in almost all heritage buildings there. The hitchhiker plants are found to grow on facades, roofs, gutter drainage, and building slits. The hot and humid tropical climate allows this type of plant to grow easily and quickly (Jim, 1998, 2018; Jim & Chen, 2010; Wee, 1992). Out of the 27 buildings, there are eight (8) buildings that have not been attacked by hitchhiker plants which are Cyberpool Building, Batu

Lama School Building, Hall One, KEMAS Kindergarten Building, Adjutant Residence, PULAPOL Surau, and Women Police Children's Dormitory. The buildings most affected by the hitchhiker plants are Deputy Commandant Residence (Administration & Garage), Single Men Barrack, Martial Arts Office (SMD) Building, Physics Intelligence Test building (UKF), and the Marching Band Building. The type of hitchhiker plants identified are Ficus sp, Pyrrosa longifolia, Cleome rutidosperma, Davallia dentivulata, and Bulbophyllum sp. The existence of these hitchhiker plants especially from the type of Ficus. sp affects the structure of the building because of its root system that penetrates the walls, difficult to remove, and difficult to eliminate (Zahari, 2020).

a) *Pyrrosa longifolia* grows at sanitary channel | b) *Cleome rutidosperma* grows at window | c) *Ficus religiosa* grows on roof | d) *Davallia dentivulata* grows in gutter channel

Figure 8. Types of Hitchhiker Plants in the Heritage Building of PULAPOL Kuala Lumpur

Insect and pest attack was found in only seven (7) buildings. The existence of these termites can be observed on the roof of the Class F Family House based on the decaying activity and the effects of the pest's nest that already dominate the inside of the roof structure. Other buildings that were also attacked by the termites are the Deputy Commandant Residence (Training), Deputy Commandant Residence (Administration & Garage), Hall One, Batu Lama School Building, and Sports Buiding Complex (Zahari, 2020). Meanwhile, the honeybees were also observed to dominate the floor part sheltered by the ceiling structure in KEMAS Kindergarten Building. The presence of these honeybees will not cause damage to the building but it can threaten the safety of children at KEMAS Kindergarten. The presence of these two insects indicates the high humidity of the building.

a) Termites attack at Class F Family House | b) Honeybee at KEMAS Kindergarten building

Figure 9. Types of Insect and Pest Attack in the Heritage Building of PULAPOL Kuala Lumpur

Causes of Damage

In general, the Men Barrack Building and the Deputy Commander residence (Administration & Garage) are the buildings that experience the worst damage. The study found that the main factor of this damage is high level of moisture. The moisture issue normally will affect and bring further problems such as attracting the hitchhiker plants, pests such as termites, paint exfoliation, damage on the structures and finishing elements, and the formation of moss and rust. The moisture part of the buildings is found mostly on the wall section of toilets and bathrooms of Men’s barracks. The moisture on the wall is caused by the leaking of the piping system besides active use of the area for activities such as shower and laundry making the walls condition to have constant high humidity. Moisture is also caused by the hot and humid weather throughout the year plus the dim environment due to surrounding plants. This situation can be noticed through the presence of black stain and moss on the plinths, columns, and the lower structures of the buildings. Moisture also attracts some insects such as termites to build their colony. Such insects require a damp environment with high food sources such as dry leaves, mulching crops, and plants with high cellulose content.

The fracture on the building apron, wall, and column at the toilet of the Marching Band Building (JKR 1878) is caused by the slumping of the basic building structures resulted from the unstable soil, soil structural weakness, and the land shift due to drainage and system and piping leakage causing water to continue flowing in the soil nearby the buildings that weakened the soil structure over time (Zahari, 2020). The fracture identified occurred on the load-bearing wall and column need to be given more attention because both are the main structures of the buildings. The wall and column fractures occurred mostly because of the leaking in the pipes, sanitary funnel, or the water presence that weakened the soil structure for a long time. The hole or leakage on the bathroom or toilet floor can also be the factor that allows the water to flow directly towards the soil then into the building foundations, structures or parts. The fracture on the building apron is seen as a less serious issue because usually, almost all buildings experience apron fracture whether the building is new or old. However, this small fracture on the building apron should be taken into account because small fracture might be a signal for serious structural damage that can’t be detected. Besides, the building fractures often become a spot for hitchhiker plants to grow. However, further investigation needs to be done to determine the exact cause of the crack.

The PULAPOL area houses mature wooden trees where most of them drop the leaves and have branches and twigs that are easily broken. Therefore, maintenance work needs to be done more often and more efficiently to ensure that the area does not become the habitat for insects and pests. Planting activity with no systematic plan as well as no knowledge of each plant’s functions and characteristics could contribute to the building's damage. The presence of various plants could lead to high humidity conditions in the environment, a messy area with dry leaves, and structural damage to the building. This situation will attract insects such as termites to build their colony through the wall cracks in the building.

RECOMMENDATIONS

Overall, almost all heritage buildings at PULAPOL Kuala Lumpur are experiencing damages. Men Barracks and Deputy Commander Residence (Administration & Garage) are the buildings that have the worst damages that can be observed through the damage at rooftops, decaying activities, moisture issues, the formation of moss and rust, and attack from hitchhiker plants. The periodic inspection also needs to be carried out to monitor the condition of the buildings as well as to detect the presence of any new damage (Zuraidi et al., 2020). This is to prevent any existing damage from becoming more serious. The inspection needs to be carried out on the piping system, sanitary funnel, gutter, drainage system, roof structure, walls, and pillars.

Besides, the detection or inspection of the termite colonies invasion needs to be done because several buildings have been threatened by them. In this case, there are two things that need to be focused on. The first one is eliminating the whole termite colonies on the buildings and their surrounding environments. This task needs to be carried out by a professional individual, an expert in handling the pests. Secondly, the termite elimination must be carried out by identifying the moisture problem and their food source surrounding the buildings. This task can be done by organizing a rearrangement of the landscape in that area through a proper maintenance and correct plant selection. The efficient practice of landscape maintenance should be carried out to ensure that dry leaves and mulching crops which act as the food sources for the termites are not accumulated and present in the area. Therefore, individuals with officer positions who have expertise and knowledge in landscape design, and environment maintenance and management should be assigned to PULAPOL because the existing management unit has been run by individuals from the police department. Landscape management requires individuals who are recognized as architects or engineers because such a task cannot be carried out by the gardener.

Minor damages such as less serious paint exfoliation, small fracture on the building apron, and weed growth in the drains due to the sedimentation process need to be focused on because such damages have the potential to become more severe from time to time. For example, small fractures invite hitchhiker plants and weeds to grow and if not discarded, they might cause severe fractures due to the root growth in the building structures. The roots that are growing larger will push the brick walls and then further creating gaps within the structures and eventually weakened the building structures. On the other hand, paint exfoliation on the walls indicates the presence of water due to the rain splashing or leakage in the piping system. A periodic inspection needs to be carried out to prevent a recurring problem. Weed growth due to the sedimentation process in the drains indicates the presence of nutrients and moisture. Moisture is the main enemy to buildings because from that, other problems could exist such as the salt invasion to the building structures, fungi and moss formation that are not only harmful to human health but also encourage other serious problems.

CONCLUSION

The condition of the heritage buildings at PULAPOL Kuala Lumpur is worrying and needs urgent action because the damages to some buildings and structures are identified as serious. Continuous damage to buildings will limit the space usage of the buildings and this limitation on space will consequently affect certain activities. The negligence on the buildings maintenance and management from responsible bodies will affect many parties negatively because this academy is an important heritage legacy in Malaysia's historical record. Although these buildings are in a fenced area under PULAPOL Management, making it a non-tourism spot, it doesn’t mean that the maintenance and preservation works are not significant. Thus, attention and action need to be taken because of its status as a heritage site as recognized by National Heritage Act 2005 (Files 645). This worn-out-looking and damaged buildings are seen to give a negative impact on the identity and image of Malaysia's first police academy where its fame and strength are seen to be slightly lost. Because of this, not many people are aware that PULAPOL Kuala Lumpur is one of the most important locations in Malaysian historical records.

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FACTORS AFFECTING CONSTRUCTION DELAYS OF FOUNDATION WORKS IN KLANG VALLEY, MALAYSIA

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Abstract
Delays in project completions have been challenging and continuing issue for construction industry in Malaysia. Current data shows that 17.3% of construction projects are suffered from delays. There have been very few studies and thus literatures that focus on the early stage of the work which is the foundation works. Furthermore, there has also been no study conducted to identify the causes of delays in foundation works in Klang Valley, Malaysia. The objective of this research is to identify and examine the factors that cause the delays in foundation works using a quantitative approach and method. From the study of related literatures, geotechnical information, foundation design, plant and equipment, project progress payment and supply of materials are identified to be the possible factors that cause the delays in foundation works. Survey questionnaires are delivered to developers, architects, engineers, quantity surveyors and contractors randomly selected respondents who are in the construction companies in Klang Valley, Malaysia, to obtain 289 data for the statistical tests and analysis such as correlation and regression tests and analysis. The results show that all of the five independent variables are found to be significantly and positively affect the delays in foundation works which is the dependent variable. In addition, when a multiple regression test and analysis were carried out, the results show an interesting finding that only two out of five independent variables namely geotechnical information and plant and equipment are significantly and positively affecting the dependent variable. The findings of the research will help to reduce the project constructions losses due to the delays in foundation works and the legal issues arising from the problem. The industry players will be more informed about the causes of delays in foundation works.

Keywords: *Delays in foundation works; geotechnical information; plant and equipment.*

INTRODUCTION

In 2018, construction sector had contributed USD 16 billion, about 4.5% to the Gross Domestic Product (GDP) of Malaysia (Ng, Tobi, & Fathi, 2018). Nevertheless, there are always challenges in this industry, with no more than projects delays. In Malaysia, construction industry has a relatively poor reputation in coping the delays. According to Ali, Smith, Pitt and Choon (2007), 17.3% of construction projects had suffered from delay of more than three months and some of them were forced to abandon. Delays are postponement of works completion or non-completion of works from original duration in the contract caused by the project participants, namely developer, architect, engineer, quantity surveyor, and contractor.

As a result of delays in construction, there will be additional time and cost implications to the project, resulting increase in cost due to inflation, termination of contract, contract dispute, additional effort for negotiation, litigation, lawsuit, and abandonment (Venkatesh & Venkatesan, 2017). Furthermore, intangible asset such as reputation of the project suffering from delayed will be tarnished, and the loss of confident from the public.

The foundation works involve specialization in geotechnical engineering field, such as piling system, pile cap, and basement construction. On top of that, there are unforeseen risks underneath the groundwork, since the information of underground condition is always ambiguity. For the ground condition in Klang Valley, the biggest challenges being faced by the foundation contractor is the limestone formation, where the presence of cavities within the limestone may cause underground collapse and sinkholes, which will be hazardous to the site working team (Koo, 2013). Therefore, the factors affecting construction delays in foundation works are to be evaluated separately from the general construction delays.

Nevertheless, there has been few studies conducted to identify the causes of delays in construction works in Klang Valley. Despite these researches on the construction delays, there is no study that focused on the delays in foundation works. The lack of these findings basically inspires the researcher to undertake this study. Therefore, this research aims to establish that the delays for foundation works are a concern in the construction. The specific objectives are to identify the factors contributing to the delays of foundation works and the relationship between the factors. Arising from the objectives, the research questions were derived as 1) What is the extent of the foundation delays problem in Klang Valley? 2) What is the duration of these delays? 3) What are the factors contributing to the foundation delays problem?

This research specifically investigates the causes of delays of the foundation works in Klang Valley, which will be added as new knowledge to the previous research generally on the construction delays. The findings from the study also can serve as a reference for researchers in this field. The findings of the research will help to reduce the slowing down of the construction activities in the industry. The industry players will be more informed about the causes of delays in foundation works. To the larger picture, the construction industry will offer higher contribution the national GDP.

LITERATURE REVIEW

Construction delays are scenario where actual completion duration of a project exceeds the scheduled completion date, or any failure to complete a specific construction activity within the time planned for it (Ness, 2010). The root causes of delays are related to project participants, from project owners, architects, consulting engineers, quantity surveyors, and contractors (Alaghbari, Kadir, Salim, & Ernawati, 2007). Under the construction delays, there are non-excusable delays and excusable delays. Excusable delays are also known as force majeure delays, where the delays are caused by uncontrolled factors, such as Act of God, shortage of materials in national wide, etc.; Non-excusable delays are man-made delays through the improper planning and management by the project participants. Ahmed (2003) cited that the causes of delays were related to developer or its agent’s responsibility and contractor’s responsibility. Under the latter case, contractor would be granted neither time nor cost compensation.

Afshari, Khosravi, Ghorbanali, Borzabadi and Valipour (2010) summarizes the main causes of non-excusable delays are poor management of the project valuations, or changes made in the midst of construction. Direct and indirect costs are increased following from the changes (Afshari et al., 2010). They concluded that executing the scope of work with well-managed time performance is the key characteristic of the projects. On top of that, improper managing of sub-contractor, inadequate experience from the contractor, poor site management, equipment availability and failure, and mistakes during works execution by contractor are the causes of the delays (Sambasivan & Yau, 2007). Causes of construction delays in developing countries, especially in Thailand can be categorized in three areas, which are problems caused by inadequate in industry infrastructure, problem caused by clients and consultants, and problems caused by incompetency of contractor who executes the works (Ogunlana & Promkuntong, 1996). However, in Baghdad City, Jahanger (2013) concluded that mistakes and discrepancies in design documents, such as construction drawings are the main causes of the project delays, followed by ineffective planning and scheduling of the projects. In Malaysia, Hamzah and Khoiry (2011) summarizes that technical factors, resources factors, and project planning perspectives are significantly causing the delays in the construction industry. The study is unbiased to any project participants since they grouped the factors into issues related.

From the outlook of developers, Mydin, Sani, Taib and Alias (2014) have identified weather condition, bad site condition, poor project management by the contractor, incomplete documents and construction drawings for execution are the main culprits of the construction delays. From their findings, causes of delays are mainly from the main contractors (Mydin et. al., 2014). However, the statement is differed by Hamid, Botiti and Mohandes (2015), they further argues that non-continuous payment from the project owner is one of the main causes of hindering the progress of works at site (Hamid et al., 2015). In view of the seriousness of the monetary issue, the government of Malaysia enacted the Construction Industry Payment and Adjudication Acts (CIPAA) in 2014. The act serves to resolve the non-payment cases through adjudication. On top of that, the non-payment issues are supported by Hasmori et al. (2018), where financial difficulties are recognized as the most significant factor that causes delay. Without prompt payment from the owner, cash flow of the contractors is greatly affected and consequently supply and delivery of resources are expected to be delayed (Hasmori et al., 2018).

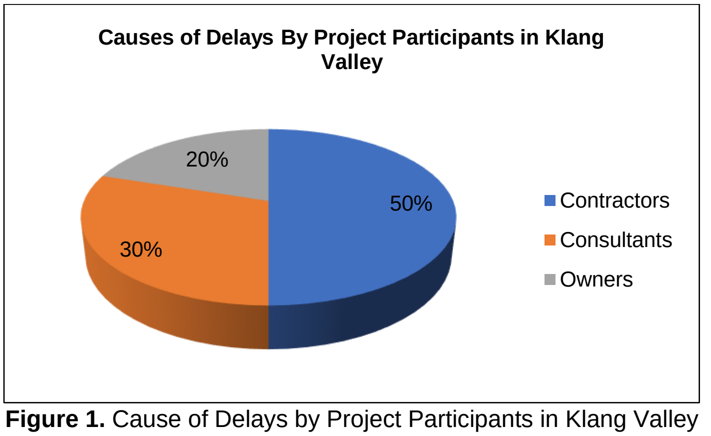

Figure 1. Cause of Delays by Project Participants in Klang Valley

Kumaraswamy and Chan (1996) indicate that high degree of divergence in perception of construction delays between project owners and contractors in Hong Kong. From the owners and their agents (consultants), the delays are mainly due to poor site management and supervision, and inadequate contractor experience, which are bias towards contractor. On the other hand, contractors are always accusing on client-initiated changes during construction, unforeseen underground condition, and unrealistic contract durations imposed by clients are the main culprits of the delays (Kumaraswamy & Chan, 1996). As a conclusion, Hasmori et al. (2018) summarizes that 50% of the construction delays in Klang Valley are caused by contractors, followed by owner's agent (30%) and owners themselves (20%).

Foundation Works

In engineering construction work, a foundation is an element of structure which contacts to the ground, and the function is to transfer the loads from top to the firm ground (Zumrawi, 2014). The scope of foundation is within sub-structure works, which comprise of piling system, pile cap, earthwork excavation, basement construction and earth retaining structures (Das, 2007). Previous study was focused on the overall construction delays and its recommended mitigation measures. Due to the works involve specialist foundation contractor, and pose unforeseen risk underground, the delays in foundation works shall be assessed separately from other construction works (Zumrawi, 2014).

Factors Affecting Construction Delays in Foundation Works

Geotechnical information is obtained from geotechnical investigation (Nazir, 2014). The required information is primarily the physical properties of foundations for proposed structures (Zumrawi, 2014). Additionally, a geotechnical investigation will include surface exploration and subsurface exploration. According to Koo (2013), geotechnical investigation is essential to determine the soil and rock profile in the foundation engineering works. The quantum of geotechnical investigation will increase the accuracy of the design conducted by the engineer for foundation for the building (Koo, 2013). Without sufficient information, foundation contractors are exposed to the unforeseen risk underneath the ground, such as sinkholes, soil collapse, and equipment failure (Zumrawi, 2014). In United Kingdom, since most of the foundation contractor is sub-contracted from the main contractor, sufficient soil information should be given to them during tender stage, and the scope and liability of the sub-contractor should be demarcated and spelled out clearly in the tender documents (Greenwood, Hogg, & Stanley, 2005).

Construction plant and equipment are mainly mechanically or pneumatically operated machines to replace human force which can accelerate the working rates (Das, 2007). Foundation works involve extensive use of machineries, such as drilling rigs, crawler cranes, excavators, dump trucks, and backhoe (Zumrawi, 2014). Therefore, the effectiveness of machineries has direct relation to the progress of foundation works. Sambasivan and Yau (2007) conclude that the effective use of machineries is the best practice for foundation works. They suggest that the machines shall be properly maintained to uphold the optimum performance of the machines. Assaf and Al-Hejji (2005) draws conclusion on the causes of delays for construction in Saudi Arabia primarily contributed by variation order, and plant and equipment problems, either failure or shortage during initial stage of the projects. They recommended that contractor should always keep the plants and machineries in working condition and conducts scheduled maintenance regularly (Assaf & Al-Hejji, 2005).

Foundation design is the creation of a construction plan for a building foundation. It is a highly specialized function and usually performed by a structural engineer (Das, 2007). Alaghbari et al. (2007) relates the design of building works with delays in construction. It is highlighted that the owner's changes in design, and owner's disruption and/or change in the sequence of the work has direct impact on the progress of works. Assaf and Al-Hejji (2005) conduct a time performance survey of different types of construction projects in Saudi Arabia to determine the causes of delays and their importance according to each project participant (owner, consultant, and contractor). They have identified seventy-three (73) causes of delays during the research. The most common cause of delays identified by all three parties is “change order” in the design. In the United States of America, Ness (2010) cited in his legal experiences that design responsibilities carry weight on the initial construction delay. The design failure of piled foundation, either by the engineers or the contractors in a design and build contract, are leading to the delays of works.

In construction, a progress payment is a partial payment that covers the amount of work that has been completed up to the point of invoicing. There are several ways to structure these payments. The most common way of billing for progress payments is billing by stage and invoicing by percentage of completion (Aibinu, 2009). Hamid et al. (2015) concludes that financial related factors such as late progress payment, or non-continuous payment from the project owners to the contractors as the most significant factors contribute to the delay. On top of that, the non-payment issues are supported by Hasmori et al. (2018), where financial difficulties are recognized as the most significant factor that causes delays. Without prompt payment from the owner and late certification of payment from the architects, cash flow of the contractors is greatly affected and consequently supply and delivery of resources were expected to be delayed (Hasmori et al., 2018).

In foundation works, shortage and delays in materials supply are argued to be one of the most important factors that lead to delays in construction project globally (Hamzah & Khoiry, 2011). However, the relevant underlying reasons vary from country to country (Rahman, Yap, Ramli, Dullah, & Shamsuddin, 2017). Rahman et al. (2017) identifies lack of locally available construction materials is the core of shortage of materials which affect the delivery. On the other hand, inability to timely procures and maintains a suitable inventory system seems to be the most important cause of delays in materials supply. This is primarily due to the late identification of materials to be required by the contractors, which is originated from change orders and very late changes in decisions (Frank and Adwoa, 2010). Sweis, Hammad and Shboul (2007) added that shortage of materials, delays in materials delivery and materials price fluctuation causes the delays of construction works in Jordan, while Frank and Adwoa (2010) agrees that late delivery of materials is the major factors of delays for construction works in Ghana. In Klang Valley, especially Kuala Lumpur, traffic congestion is the cause of delays for materials delivery, especially ready-mix concrete (Ali et al., 2007). Therefore, on top of proper planning on materials delivery, alternative materials suppliers should be prepared to mitigate construction delays (Ali et al., 2007).

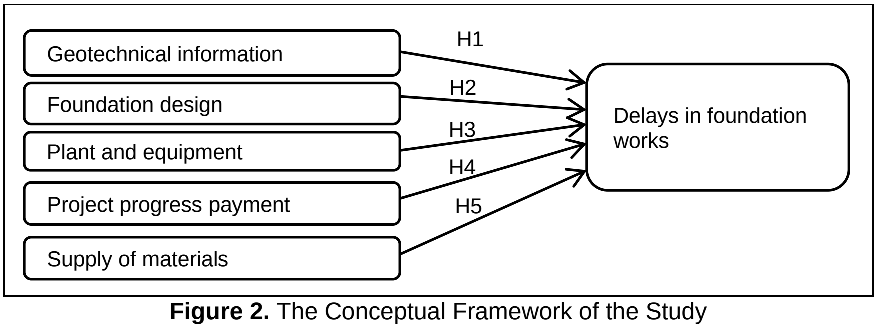

Figure 2. The Conceptual Framework of the Study

Five hypotheses were developed based on the relationship between the delays and the factors affecting construction delays in foundation works. Therefore, the conceptual framework of the study is as shown in Figure 2.

RESEARCH METHODOLOGY

In this study, a quantitative research method using data obtained from questionnaire survey was adopted to test the research hypotheses (Aibinu, 2009; Rahman et al., 2017; Assaf and Al-Hejji, 2006). Questionnaires were developed in order to evaluate the frequency of occurrence of the identified causes of the delays in foundation works. The information of the project participants (developers, consultants and contractors) in Klang Valley were collected from the Construction Industry Development Board (CIDB), Malaysia. By taking in view of owners, consultants and contractors, Likert Scale was adopted, which measure the extent of participants agree or disagree with a given statement, and typically range from 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree) and 5 (strongly agree). Therefore, they were measured under interval scale (Wood & Ashton, 2007) (Banobi & Jung, 2019). Subsequently, the collected data was analysed using Average Index (Hamid et al., 2015). The complete set of questionnaires had been reviewed by the industrial experts and academicians related to the study.

In statistics, the standard deviation is a measurement of the amount of the variation of a set of values. Sekaran and Bougie (2016) highlighted it is commonly used in measuring of dispersion. At the significance of 0.05 (or confidence level of 95%), the correlations in the sampling are generally accepted in the research. Based on the directory year 2019 from the Construction Industry Development Board (CIDB) of Malaysia, there are 895 construction companies established in Klang Valley (Kuala Lumpur and Selangor states). For this research, samples were collected from the research population which consists of 895 construction companies. The sampling method adopted in this study is probability sampling (or random sampling), which is supported by the studies from Assaf and Al-Hejji (2005), Doloi (2013), Alaghbari et al. (2007) and Hasmori et al. (2018). With the confidence level of 95%, the sample size is 270 (n = 270). From the 895 of the construction companies, 500 of them were randomly selected. Questionnaires were delivered to the respondents via electronic mail and WHATSAPPS phone apps. The data was analysed using Average Index or mean score (Hamid et al., 2015). The Average Index is computed as:

$$\text{Average Index} = \frac{\sum a_i x_i}{\sum N} \tag{1}$$

Testing of Hypothesis

The purpose of hypothesis testing is to confirm whether the null hypothesis can be rejected in favour of the alternate hypothesis. The significance level of the hypothesis is set at 5%. There are two types of errors. If the null hypothesis is rejected, then a Type I error is made (Weiers, 2011). On the other hand, Type II error is the probability of failing to reject the null hypothesis when it is actually true (Weiers, 2011). Correlation of independent variables with dependent variable is tested using Pearson's correlation. Five coefficients of correlation were tested using Pearson's product-moment correlation and the significance levels of all correlation coefficients are set at 0.05 (2-tailed).

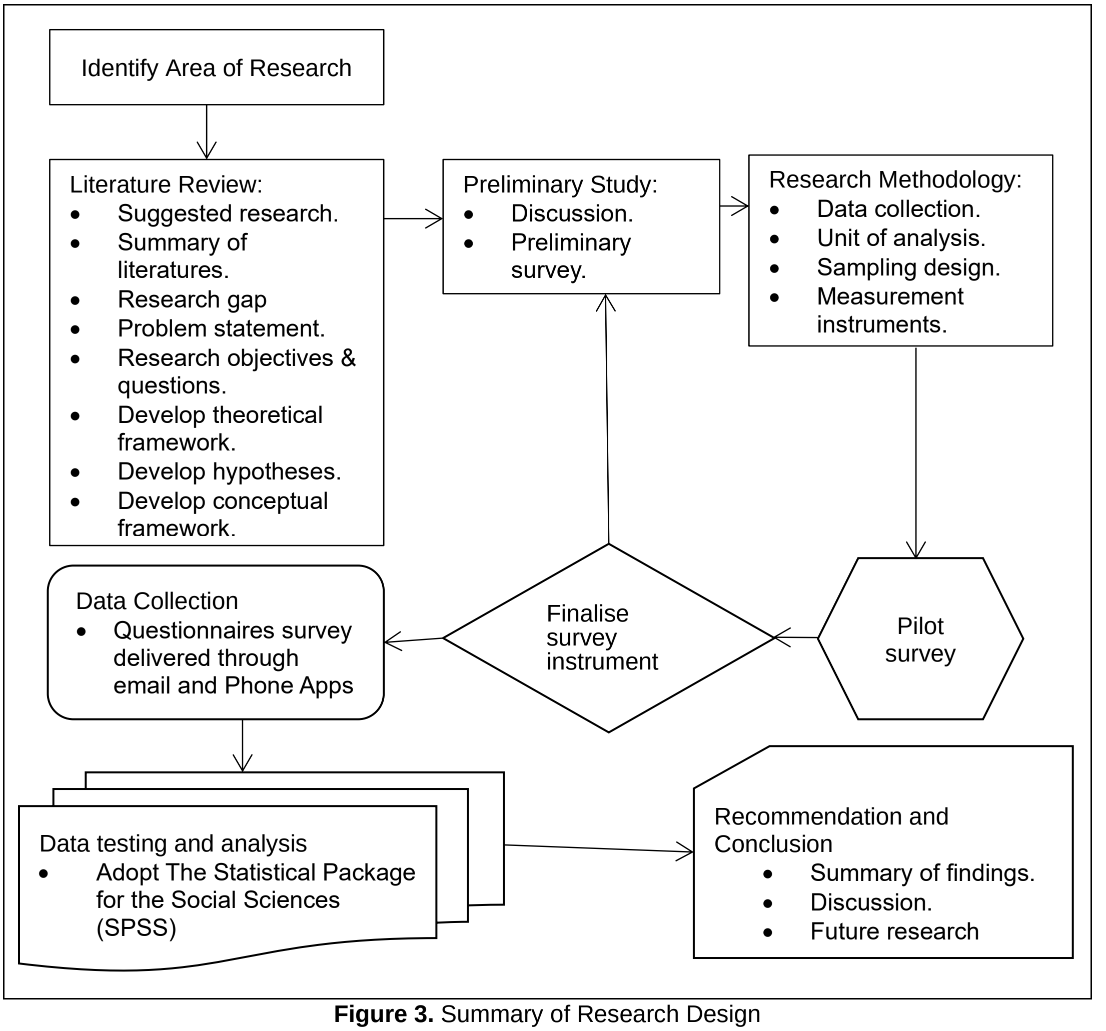

Figure 3. Summary of Research Design

RESEARCH RESULTS AND FINDINGS

After data cleaning was performed on the data, there are only 289 usable data from the survey responses. It can be concluded that only 58% of the respondents answered the questionnaires. Table 1 shows a summary of the descriptive analysis.

Average Index for the Main Survey

In this study, the classification of rating scale is 1.0 < Average Index < 1.5 (Strongly Disagree), 1.51 < Average Index < 2.50 (Disagree), 2.51 < Average Index < 3.50 (Neutral), 3.51 < Average Index < 4.50 (Agree), and 4.51 < Average Index < 5.0 (Strongly Agree). The Average Index for each variable is presented in Table 2.

Table 1. The Demographic Profile of the Respondents

Variable	Category	Frequency, N	Percentage, %
Gender	Female	80	27.7
	Male	209	72.3
	Total	289	100.0
Age	21-30 years	31	10.7
	31-40 years	63	21.8
	41-50 years	125	43.3
	51-60 years	70	24.2
	Total	289	100.0
Nationality	Malaysian	288	99.7
	Non-Malaysian	1	0.3
	Total	289	100.0
Ethnic Group	Malay	50	17.4
	Chinese	203	70.2
	India	33	11.4
	Others	3	1.0
	Total	289	100.0
Education Background	Bachelor’s Degree	144	49.8
	Professional Diploma	17	5.9
	Master’s Degree	108	37.4
	Ph. D	20	6.9
	Total	289	100.0
Profession	Developer	59	20.4
	Architect	40	13.8
	Engineer	79	27.3
	Quantity Surveyor	46	15.9
	Contractor	56	19.4
	Others	9	3.1
	Total	289	100.0
Working Experiences	Less than 5 years	18	6.2
	5-10 years	49	17.0
	11-15 years	83	28.7
	15 years above	139	48.1
	Total	289	100.0

Table 2. Average Index for Each Variable

Variable	Average Index	Rating Scale
Geotechnical Information	3.85	Agree
Foundation Design	3.27	Neutral
Plant and Equipment	3.78	Agree
Project Progress Payment	3.48	Neutral
Supply of Materials	3.21	Neutral

From the table above, the geotechnical information, plant and equipment and project progress payment are the variables that rated as "agree" in Average Index, whereas the foundation design and supply of material are the variables that rated as "neutral".

Validity Tests (Kaiser-Meyer-Oikin and Bartlett's Tests)

The five independent variables, with 6 questions for each variable were subjected to Confirmatory Factor Analysis (CFA) using SPSS software. In this analysis, the result of analysis shows the coefficient for Kaiser-Meyer-Oikin (KMO) of 0.911, which has exceeded the acceptance value of 0.50. Furthermore, the result of the Bartlett's Test of Sphericity shows achieves statistical significance, with the level of confidence more than 95%. The results are presented in Table 3.

Table 3. The KMO Test and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.911
Bartlett's Test of Sphericity	Approx. Chi-Square	7129.670
	df	435
	Sig.	0.000

Reliability Test

The reliability test is a method for checking and confirming internal consistency of the questionnaires. Under the approach, Cronbach's Alpha coefficient is used as an indicator to check the degree of consistency. In this study, the researcher has targeted 0.7 as a minimum requirement for the coefficient. From the result of analysis from SPSS, it can be concluded that all of the constructs in this study are consistent and reliable. Table 4 shows the summary of the reliability test for each variable.

Table 4. Summary of the Cronbach's Alpha of Each Scale

Independent Variables	Cronbach's Alpha Value
Geotechnical Information	0.908
Foundation Design	0.919
Plant and Equipment	0.938
Project Progress Payment	0.937
Supply of Materials	0.889

Correlation Analysis

Pearson's correlation coefficient is the statistical test method that measures the relationship between two variables under the quantitative analysis. Subsequently, the strength of the relationship is determined.

From the correlation analysis in Table 5, there is a medium strength of relationship between the geotechnical information and the plant and equipment with the delays in foundation engineering works, with a positive correlation of 0.417 and 0.305 respectively. Other independent variables, which are foundation design, project progress payment and supply of materials, are having weak strength of relationship with the delays, with the recorded Pearson's r value of 0.213, 0.279 and 0.200 respectively.

Table 5. Pearson's Correlation

		Delay	GI	FD	PE	PP	SM
Pearson Correlation	Delay	1.000					
	GI	0.417	1.000				
	FD	0.213	0.386	1.000			
	PM	0.305	0.402	0.303	1.000		
	PP	0.279	0.529	0.493	0.342	1.000	
	SM	0.200	0.299	0.508	0.445	0.228	1.000
Sig. (2-tailed)	Delay						
	GI	0.000					
	FD	0.000	0.000				
	PM	0.001	0.000	0.000			
	PP	0.000	0.000	0.000	0.000		
	SM	0.000	0.000	0.000	0.000	0.000	

Based on the Pearson's correlation, hypothesis made in the previous chapter are explained in the following:

H1: There is a significant relationship between geotechnical information and delays in foundation engineering works.

From the correlation analysis, there is a medium strength of relationship between the geotechnical information and the delays in foundation engineering works, with a positive correlation ($r=0.417$, $p< 0.05$). Therefore, H1 is supported.

H2: There is a significant relationship between foundation design and delays in foundation engineering works.

From the correlation analysis, there is a weak strength of relationship between the foundation design and the delays in foundation engineering works, with a positive correlation ($r=0.213$, $p<0.05$). Therefore, H2 is supported.

H3: There is a significant relationship between plant and equipment and delays in foundation engineering works.

From the correlation analysis, there is a medium strength of relationship between the plant and equipment and the delays in foundation engineering works, with a positive correlation ($r=0.305$, $p<0.05$). Therefore, H3 is supported.

H4: There is a significant relationship between project progress payment and delays in foundation engineering works.

From the correlation analysis, there is a weak strength of relationship between the plant and equipment and the delays in foundation engineering works, with a positive correlation ($r=0.279$, $p<0.05$). Therefore, H4 is supported.

H5: There is a significant relationship between supply of materials and delays in foundation engineering works.

From the correlation analysis, there is a weak strength of relationship between the supply of materials and the delays in foundation engineering works, with a positive correlation ($r=0.200$, $p<0.05$). Therefore, H5 is supported.

As a conclusion, none of the hypothesis is rejected from the Pearson's correlation analysis.

Multiple Regression Analysis

Multiple regression is a method to explore complex relationship between one dependent variable and several independent variables. An equation that explains the relationship has been derived at the end of the analysis.

Table 6. Coefficients for Multiple Regression Analysis

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.581	0.360		4.387	0.000
	GI	0.315	0.094	0.254	3.671	0.000
	FD	0.067	0.081	0.060	0.826	0.409
	PE	0.128	0.087	0.101	2.045	0.037
	PP	0.019	0.082	0.017	0.232	0.817
	SM	0.078	0.084	0.059	1.168	0.244

In Table 6, the largest standardized coefficient beta value is 0.254, which is from the geotechnical information, followed by the plant and equipment, which has the beta coefficient of 0.101. This indicates that the geotechnical information has a higher contribution in explaining the delays in foundation engineering works compared to the plant and equipment. Both variables have a significance contribution to the prediction of the dependent variable, with the p-value less than 0.05. However, the foundation design, project progress payment and the supply of materials are not statistically significance, with p-value exceeds 0.05. Therefore, only those variables that have a significance value will be adopted into the equation. As a conclusion, the multiple regression equation is generated as follow:

$$\text{Delays} = 1.581 + 0.315\ \text{GI} + 0.128\ \text{PE} + \varepsilon \quad (2)$$

CONCLUSIONS

This section answers the research questions, which lead to the flow of discussion. Out of 289 respondents, 91.2% opined that the delays in foundation works are the concern for the overall progress of the entire project. Therefore, conclusion can be made that there are delays in construction of foundation works in Klang Valley.

All five independent variables, the geotechnical information, foundation design, plant and equipment, project progress payment and supply of materials are the factors that contributed to these delays. Based on the results, the geotechnical information and plant and equipment are the factors that mostly agreed by the respondents, with the mean of 3.85 and 3.78 respectively. They further agree that sufficient geotechnical investigations should be carried out for the projects to prevent any unforeseen condition which may lead to construction delays in foundation works. The project participants are also agreeable that plant and equipment should be well maintained to reduce the breakdown, which will prevent delays in the works. However, the results of multiple regression show that only two independent variables, namely the geotechnical information and the plant and equipment were proven statistically significance to the relationship.

This implied that if a geotechnical investigation is sufficient, the project participants, especially the contractor will be provided with more accurate of geotechnical information for their planning, execution and mitigating the risks arising from the unforeseen underground problem. The result is also concluding Zumrawi's finding (2014), where geotechnical investigations should be carried out sufficiently prior to commencement of the works. Hence, this factor can be considered as among the factors that cause the delays in the foundation works. Industry players, especially the project participants can use this factor for their implementation of the project.

Should the plant and equipment be well maintained, or in optimum condition, the foundation works can be executed smoothly and any delays due to breakdown can be reduced or prevented. The finding is concluding the conclusion made by Sambasivan and Yau (2007), where the effective use of machineries is the best practice for foundation engineering works. The respondents, who are the project participants, agree that the condition of plant and equipment are governing the speed of construction works. The project participants can adopt this factor as direction of mitigating delays prior to commencement of works, such as well maintaining the plant and equipment and preparing alternative machines in the event of breakdown. Furthermore, consideration of machine size and capacity shall be given priority in dealing with the works.

Contribution of the Study

This research has highlighted the factors affecting the construction delays of foundation works in Klang Valley. It has provided important insight to both academician and industry players, as well as the authority to understand better of the problems. The factors being discussed in the previous chapters can assist them to prevent the problem and mitigate the issue.

Recommendations

In the future study, it is recommended that the factors affecting construction delays in foundation works to be categorized on project participants, such as contractor related factor, consultant related factor, and developer related factor. The factor that involves project participant will cover more detailed on the scope and responsibility of the project participants that contributed to the delays.

Lastly, to make the research more interesting, it is recommended to include mitigation measures in the future study. Under this study, the factors affecting construction delays are informed. However, the factors should be related to the mitigation on how to prevent the delays. This recommendation will encourage the industry player to share their experience when dealing with delay, and provide the measures to prevent it from happening, which will be beneficial to the construction market.

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GUIDE TO AUTHORS

Aims and Scope:

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

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CODIFICATION AND APPLICATION OF SEMI-LOOF ELEMENTS FOR COMPLEX STRUCTURES

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Abstract (Arial Bold, 9pt)
Damage assessment …… ……(Arial, 9pt. Left and right indent 0.64 cm, it should be single paragraph of about 100 – 250 words.)

Keywords:(Arial Bold, 9pt) *Finite Element Analysis; Modal Analysis; Mode Shape; Natural Frequency; Plate Structure (Time New Roman, 9pt)*

HEADING 1 (Arial Bold + Upper Case, 11pt)

Heading 2 (Arial Bold + Lower Case, 11pt)

Heading 3 (Arial Italic + Lower Case, 11pt)

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

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

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

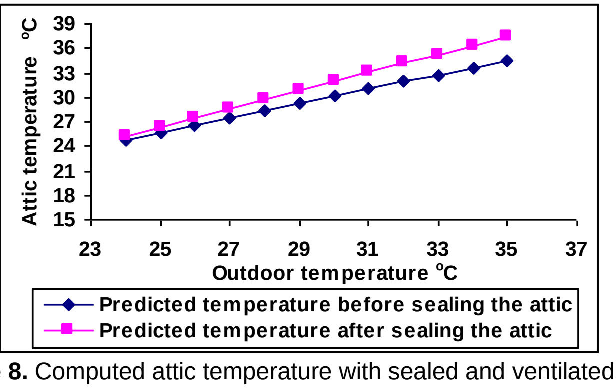

Figure 8. Computed attic temperature with sealed and ventilated attic

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

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

Table Line: 0.5pt.

Table 1. Recommended/Acceptable Physical water quality criteria

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

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

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

Citation:

Passage Type	First reference in text	Next reference in text	Bracket format, first reference in text	Bracket format, next reference marker in text
One author	Walker (2007)	(Walker, 2007)	(Walker, 2007)	(Walker, 2007)
Two authors	Walker and Allen (2004)	Walker and Allen (2004)	(Walker & Allen, 2004)	(Walker & Allen, 2004)
Three authors	Bradley, Ramirez, and Soo (1999)	Bradley et al. (1999)	(Bradley, Ramirez, & Soo, 1999)	(Bradley et al., 1999)
Four authors	Bradley, Ramirez, Soo, and Walsh (2006)	Bradley et al. (2006)	(Bradley, Ramirez, Soo, & Walsh, 2006)	(Bradley et al., 2006)
Five authors	Walker, Allen, Bradley, Ramirez, and Soo (2008)	Walker et al. (2008)	(Walker, Allen, Bradley, Ramirez, & Soo, 2008)	(Walker et al., 2008)
Six or more authors	Wasserstein et al (2005)	Wasserstein et al. (2005)	(Wasserstein et al., 2005)	(Wasserstein et al., 2005)
Organisation (easily identified by the initials) as the author	Sultan Idris Education University (UPSI, 2013)	UPSI (2013)	(Sultan Idris Education University [UPSI], 2013)	(UPSI, 2013)
Organisation (No abbreviation) as the author	Pittsburgh University (2005)	Pittsburgh University (2005)	(Pittsburgh University, 2005)	(Pittsburgh University, 2005)

(Source: UPSI, 2019)

Reference: Times New Roman, 11pt. Left indent 0.64 cm, first line left indent – 0.64 cm.

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.

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

Siti Hawa, H., Yong, C. B. and Wan Hamidon W. B. (2004) Butt Joint in Dry Board as Crack Arrester. Proceeding of 22nd Conference of ASEAN Federation of Engineering Organisation (CAFEO 22). Myanmar, 55-64.

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