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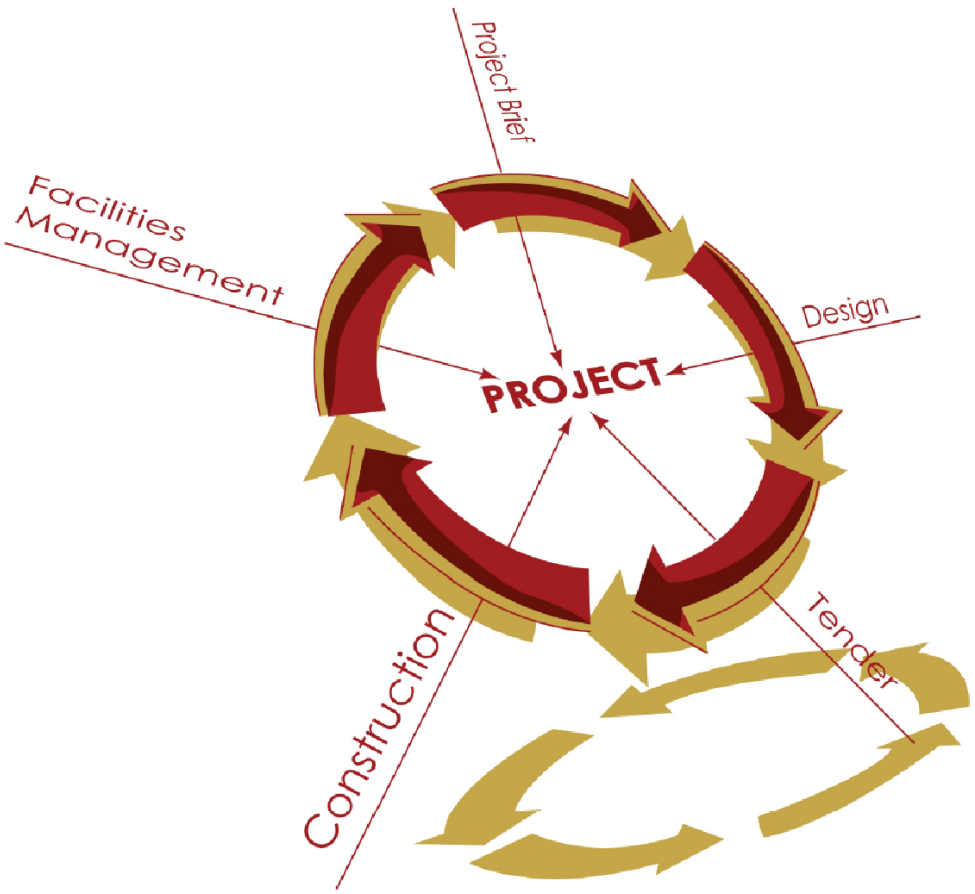
3RD VIRTUAL GO-GREEN: CONFERENCES AND PUBLICATION (V-GO GREEN 2020)



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CIDB MALAYSIA

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Introduction

Welcome to this special issue in Malaysian Construction Research Journal (MCRJ) for the 3rd Virtual Go-Green Conferences and Publication (v-Go Green 2020). This unprecedented virtual conference was organised by the Research, Industrial Linkage Community and Alumni Network Office (PJIM&A) and co-organisers Faculty of Architecture, Planning and Surveying (FSPU) & Centre for Post Graduate Studies (CGS), Universiti Teknologi MARA, Perak Branch, Seri Iskandar. The purpose of organizing this conference is to achieve the empowerment of research-based papers on Sustainable Development Goals (SDG), as well as promoting national level publications towards international level. It has also been the intention of this conference to encourage conferential research projects into producing high quality publications.

This virtual conference also has the envision of bridging knowledge and research aspects of green-oriented construction, built environment, design, architecture, ecology, environmental sustainability, and social parameters. The theme of the conference which is "*Sustainable Environment, Resilience and Social Well-Being*" is seen to coincide with the Malaysian government green initiatives towards achieving sustainable development in built environment and construction industry. Green initiatives are highlighted in the Construction Industry Transformation Program (CITP) 2016-2020 and extended in the National Constuction Policy (NCP) 2030. As Malaysia moves from developing country towards a developed nation, construction industry need to respond the changes in construction demand. Hence, the theme of this seminar creates awareness towards the goal of sustainable construction in reducing the industry's impact on the environment and inclusiveness on the economics, social and environment.

Sr Dr. Natasha Khalil
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Malaysia

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Editorial

Welcome from the Editors

Welcome to this special issue in Malaysian Construction Research Journal (MCRJ) for the 3rd Virtual Go-Green Conferences and Publication (v-Go Green 2020). We would like to express our sincere gratitude to our contributing authors, reviewers, organizers and readers.

This special issue in MCRJ for the 3rd v-Go Green 2020 contains twenty (20) interesting papers covering the theme of "Sustainable Environment, Resilience and Social Well-Being". *Sustainable environment* is known as the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout of building life cycle from design, construction, operation, maintenance, renovation and deconstruction. While *resilience and social well-being* represents the quality of life for people, such as health, comfort, resilient and safety livings of communities in the context of built environment. Hence, all the papers are highly relevant to the stated themes and addressed all protruding elements of sustainable environment, resilient and well-being in construction industry. It is hoped that the readers would greatly benefit from the scientific content and quality of papers published in this issue.

Brief introduction of each article is given as hereunder:

Azmi Che Leh et al., have identified the accident causations and implementation of Integrated Management System (IMS) in managing construction safety accidents that able to improve safety and health management processes, improve construction project performances and environmental sustainability.

Faris Hamizan Zulkhairi et al., have revealed the current implementation of Construction Industry Payment and Adjudication Act (CIPAA) in identifying the factors contributed to the payment problems, and determine the limitations of CIPAA in settling disputes of construction projects.

Muhammad Anas Othman et al., have analysed the building environmental issues by revitalize studies on the passive daylighting strategies involving Educational Studios (ES) in the constructed and occupied university buildings.

Noor Anis Afifa Shamsu Kamal Bahrin et al., have determined the analysis on the effects of orientation towards thermal comfort condition and occupant satisfaction in low-cost detached housing construction.

Raja Nurulhaiza Raja Nhari & Sitti Asmah Hassan have presented an initial conceptual matrix for the development of Road Safety Assessment Tool (RSAT) as a pre-basis guidance evaluation to the safety in road designs towards enhancing safety in road construction.

Izatul Farrita Mohd Kamar et al., have analysed the Personal Protective Equipment (PPE) costs that are most incurred by MRT project contractors in allowing reliable safety budget and systematic calculation specified in the contract document during the pre-contract stage and construction stage.

Mohammad Hassan Khairil Anuar et al., have determined the analysis of criteria and process needed in implementing green procurement (GP) for developing and constructing green projects, that initially helps to reduce the environmental issues in construction by considering green products and sustainable construction materials.

Wan Nur Syazwani Wan Mohammad et al., have determined the significant uses of Building Information Modelling (BIM) from the contractor's perspective which covers six (6) BIM uses during the construction phase. The findings show that the 3D coordination and the record model was remarked as the top significant uses in the construction phase.

Mohd Nazri Abdullah & Syed Abdul Haris Syed Mustapa have analysed the factors contributed to the variation order (VO) from ten (10) case studies of mosque construction projects in Perak, Malaysia. The study has revealed that variations are mostly inevitable despite leading to dispute among stakeholders, affecting labor's productivity and consume time and cost.

Noor Rizallinda Ishak et al., have examined the analysis on the initiatives and perspectives of construction waste management in Malaysia. Four (4) significant themes; technology, strategies, enforcement and procurement, were revealed as prominent factors for construction waste inititatives in Malaysian construction industry.

Nor Suzila Lop et al., determined factors that facilitate in improving the implementation of Key Performance Indicators (KPI) for assessing the operational performance of Public-Private Partnership (PPP) construction procurement method via qualitative interview approach.

Hazirah Azami et al., revealed a dimension of cross-cultural work adaptation elements among Malaysian construction professional expatriates that consist of socialisation, interactions, speaking and culture.

Siti Nur Aishah Mohd Noor et al., have investigated the effect of the physical properties of Rice Husk Ash (RHA) as a mineral admixture for cement in concrete and the effect of the addition of crushed ceramic tiles (CCT). The result from physical properties showed that 5 % is the optimum percentage for CCTs in concrete with 10% of RHA.

Thuraiya Mohd et al., proposed a tool in predicting the price of green buildings using machine learning model, as a reflective of property price accuracy for the developers and construction stakeholders to proceed with green projects.

Asniza Hamimi Abdul Tharim et al., have examined the association between thermal comfort and visitors' satisfaction in selected shopping complexes that emphasizes sustainability and well-being in occupied buildings.

Azirah Adnan et al., have evaluated the economic benefits of Rain Water Harvest System (RWHS) for toilet flushing uses in university buildings and analysed the most economical aspects in choosing the best solution of RWHS.

Muhammad Hafizzudin Mohamad Nasir et al., identified the barriers and key drivers in implementing Energy Efficiency (EE) in higher education buildings, with the aim to create more EE practices and reduce environmental degradations in construction industry.

Nurul Azreen Azmi et al., have analysed the significance of thermal comfort towards students' learning performance and presented cross-case studies in educational buildings within the South East Asia region.

Sitinur Kamilah Mohd Idris et al., highlighted the benefits of the application of biophilic design strategies towards occupants' perceived psychological performance in the occupied buildings.

Mohamad Haizam Mohamed Saraf et al., examined the relationship between biophilic home design experience and home-office settings towards academicians' perceived performances via partial least squares-structural equation modeling (PLS-SEM) software for hypothesis testing.

EXPLORING INTEGRATED MANAGEMENT SYSTEM (IMS) TOWARDS MINIMISING CONSTRUCTION ACCIDENTS

Azmi Che Leh[1,2], Asmalia Che Ahmad[2] and Syed Ahmad Qusoiri Syed Abdul Karim[2]
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Abstract
The current increment of accident and high fatality rate negatively reflects the nation's construction industry. This research aims to identify causes of construction accidents and the implementation of Integrated Management System (IMS) to minimise the construction accident. Systematic Literature Review was conducted to review past studies on accident causations and implementation of IMS in managing construction safety. Scopus and Web of Science were referred to as the source database. 35 journals articles were reviewed and it was found that human factors and originating influences were the causes of the accident at the construction site. 10 journals papers discussed on implementation of IMS which can improves safety and health management processes, avoid the duplication of procedures, reduce conflict of procedures, improved organisational effectiveness and efficiency, improve project performances and environmental sustainability. Therefore, it is suggested that construction companies to implement the IMS in managing workers' factors and originating influences to improve construction safety management.

Keywords: *Accident causation; Integrated Management System (IMS); construction safety.*

INTRODUCTION

The construction sector is an unsafe and hazardous workplace compared to other sectors. The high accident rates at construction sites typically involve injuries, fatalities, work-related illnesses as well as other direct and indirect losses (Fang & Wu, 2013; Sherratt et al., 2013). Chi, Han, and Kim (2013) revealed that the construction site and it's nature of work are major contributors to accidents. Durdyev et al. (2017); Al-Humaidi and Tan (2010); Hallowell and Gambatese (2009) concurred that the construction site environment that engages a diverse workforce with the use of equipment and machinery in construction as well as activities expose workers to accidents. Goh et al. (2016) revealed that workers falling from height as the highest frequency accidents that occur at construction sites in Malaysia followed by accidents due to struck by a falling object. Fang et al. (2016) statead that many accident investigations reveal that workers' unsafe behaviors are the most frequent & direct causes of construction site accident. A study by Fard et al. (2015) reported that 87% of the accidents that involved falling and strucked by equipment (non-vehicle) occurred at construction sites. Ning et al. (2018) stated that a construction site surround by several hazardous facilities has potential to be hazardous to the construction workers.

Durdyev et al. (2017) stated that the construction hazards caused by an extensive variety of works and activities that depend seriously on the workers, machines, and tools. Construction workers need work-related safety trainings that can free them from high risk such as falling from high places, suffering from uncontrolled inflammation, and being hit by

large construction machines. Table 1 shows the fatal accidents at the construction site reported to the Department of Occupational Safety and Health Malaysia (DOSH).

Table 1. Fatal Accident Cases

Date	Case	State	Summary	Causes
15/2/2020	Workers died after falling from a high place	Construction, Pahang	The victim, an electrical wiring worker died after failing at a height of 2 meters during a conduit pipe installation	Empoyer failed to provide Safety Work Procedure for electrical wiring wirk activities and conduit pipe installation. Employer failed to appoint a Site safety Supervisor (SSS)
10/1/2020	Worker died after falling from a high place	Construction, Selangor	A construction company manager died after slipping from a height of 3.9 meters while inspecting formwork.	The aluminium ladder on the scaffold used at level 1 was damaged (bent) causing the stairs to become unstable and sway. The scaffold installed aat the entrance to the 1st floor was not installed competentyl scaffolding operators. Mounted scaffold was not well maintained. The employer failed to conduct risk assessment (HIRARC) on the installation and maintenance of scaffolds. The site failed to appoint a full-time safety site supervisor.
15/2/2019	Died, crushed by steel structure	Construction, Penang	Three construction workers were killed after crushed by steel truss that collapsed due to crushing of the mobile aerial platform.	Failure to investigate the Site Safety Supervisor (SSS). The site has yet to be registered with JKKP.
22/1/2019	Died crushed by lorry	Construction, Johor	The victim of a construction worker died after the motorcycle that he was riding crushed a ghost lorry that stopped by the nearby road within the construction site.	Failed to place vehicle control measures out into the premises. Failure to appoint Site Safety Supervisor (SSS).
20/12/2018	Died falling from height	Construction, Johor	A construction worker died after 17 days of receiving treatment at the Sultan Ismail Hospital. Victims was suspected of falling from 1st floor at construction site.	Employer fails to report accident to DOSH.
21/11/2018	Died falling from height	Construction, Selangor	A helper at construction site fell from a height of 15 meters high when it bore iron rebates to a crane sling.	Failure to observe SOP. Exixting HIRARC failure for truck operator risk for load-lifting activities.
21/10/2018	Died, crushed by brick wall	Construction site, Selangor	The tower crane operator died after a brick wall collapsed and crushed the victim while on his way to the 7th floor 'resting area'.	The brick wall work was not fully assembled and there is no stiffner or support to support the brick wall.
4/10/2018	Daied falling from height	Construction site, Selangor	The victim, a subcontrsctor worker died after failing from level 9 while installing aluminimum formwork.	No fence on opening edges. Wrong usage of safety harness. Installing and transferring work for working platform not according to method statement.

Date	Case	State	Summary	Causes
18/9/2018	Died, crushed by escavator	Construction, Sarawak	General worker died after the machine operate by victim crushed by overturned escavator while down the slope.	No site registration number (construction site). Fail to produce SOP. Fail to produce training records. Fail to produce PPE records.
6/9/2018	Died falling from height	Construction site, Pulau Pinang	A general worker fell from level 6 as he was walking the scaffold's temporary ladder.	Unsafe access to the temporary ladder. Wall opening was not properly covered.
24/8/2018	Died struck by object	Construction site, Selangor	A subcontractor's worker died being hit by debris from the broken pipe during the hydrostatic test on underground pipe.	Unreported case to DOSH. No OSH document on activity involved. No record on SHO and SSS for the project above 20 million worth.
24/8/2018	Died fell into drains	Construction site, Pulau Pinang	A construction worker died after fell into a drain at depth of 1.5 meter.	The case was not reported to DOSH.
20/8/2018	Died falling from height	Construction site, Pulau Pinang	A construction worker died after fell from 17th to 9th floor. Prior to the incident, he was jacking the cage platform from level 15 to 17.	No SOP for cage platform's installation works. Wall opening.
17/8/2018	Died falling from height	Construction site, Sarawak	A general worker fell from height as he was installing the roof. He died at the scene	Not specified
11/8/2018	Died falling frim height	Construction site, Pahang	A construction worker died due to falling from floor 39 to 3rd floor as he was performing cleaning job on cantilever platform.	Wall opening was not covered.
20/7/2018	Killed by falling bricks	Construction site, Melaka	A construction worker died after being hit by falling briks	No SOP for lifting works. No SOP for working at height.
16/7/2018	Death due to accidentally struck against falling object	Construction site, Johor	A civilian died as he fell from his motorcycle due to being strucked against falling object.	Not specified
16/7/2018	Death falling from height	Construction site, Melaka	A construction worker died after he fell down from 7th floor. He was carrying down a scaffold during incident.	No record on training for working at height. Not wearing PPE.
7/7/2018	Died being ran over by lorry	Construction site, Sarawak	An accident between lorry from construction site and a car. Car driver, a civilian was died in that accident	The car found to be speedy
3/6/2018	Died falling from height	Construction site, Johor	Construction worker died as a result of failing from the height of 7.2 meter. He was working on scaffolds at the time of incident.	No railing on the scaffold

(Source: Department of Occupational Safety and Health, 2021)

Accident statistics at the construction site as shown in Table 2 shows the incerement in accident cases in 2019 with a total of 326 cases compared to in 2018 with a total of 240 cases. Accidents in 2019 shows non permanent disability (NPD) of 227 cases, permanent disability (PD) of 15 cases, and deaths of 84 cases. In 2018, the number of NPD shows 123 cases, PD

6 cases, and 111 deaths. The accident rate in 2020 shows a decrease with a total of 199 cases with NPD of 141 cases, PD 4 cases, and death of 54 cases. This decline in cases number may be due to the COVID-19 pandemic causing the sector to cease its operation. However, the death rate is still high.

Table 2. Construction Accident Statistic by Years

Sectors	2018 (Until Oct)				2019				2020 (Until Oct)			
	NPD	PD	Death	Total	NPD	PD	Death	Total	NPD	PD	Death	Total
Construction	123	6	111	240	227	15	84	326	141	4	54	199

PD – Permanent Disability
NPD – Non Permanent Disability
(Source: International Policy and Research Development Division)

Malaysia construction sector has contributed the highest fatality rates compared to other sectors. Referring to the construction sector, there was rise of fatality rate from 81 deaths in the year 2018 to 84 deaths in the year 2019. In 2020, the death rate in the construction sector shows decrement of 54 cases, this number is the same as the manufacturing sector. This decrement is due to the MCO which started on 18 March 2020 to 14 April 2020 where all sectors stopped operating to avoid the spread of Pandemic COVID-19. Despite that, the Malaysia construction sector is still the main contributor to the highest fatality in the year 2018, 2019, and 2020 as shown in Table 3.

Table 3. Fatality Rate by Sectors

Sector	2018 (Until Oct)	2019	2020 (Until Oct)
	Fatality Rate	Fatality Rate	Fatality Rate
Manufacturing	25	73	54
Mining & Quarrying	2	5	2
Construction	81	84	54
Agriculture, Forestry, Logging & Fishery	18	43	39
Utility (Electricity, Gas, Water & Sanitary Services)	1	9	4
Transport, Storage & Communication	9	21	5
Wholesale & Retail Trade	1	0	1
Hotel & restaurant	1	5	1

(Source: Internal Policy and Research Development Division, 2021)

Accidents are unforeseen occurrences that cause damages or injuries. It needs to be addressed immediately due to its devastating impacts on the contractors and construction sector. Studies found that the consequential effects of accidents were classified into direct and indirect costs (Wan Azmi & Misnan, 2013; Williams et al., 2018). The direct costs involved were insurance (Kolo, 2015), medical bills, liability and property loss, and premiums for compensation benefits (Agwu & Olele, 2014). The indirect costs include transportation, loss of time in attending burial ceremonies, loss of time in fatality investigation, downtime of damaged equipment, and losses arising from site closure (Agwu & Olele, 2014; Williams et al., 2018). In terms of project delivery, construction accidents has led to project delays, increment in expenses, and loss of contractor reputation (Williams et al., 2018; Shahab Hosseinian & Jabbarani Torghabeh, 2012; Wang, Liu, & Chou, 2006). Sakthi and Rajesh (2017) revealed that the top five effects of accidents to projects are the cost of medical expenditures, time loss of project execution, productivity loss, doubtfulness to the contractors,

and cost of training given to the new employees. The high fatalities also will affect the country's reputation due to poor management of construction safety (Islam, Razwanul, & Mahmud, 2017). Ultimately, it will also negatively affect the economy since the construction sector is one of the country's main Gross Domestic Product (GDP) contributors (Khan et al., 2014; Chia et al., 2014; Oladinrin et al., 2012).

METHODOLOGY

A systematic literature review was utilised to identify the articles and journals related to the accident causation that occurred at the construction site as well as the implementation of the Integrated Management System (IMS). Mallett et al. (2012) noted that a systematic literature review would assist the researcher to find relevant sources related to the research from an academic database with precise detail and being comprehensive. Thus, it gives a clear advantage to the researcher in evaluating previous research as a data collection compared to traditional literature review.

The data obtained from the systematic literature review is used to fulfill the research questions by analysing the main cause of accidents and the implementation of the Integrated Management System (IMS) implementation at the construction sites. The purpose of this study is to fulfill the following research questions.

- RQ1. Which of the shaping factors that contribute to the accidents at construction site?
- RQ2. How Integrated Management System (IMS) implementation minimize the accident at a construction site?

The systematic literature review process is as follows. The first step is to identify the highest frequency of accident causation based on the accident causation model by Haslam et. al. (2005). The second is to rank the factors of accident causation. Next is to evaluate the IMS implementation. The final step is to conclude and justify relationship between IMS and accident causation among construction workers. The databases utilised in conducting the systematic literature review were Scopus and Web of Science. According to Mohamed Shaffril et al. (2019) both databases; Scopus and Web of Science ; are vigorous and conceal more than 256 field of studies.

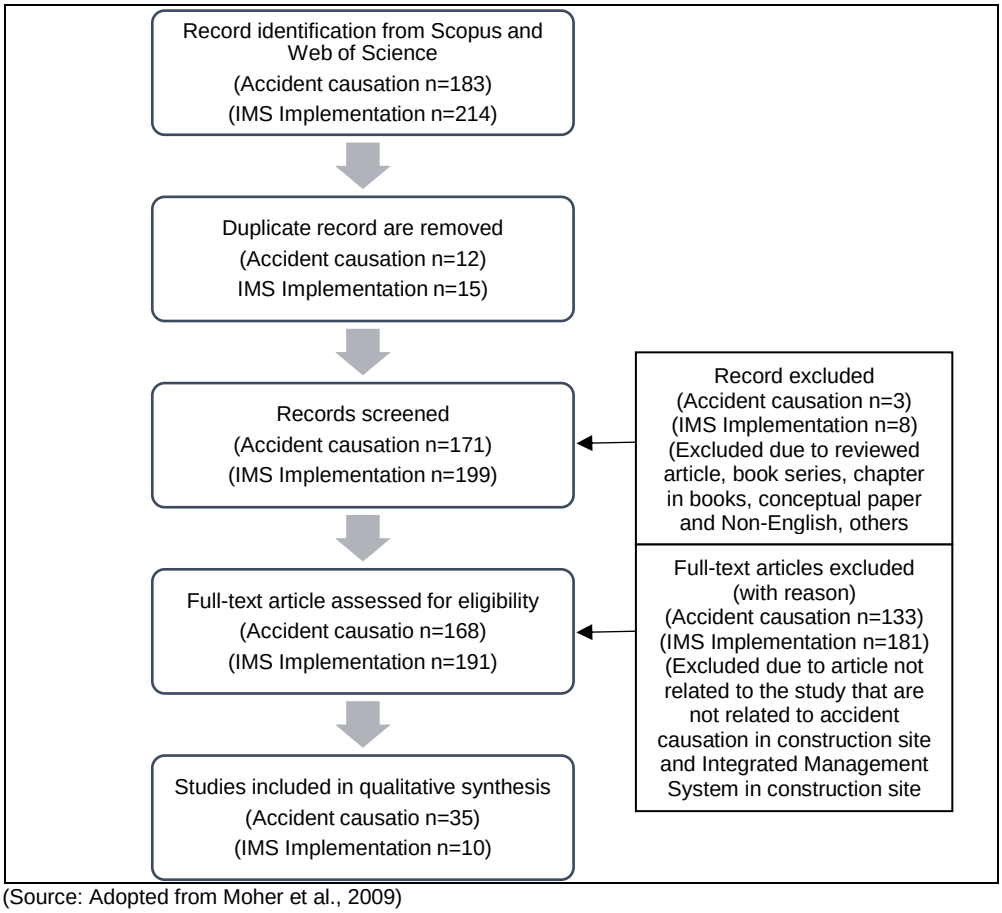
Searching

The process of selecting the articles was through keywords related to the accident causations and IMS with synonyms based on previous research keywords, dictionaries, and thesaurus. Process searching was performed by using a keyword (as shown in Table 4) that deals with accident causation in the field of construction sector which focusing on the construction site. A total of 183 articles on accident causation and 214 articles on IMS implementation were obtained from both databases.

Table 4. Search String

Database	Search String	Area
Scopus	TITLE-ABS-KEY (("accident causation" OR "accident factor*" OR "accident cause*" OR "construction accident" OR "accident causal factor*") AND ("construction site" OR "construction stage" OR "construction phase" OR "execution phase"))	Accident Causation
	TITLE-ABS-KEY((“Integrated Management System” OR “Integration Safety Management” OR “Integrating Safety” OR “Quality Management, Safety and Health Management, Environment Management”) AND (Construction OR “Construction Industry” OR “Construction Sector”))	IMS Implementation
Web of Sciences	TS=(("accident causation" OR "accident factor*" OR "accident cause*" OR "construction accident" OR "accident causal factor*") AND ("construction site" OR "construction stage" OR "construction phase" OR "execution phase"))	Accident causation
	TS=((“Integrated Management System” OR “Integration Safety Management” OR “Integrating Safety” OR “Quality Management, Safety and Health Management, Environment Management”) AND (Construction OR “Construction Industry” OR “Construction Sector”))	IMS Implementation

Screening



(Source: Adopted from Moher et al., 2009)

Figure 1. Study Flow Chart

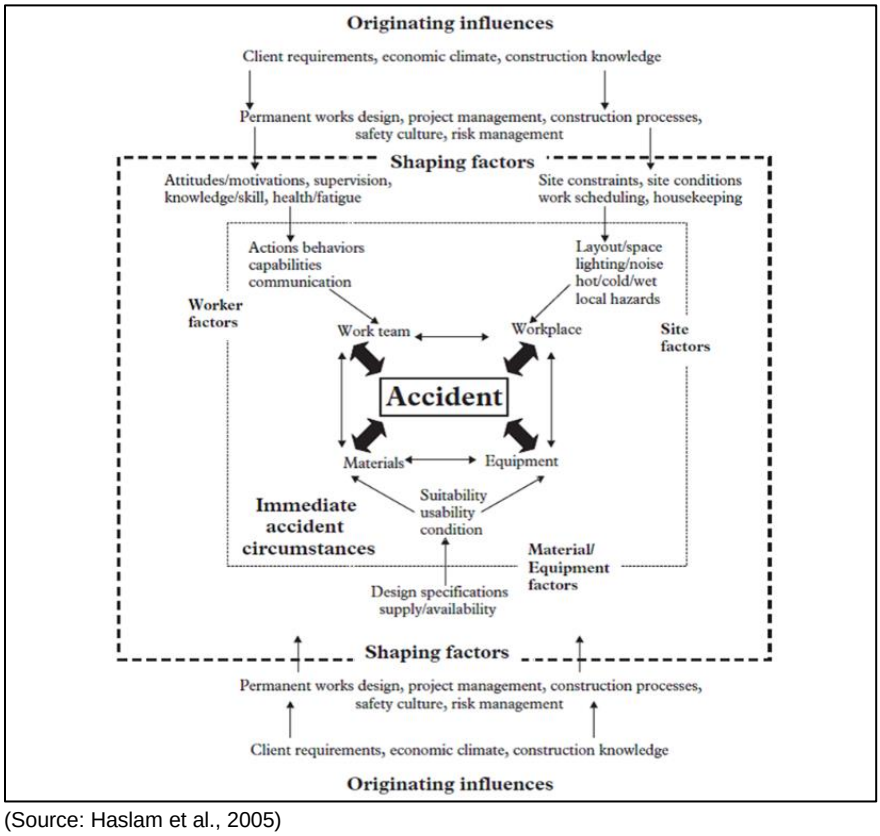
At the screening stage, all duplicate articles were deleted, the remaining was 171 articles for the cause of the accident and 199 articles for the IMS implementation. Irrelevant articles also were removed because only journal articles are needed. According to Mohamed Shaffril et al. (2019) asserted that journal articles provide empirical data. As such, they can be a major source of data collection. This paper focuses on the articles in the field of construction sector and IMS with the combination of ISO 9001, ISO 45001, and ISO 14001.

Determining the relevant articles is important in meeting the research needs. The unrelated article were 133 articles on accident causation and 181 articles on IMS implementation. Thus, the relevant articles to be analysed were 35 articles on accident causation and 10 articles IMS implementation in construction sector. A flow chart of the articles eligibility is shown in Figure 1.

FINDINGS

Accident Causation at Construction Site

The Accident Causation Model by Haslam et al. (2005) as shown in Figure 2 was used in this paper and it consists of four factors which are originating influences, shaping factors that covered workers factors, site factors, and material/equipment factors. These factors were used to analyse the causes of the accident at the construction site and the finding was tabulated to identify the frequency of the causes.



(Source: Haslam et al., 2005)

Figure 2. Accident Causation Model

A total of 35 journals related to the causes of accidents at construction sites were analysed. Table 5 shows the result which most frequent factors causes of accident at the construction site were workers factors which contribute 27 times and originating influences was 21 times. These show workers factors as the first contributor followed by originating influences.

Table 5. Accident Causes

No.	Authors	Workers Factors	Site Factors	Material/ Equipment Factors	Originating Influence
1.	Abdelhamid and Everett (2000)	Construction workers			Management
2.	Al-Tabtabai (2002)				Management practice
3.	Zhenghui and Yaoxing (2010)	People problems			Management problems
4.	Manu, Ankrah, Proverbs, and Suresh (2010)		Nature of project, Site restriction		Method of construction, Project duration, Procurements system, Design complexity, Level of construction
5.	M. Bashir, Suresh, Proverbs, and Gameson (2011)	Physical and mental inability of workers, Poor communication			Poor Planning, Poor work methods
6.	Lin, Chen, and Wang (2011)	Not using handrails or safety belt			
7.	Zou (2011)				Safety culture
8.	Behm and Schneller (2012)	Workers action & behaviours, Workers capabilities, Knowledge & skill, Attitude &motivation	Local hazard		Risk management, Project management
9.	Ismail, Doostdar, and Harun (2012)				Safety management system
10.	Chi, Han, and Kim (2013)	Workers behaviour	Working conditions		
11.	Cokeham and Tutesigensi (2013)				Nature of work
12.	Manu, Ankrah, Proverbs, and Suresh (2014)				Construction project features (CPFs)
13.	Chi, Lin, and Sari Dewi (2014)	Communication			Risk management
14.	Shin, Lee, Park, Moon, and Han (2014)	Safety attitudes & safety behaviour			
15.	Kadiri et al (2014)	Workers negligence			
16.	Yilmaz (2015)	Unsafe behaviours			
17.	Asanka and Ranasinghe (2015)	Human main cause of construction accidents			
18.	Shamsuddin, Ani, Ismail, and Ibrahim (2015)	Failure to obey the work procedures, Workers' carelessness, Operating equipment without safety device, Low understanding & skill level of workers, Poor workers attitude about safety, Failure to use PPE.	Poor site management		Work at high elevation

No.	Authors	Workers Factors	Site Factors	Material/ Equipment Factors	Originating Influence
19.	Alomari and Gambatese (2016)	connectivity's among construction workers			
20.	Guo, Yiu, and Gonzalez (2016)	Workers' unsafe behaviours			
21.	Sakthi and Rajesh (2017)	Failure to follow safety rules, Ignorance of PPE, Improper use of safety items, Improper equipment	Space congestion		
	Kim and Kim (2017)	Negligent supervisor, Violations of safety regulations			
22.	Li, Ho, and Tang (2018)	Improper use of the equipment			Lack of supportive equipment
23.	Ayob, Shaari, Zaki, and Munaaim (2018)	Lack of supervision, Lack of adherence to safe work technique, Failure to ware PPE, Failure to comply with the safe use of tools		Vehicles, machines	
25.	Al-Khaburi and Amoudi (2018)	Poor instruction by the supervisor, Lack of training, Lack of workers' awareness, Lack of underestimating danger by workers		Lack of maintenance of equipment	
27.	Othman, Majid, Mohamad, Shafiq, and Napiah (2018)	Unsafe act	Site condition		Unsafe method
	Laal, Pouyakian, Madvari, Khoshakhlagh, and Halvani (2019)	Less experience & trained personnel, Rush to carry out the activities, Lack of sufficient skills in using machines & equipment			
28.	Ahmed (2019)	Unawareness of safety-related issues, Lack of knowledge, Lack of training on equipment			Lack of personal protective equipment, Lack of safety eliminating/avoiding design, Unfit equipment
29.	Betsis, Kalogirou, Aretoulis, and Pertzinidou (2019)	Inexperienced personnel & workers			
30.	Hamid et al (2019)		Job site condition		Unsafe methods
31.	Kang and Ryu (2019)	Mentally unstable workers, insufficient safety training			Safety policy
32.	Sanni-Anibire, Mahmoud, Hassanain, and Salami (2019)	Poor use of PPEs	Site condition		
33.	Williams, Adul Hamid, and Misnan (2019)	Slip & trip, and falls, Safety standard violations, Loss of control over body movement, Non-usage of PPE, Horseplay	Poor housekeeping	Contact with working tools, vehicle-related, Overloading of scaffold &	Failure in the design, Absence of warning signs, Safety planning

No.	Authors	Workers Factors	Site Factors	Material/ Equipment Factors	Originating Influence
				carne, Wrong placement of ladder, Over speeding of vehicle, wrong selecting of working tools, Improperly installed equipment	
34.	Winge, Albrechtsen, and Mostue (2019)				Poor safety management
35.	Zhang, Zhu, Zhang, and Zhao 2020)	Inadequate safety inspection, Non-compliance of workers, Faulty of safety engineers, Inadequate safety training, Lacking of safety awareness			Delay hazard elimination, No enough professional safety engineers
	Frequencies	27	9	3	21

Although the worker factor is the main cause of accidents at the construction site, do not forget also the originating influences which is the second cause of accidents. This Originating influences is the responsibility of the employer in ensuring that the safety management in place and construction workers was well trained. Jamalullah et al. (2018) found that lack of training was a factor of non-compliance with health and safety requirements and is a root cause of the accident. The worker with zero knowledge and experience will be exposed to the hazard while the work is being carried out. Therefore, it is important for employers to provide safety training to construction workers before they are assigned to construction sites to ensure accidents can be controlled (Haslam et al., 2005). Mazlina and Hadikusumo (2017) urged that, an improvement in workers' safety behavior can be achieved by focusing on the technical intervention with five important safety practices such as:

i. Workplace safety inspections.
ii. Personal protective equipment (PPE) programmes.
iii. Safety equipment availability and maintenance.
iv. Safety work practices.
v. Safety permits.

These safety practices help the construction management team to identify the specific interventions for workers' safety behavior improvement. Cokeham and Tutesigensi (2013) suggested that the incident rates can be minimised to all workers by means of H&S training. The curriculum should however be tailored to suit the particular hazards of different areas of work. Furthermore, employees should not switch between areas of work unless they have been adequately trained. Simukonda (2019) stated that adequate OSH training and induction is one of the solutions in preparing beginners to perform their tasks. Construction workers that do not have proper training on OSH issues, process, and reporting are unreliable. Ahmed (2019) mentioned that training and workshop programs should be developed to provide the appropriate skills and techniques for stakeholders regarding scheduling, cost and time management, equipment technology, and risk analysis. It was the responsibility of the

employer as well as employees. Hamid et al. (2019) stated that under OSHA 1994, it is the responsibility of both employers and their workers to ensure safety and health at the workplace. Employers and contractors who fail to provide a safe and healthy working environment for their employees can be charged under Section 15 of OSHA 1994, which carries a maximum sentence of a RM50,000 fine, or two years' jail, or both.

Integrated Management System (IMS)

An IMS is a combination of processes, procedures and practices used in an organisation to implement several management policies (Giacomello, Kern, & Stumpf, 2014). Implementation of the new system will go through various challenges and need for comprehensive education covering from management level until operational level. The complexity of the process that occurs in the process of system integration can impose barriers to the development of management activities in construction companies. Zeng et al. (2008) disclosed that there are two clusters of barriers, which are first, the internal barrier, whereby the challenge in the organisation that encompasses of understanding, culture, perception, and human resources. The external barriers include authorities' regulations, standards, customers, and stakeholders. There is no denying that every implementation of the new system will have obstacles.

However, the advantages of IMS can help construction organisations in controlling accidents rates that impact the construction sector, whereby Zeng et al. (2010) stated that it is difficult to deal with detached management systems covering OHS, environment, and quality and to ensure their alignments with organizational strategies. Chountalas and Tepaskoualos (2019) noted that the detached systems are complex and bureaucratic where poor total management of HSE and quality issues from top-level can be a risk to strategic management practices. IMS is an innovative method that benefits the organisation in improving performance, managing various management functions and procedures used in each construction project stage (Griffith & Bhutto, 2007; Griffith & Bhutto, 2008).

Tepaskoualos and Chountalas (2017) emphasize that, IMS helps in reducing the cost of operation and management, fully monitor and solve the safety issues, significant reducing bureaucracy thus, effectively meeting the stakeholders' needs. Laal et al. (2018) proves that the implementation of safety programs especially IMS and annual audits have had a significant impact on reducing accident indices and improving safety. Therefore, health and safety management systems are appropriate tools for managing construction accident. Table 6 shows the IMS implementation in the construction sector from previous research.

Table 6. Integrated Management System (IMS) Implementation

No.	Authors	Focus Area	Integration of Management System	Result
1.	Griffith (2000)	Project control	QMS, EMS and H&SMS	Blue print for organizational efficiency and effectiveness.
2.	Zeng, et al. (2005)	Construction firms	ISO 9001 and ISO 14001	Avoidance duplication of procedures, reduced conflict of procedures, reduced requirements for resources.
3.	Zeng et al. (2008)	Construction Industry	ISO9001 & OHSAS18001	Avoid duplication, reduce resource inputs.
4.	Griffith et al. (2008a)	Contractors' experience	Quality, safety & environment	Greater organisational effectiveness and efficiency, improve project performance.

5.	Griffith et al. (2008b)	Construction sector	QMS, H&SMS and EMS	Higher levels of environmental performance
6.	Gasparik (2009)	Construction company	ISO9001, ISO14001 & OHSAS18001	Improving quality, employees safety, comply with environment standard, fulfil customer satisfaction.
7.	Masood et al. (2014)	Construction firms	ISO9000, ISO14000, ISO18000	Improve communication, quality and safety & health management process
8.	Giocomello et al. (2014)	Building company	QMS, OHSMS & EMS	Greater stakeholder participation, improvement productivity, high awareness on environmental.
9.	Setyorini et al. (2018)	Construction company	Quality, OSH & EMS	Improving project monitoring process
10.	Masuin at el. 2020	Construction company	Quality, health and safety, environment management	Improving performance, productivity, profitability, and worker safety as an organisational strategy especially at construction company.

DISCUSSION

The results from this paper found that the shaping factor of accidents at the construction site is caused by construction workers in which among the factors are workers action, negligence, attitudes, knowledge, skill, awareness, capabilities, motivation, poor communication, physical and mental inability, lack of supervision, lack of training and behavior. Therefore, the role of the employer is very important in determining the level of knowledge of his employees regarding safety at the construction site. Sanni-Anibire et al. (2019) recommended that, continuous training on safety laws and requirements should be provided to all workers on site according to their job task, provision and enforcement of PPE for various construction site activities can improve the safety performance.

The implementation of IMS can solve issues that may arise during the implementation of a detached management system. A detached management system was considered rigid and bureaucratic, gives difficulty for innovation and continuous improvement (Eriksson & Hansson, 2006). According to Zeng et al. (2007) the detached management system comprised of the quality management system, health and safety management system, and environmental management system was difficult to manage and adapted with organisational strategy.

Therefore, the implementation of IMS in controlling accidents at construction sites is very necessary. Integration of ISO9001, ISO45001, and ISO14001 has many advantages and one of them is able to improve safety and health management processes at the construction site. In combination with ISO9001, ISO45001, and ISO14001 the construction company can avoid the duplication of procedures, reduce conflict of procedures, and in turn improved organisational effectiveness and efficiency, and improved project performance by also paying attention to environmental sustainability.

CONCLUSION AND RECOMMENDATION

In conclusion, the implementation of IMS in the construction sector is important because this sector always have the tendency to have issues in quality, safety and environmental sustainability. With reference to accident statistics, it shows that the accident rate increases every year with a high mortality rate. The quality of construction also plays a role in ensuring the safety of building users. Many issues related to buildings collapse during construction also

after completion and this involves the quality of building construction which also needs to be addressed. Landslides and flash floods caused by construction are also critical issues and also need to be addressed. To address these issues, construction companies need a management system that can integrate ISO into one system. Therefore, IMS is the solution to this problem, and it is proposed for the implementation of IMS to construction companies, especially during the construction stage to control the safety of workers and also ensure the quality of construction and environmental issues can be effectively managed. It is the responsibility of the employer, which is the construction company to apply the correct safety techniques in ensuring the safety of their workers at the construction site for them to carry out the construction activities (Williams et al., 2018).

REFERENCES

Abdelhamid, T. S., & Everett, J. G. (2000) Identifying Root Causes Of Construction Accidents. *Journal of Contruction Engineering and Management*, 126(1):52–60.

Agwu, M. O., & Olele, H. E. (2014) Fatalities in the Nigerian Construction Industry: A Case of Poor Safety Culture. *British Journal of Economics, Management & Trade*, 4(3):431–452.

Ahmed, S. (2019a) Causes and effects of accident at construction site: A study for the construction industry in Bangladesh. *International Journal of Sustainable Construction Engineering and Technology*, 10(2):18–40.

Ahmed, S. (2019b) Causes of Accident at Construction Sites in Bangladesh. *Organization, Technology and Management in Construction: An International Journal*, 11(1):1933–1951.

Al-Humaidi, H. M., & Tan, F. H. (2010) Construction Safety in Kuwait. *Journal of Performance of Constructed Facilities*, 24(1): 70–77.

Al-Khaburi, S., & Amoudi, O. (2018) Analysis of Accident Causes at Construction Sites in Oman. *Jordan Journal of Civil Engineering*, 12(2): 279–294.

Al-Tabtabai, H. M. (2002) Analyzing construction site accidents in Kuwait. *Kuwait Journal of Science and Engineering*, 29(2): 213–238.

Alomari, K., & Gambatese, J. (2016) Degrees of Connectivity Impact on Construction Worker Safety. *Proceedings Construction Research Congress 2016*, 2783–2792.

Asanka, W. A., & Ranasinghe, M. (2015) Study on the Impact of Accidents on Construction Projects. *6th International Conference on Structural Engineering and Construction Management 2015*, 58–67.

Ayob, A., Shaari, A. A., Zaki, M. F. M., & Munaaim, M. A. C. (2018) Fatal occupational injuries in the Malaysian construction sector-causes and accidental agents. *IOP Conference Series: Earth and Environmental Science*, 140(1):1-10

Behm, M., & Schneller, A. (2012) Application of the Loughborough Construction Accident Causation model: a framework for organizational learning. *Construction Management and Economics*, 31(6): 580–595.

Betsis, S., Kalogirou, M., Aretoulis, G., & Pertzinidou, M. (2019) Work Accidents Correlation Analysis for Construction Projects in Northern Greece 2003–2007: A Retrospective Study. *Safety*, 5(33): 1–17.

Chi, C.-F., Lin, S.-Z., & Sari Dewi, R. (2014) Graphical fault tree analysis for fatal falls in the construction industry. *Accident Analysis and Prevention*, 72:359–369.

Chi, S., Han, S., & Kim, D. Y. (2013a) Relationship between unsafe working conditions and workers' behavior and impact of working conditions on injury severity in U.S. construction industry. *Journal of Construction Engineering and Management*, 139(7): 826–838.

Chi, S., Han, S., & Kim, D. Y. (2013b) Relationship between Unsafe Working Conditions and Workers' Behavior and Impact of Working Conditions on Injury Severity in U.S. Construction Industry. *Journal of Construction Engineering and Management*, 139(7):826–838.

Chia, Fah Choy, Skitmore, Martin, Runeson, Goran, & Bridge, A. (2014) Economic Development And Construction Productivity In Malaysia. *Construction Management and Economics*, 32(9):874–887.

Chountalas, P. T., & Tepaskoualos, F. A. (2019) Selective integration of management systems: a case study in the construction industry. *TQM Journal*, 31(1):12–27.

Cokeham, M., & Tutesigensi, A. (2013) An investigation of construction accidents in Rwanda: Perspectives from Kigali. *Proceedings of Institution of Civil Engineers: Management, Procurement and Law*, 166(4):179–187.

Durdyev, S., Mohamed, S., Lay, M. L., & Ismail, S. (2017) Key Factors Affecting Construction Safety Performance in Developing Countries: Evidence from Cambodia. *Construction Economics and Building*, 17(4):48–65.

Eriksson, H., & Hansson, J. (2006) Integrated Management Systems – Theoretical and Practical Implications. *Asian Journal on Quality*, 7(2):69–82.

Fang, D., & Wu, H. (2013) Development of a Safety Culture Interaction (SCI) model for construction projects. *Safety Science*, 57:138–149.

Fang, D., Zhao, C., & Zhang, M. (2016) A Cognitive Model of Construction Workers' Unsafe Behaviors. *Journal of Construction Engineering and Management*, *142*(9):1–10.

Fard, M. M., Terouhid, S. A., Kibert, C. J., & Hakim, H. (2015) Safety concerns related to modular/prefabricated building construction. *International Journal of Injury Control and Safety Promotion*, 24(1):10–23.

Giacomello, H., Kern, A. P., & Stumpf, M. A. G. (2014) Implementation of an integrated management system into a small building company. *Journal of Construction*, *13*(3):10–18.

Goh, K. C., Goh, H. H., Omar, M. F., Toh, T. C., & Mohd Zin, A. A. (2016) Accidents preventive practice for high-rise construction. *MATEC Web of Conferences*, *47*:3–8.

Griffith, A., & Bhutto, K. (2007) Establishing Integrated Management Systems (IMS) within Principal Contracting Organisations. *International Journal of Construction Management*, *7*(1):17–27.

Griffith, A., & Bhutto, K. (2008) Contractors' experiences of integrated management systems. *Proceedings of Institution of Civil Engineers: Management, Procurement and Law*, *161*(3):93–98.

Guo, B. H. W., Yiu, T. W., & González, V. A. (2016) Predicting safety behavior in the construction industry: Development and test of an integrative model. *Safety Science*, *84*(2016):1–11.

Hallowell, M. R., & Gambatese, J. A. (2009) Construction Safety Risk Mitigation. *Journal of Construction Engineering and Management*, *135*(12):1316–1323.

Hamid, A. R. A., Noor Azmi, M. R. A., Aminudin, E., Jaya, R. P., Zakaria, R., Zawawi, A. M. M., Yahya, K., Haron, Z., Yunus, R., & Saar, C. C. (2019) Causes of fatal construction accidents in Malaysia. *IOP Conference Series: Earth and Environmental Science*, *220*(1):1–11.

Haslam, R. A., Hide, S. A., Gibb, A. G. F., Gyi, D. E., Pavitt, T., Atkinson, S., & Duff, A. R. (2005) Contributing factors in construction accidents. *Applied Ergonomics*, *36*(4 SPEC. ISS.):401–415.

Islam, M. S., Razwanul, I., & Mahmud, M. T. (2017) Safety practices and causes of fatality in building construction projects: A Case Study for Bangladesh. *Jordan Journal of Civil Engineering*, *11*(2):267–278.

Ismail, Z., Doostdar, S., & Harun, Z. (2012) Factors influencing the implementation of a safety management system for construction sites. *Safety Science*, *50*(3):418–423.

Jamalullah, S. N., Rashid, Z. Z. A., Hanafi, M. H., Ulang, N. M., Riazi, S. R. M., & Nawi, M. N. M. (2018) Factors of non-compliance with occupational, health and safety legal requirements among Malaysian contractors. *Malaysian Construction Research Journal*, *3*(Special Issue 1):114–129.

Kadiri, Z. O., Nden, T., Avre, G. K., Oladipo, T. O., Edom, A., & Ananso, G. N. (2014) Causes and Effects of Accidents on Construction Sites in Nigeria. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE*, *11*(5):66–72.

Kang, K., & Ryu, H. (2019) Predicting types of occupational accidents at construction sites in Korea using random forest model. *Safety Science*, *120*:226–236.

Khan, R. A., Liew, M. S., & Ghazali, Z. Bin. (2014) Malaysian Construction Sector and Malaysia Vision 2020: Developed Nation Status. *Procedia - Social and Behavioral Sciences*, *109*:507–513.

Kim, J. S., & Kim, B. S. (2017) Analysis of Fire-Accident Factors Using Big-Data Analysis Method for Construction Areas. *KSCE Journal of Civil Engineering*, *22*(5), 1535–1545.

Kolo, D. N. (2015) *Safety Issues Involving Workers on Building Construction Sites in Nigeria : An Abuja Study*. MSc Thesis, Eastern Mediterranean University.

Laal, F., Pouyakian, M., Madvari, R. F., Khoshakhlagh, A. H., & Halvani, G. H. (2019) Investigating the Impact of Establishing Integrated Management Systems on Accidents and Safety Performance Indices: A Case Study. *Safety and Health at Work*, *10*(1):54–60.

Li, R. Y. M., Ho, D. C. W., & Tang, B. (2018) Factors Which Affect Construction Safety in Different Types of Construction Work. *Proceedings of International Conference on Applied Human Factors and Ergonomics AHFE 2017: Advances in Safety Management and Human Factors* , Vol. 604, 67–76.

Lin, Y. H., Chen, C. Y., & Wang, T. W. (2011) Fatal occupational falls in the Taiwan construction industry. *Journal of the Chinese Institute of Industrial Engineers*, *28*(8): 586–596.

M. Bashir, A., Suresh, S., Proverbs, D., & Gameson, R. (2011) A critical, theoretical, review of the impacts of lean construction tools in reducing accidents on construction sites. *Proceedings of the 27th Annual Conference* of *Association of Researchers in Construction Management (ARCOM 2011)*, 249–258.

Mallett, R., Hagen-Zanker, J., Slater, R., & Duvendack, M. (2012) The benefits and challenges of using systematic reviews in international development research. *Journal of Development Effectiveness*, *4*(3):445–455.

Manu, P., Ankrah, N., Proverbs, D., & Suresh, S. (2010) An approach for determining the extent of contribution of construction project features to accident causation. *Safety Science*, *48*(6):687–692.

Manu, P., Ankrah, N., Proverbs, D., & Suresh, S. (2014) The health and safety impact of construction project features. *Engineering, Construction and Architectural Management*, *21*(1):65–93.

Mazlina Zaira, M., & Hadikusumo, B. H. W. (2017) Structural equation model of integrated safety intervention practices affecting the safety behaviour of workers in the construction industry. *Safety Science*, *98*(1):124–135.

Mohamed Shaffril, H. A., Samah, A. A., Samsuddin, S. F., & Ali, Z. (2019) Mirror-mirror on the wall, what climate change adaptation strategies are practiced by the Asian's fishermen of all? *Journal of Cleaner Production*, *232*:104–117.

Ning, X., Qi, J., & Wu, C. (2018) A quantitative safety risk assessment model for construction site layout planning. *Safety Science*, *104*(January), 246–259.

Oladinrin, T., Ogunsemi, D., & Aje, I. (2012) Role of Construction Sector in Economic Growth : Empirical Evidence From Nigeria. *FUTY Journal of the Environment*, *7*(1):50–60.

Othman, I., Majid, R., Mohamad, H., Shafiq, N., & Napiah, M. (2018) Variety of Accident Causes in Construction Industry. *MATEC Web of Conferences*, *203*(02006), 1–9.

Sakthi, G. G., & Rajesh, M. (2017) A Study on Identification of Causes and Effects of Accidents in Construction Industry - Indian Scenario. *International Journal of Civil Engineering*, *4*(6), 43–49.

Sanni-Anibire, M. O., Mahmoud, A. S., Hassanain, M. A., & Salami, B. A. (2019) A risk assessment approach for enhancing construction safety performance. *Safety Science*, *121*(2020):15–29.

Shahab Hosseinian, S., & Jabbarani Torghabeh, Z. (2012) Major Theories of Construction Accident Causation Models: a Literature Review. *International Journal of Advances in Engineering & Technology*, *4*(2):53–66.

Shamsuddin, K., Ani, M., Ismail, A., & Ibrahim, M. (2015). Investigation the Safety, Health and Environment (SHE) Protection in Construction Area. *International Research Journal of Engineering and Technology (IRJET)*, *2*(6):624–636.

Sherratt, F., Farrell, P., & Noble, R. (2013) UK construction site safety: discourses of enforcement and engagement. *Construction Management and Economics*, *31*(6):623–635.

Shin, M., Lee, H. S., Park, M., Moon, M., & Han, S. (2014) A system dynamics approach for modeling construction workers' safety attitudes and behaviors. *Accident Analysis and Prevention*, *68*:95–105.

Simukonda, W. (2019) Occupational health and safety practices among contractors in Malawi: A generic overview. *Proceedings of Institution of Civil Engineers: Management, Procurement and Law*, *172*(3):118–124.

Tepaskoualos, F., & Chountalas, P. (2017) Implementing an Integrated Health, Safety, and Environmental Management System: the Case of a Construction Company. *International Journal for Quality Research*, *11*(4):733–752.

Wan Azmi, W. F., & Misnan, M. S. (2013) A Case for the Introduction of Designers' Safety Education (DSE) for Architects and Civil Engineers. *Advanced Engineering Forum*, 10:160–164.

Wang, W. C., Liu, J. J., & Chou, S. C. (2006) Simulation-based safety evaluation model integrated with network schedule. *Automation in Construction*, *15*(3), 341–354.

Williams, O. S., Adul Hamid, R., & Misnan, M. S. (2018) Accident Causal Factors on the Building Construction Sites: A Review. *International Journal of Built Environment and Sustainability*, *5*(1):78–92.

Williams, O. S., Adul Hamid, R., & Misnan, M. S. (2019) Causes of building construction related accident in the south-western states of Nigeria. *International Journal of Built Environment and Sustainability*, *6*(1):14–22.

Winge, S., Albrechtsen, E., & Mostue, B. A. (2019) Causal factors and connections in construction accidents. *Safety Science*, *112*(1):130–141.

Yilmaz, F. (2015) Monitoring and analysis of construction site accidents by using accidents analysis management system in Turkey. *Journal of Sustainable Development*, *8*(2):57–65.

Zeng, S. X., Shi, J. J., & Lou, G. X. (2007) A synergetic model for implementing an integrated management system: an empirical study in China. *Journal of Cleaner Production*, *15*(18):1760–1767.

Zeng, S. X., Tam, V. W. Y., & Tam, C. M. (2008) Towards occupational health and safety systems in the construction industry of China. *Safety Science*, *46*(8):1155–1168.

Zeng, Sai X., Tam, C. M., & Tam, V. W. Y. (2010) Integrating safety, environmental and quality risks for project management using a FMEA method. *Engineering Economics*, *21*(1):44–52.

Zhang, W., Zhu, S., Zhang, X., & Zhao, T. (2020) Identification of critical causes of construction accidents in China using a model based on system thinking and case analysis. *Safety Science*, *121*(April 2019):606–618.

Zhenghui, C., & Yaoxing, W. (2010) Explaining the causes of construction accidents and recommended solutions. *2010 International Conference on Management and Service Science (MASS 2010)*, 1–5.

Zou, P. X. W. (2011) Fostering a Strong Construction Safety Culture. *Leadership and Management in Engineering*, *11*(1):11–22.

CIPAA IMPLEMENTATION IN THE MALAYSIAN CONSTRUCTION INDUSTRY: FROM CONTRACTOR'S PERSPECTIVES

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Abstract
Payment disputes is prevalent among construction players and openly recognized as the main problem in construction project. Hence, Construction Industry Payment and Adjudication Act (CIPAA) is introduced in 2014 to create a rapid, efficient and impartial mechanism for resolving construction disputes in Malaysia by implementing the adjudicators' decisions. However, the Asian International Arbitration Centre (AIAC) reported that more than 50% adjudication cases are eventually re-arbitrated and re-litigated, causing further payment delays. This scenario has an unfavorable impact on the contracting parties involved in a construction project including delay in project completion. Therefore, the objectives of this paper is to identify the current implementation of CIPAA, identify the factors contributed to the payment problems, and to determine the limitations of CIPAA in settling disputes of construction projects. A quantitative approach is used in this study; using questionnaire as the survey instrument. The survey was disseminated to 268 nos. of G7 contractors in Kuala Lumpur and Selangor. The results shows that disagreement on the valuation of work done is the main factor that contributes to payment problems. Thus, the implementation of CIPAA allows the disputes parties to remain confidential and helps to improve the cashflow in the construction industry. However, CIPAA's limitations in resolving payment disputes include the non-finality of an adjudication jurisdiction and the competency of the adjudicator.The findings will help in the improvement of dispute resolution in Malaysia through statutory adjudication.

Keywords: *Payment disputes; Construction Industry Payment and Adjudication Act (CIPAA); factors; limitations; construction industry.*

INTRODUCTION

As a developing nation, the construction industry is extremely imperative in fostering economic development to generate wealth and improve the quality of life in Malaysia. Although the contributions of the construction sector to economic growth is statiscally small compared to other sectors such as service, manufacturing and agriculture, the importance of construction sector towards Malaysia's economy cannot be overlooked. However, defaults in payment is prevalent among construction players and openly recognized as the main problem recurring from project caused by a variety of causes. Seng and Susy (2019) mentioned that these problems may inevitably become disputes if not adequately handled which may affect the construction project goals. Moreover, Loo Seong King et al. (2019) noticed that the issue of payment has always been the main subject of disputes. Therefore, in order to address the issue of payment defaults in the construction industry, the Malaysian government has introduced the Construction Industry Payment and Adjudication Act (CIPAA) to combat payment disputes statutorily through an enforcement mechanism.

Since CIPAA implementation in 2014, Seah (2018) observed that based on the Malayan Law Journal Unreported (MLJU), out of 54.35% of adjudication decisions are re-arbitrated

or re-litigated. Almost half of this percentage, a total of 62 adjudication cases arising from payment problems have been referred to the court as of February 2018. Despite a significant portion of the cases which is 75.8% of them being accepted by the court of their initial adjudication decision, the trend of increasing number of adjudication cases being referred to the court. This is contrary to one of the main objective of CIPAA's implementation set out in the Preamble which is to provide a mechanism for speedy dispute resolution through adjudication. An intervention by court lengthens the process of payment and hurts the cash flow in the construction industry which affects the project's success (Che Munaaim, 2012). Mazani et al. (2019), concluded that there are proof of that CIPAA has been effective in resolving payment disputes occurring in the Malaysian construction industry since its implementation in 2014. However, it has also been noticed that the number of adjudication cases intervened by the court has exponentially increased indicating the presence of doubt among construction players towards the decisions made by adjudicators (Mazani et al., 2019). The concept will therefore be intended to identify the cause construction player's doubt about the decisions made by adjudicators.

Mat Isa et al. (2015), found that late payment is one of the most critical problems in the construction industry with 51% of their respondents have experienced late payment. Loo Seong King et al. (2019) further emphasized that payment issues are not only caused by client but can also be attributable to the contractor. Jalil et al. (2017) stressed that the payment mechanism is so crucial and its flow must be well arranged to protect the rights and interest of the parties involved, and it has been one of the major factor that contribute to project success. Thus, CIPAA implementation in 2014 is to enable swift dispute resolution and improve cash flow in the construction industry. Asian International Arbitration Centre (AIAC) reported that there is an increase of adjudication matters registered every year from 2014 to 2018. This indicates that construction players are becoming more aware of CIPAA and are using CIPAA for its intended use thus resolving payment disputes as fast as possible. However, several studies have noticed that there is a trend in the increase of adjudication cases being re-arbitrated or re-litigated. This scenario causes more delay in payment which defeats the purpose of CIPAA in the first place. This paper will therefore be focused on investigating the limits of CIPAA implementation in the construction industry.

CONSTRUCTION INDUSTRY PAYMENT AND ADJUDICATION ACT 2012 (CIPAA)

The Construction Industry Payment and Adjudication Act 2012 (CIPAA) was recently gazetted as a speedy dispute resolution mechanism. The process is quick and relatively cheap, particularly in comparison to litigation and to those arbitrations that have somewhat unfortunately, for whatever reason, been allowed to become more time consuming and costly than they should have been. The primary objective of the Act is to address cash flow problems in the construction industry. It removes the pervasive and prevalent practice of conditional payment (pay when paid pay if paid) and reduces payment default by establishing a cheaper and speedier system of dispute resolution in the form of adjudication. The Act also provides for the recovery of payment upon the conclusion of the adjudication. The Act also provides for the recovery of payment upon the conclusion of the adjudication process in addition to a host of other remedies such as a right to reduce the rate of work progress or to suspend work or even to secure direct payment from the principal (Azman et al., 2013).

CIPAA is introduced to ensure quick and inexpensive resolution to payment problems to the betterment the cash flow in our construction industry (Nasir et al., 2018), by ensuring on time payment was made possible with a quick and a proper payment recovery mechanism (Arzlee Hassan et al., 2019). In order for it to be effective, the mechanism has to come with sufficient authority in order to enforce the decisions made and guarantee that security of payment is crucial, hence an adjudication act was gazetted.

Table 1. The Implementation of CIPAA

The Implementation of CIPAA
CIPAA helps to ease cash flow of the constractors
Parties in dispute are able to remain confidential
CIPAA encourages professionalism and promotes integrity amongst construction parties
CIPAA provides Legal Remedy to Non-Payment
CIPAA enhances the value of human capital in the construction industry
CIPAA offers lower fees by having adjudication as a method of dispute resolution
CIPAA will improve delivery system by providing quicker dispute resolution

(Source: Hadi et al., 2018)

There are a variety of causes to default in payment, namely cash flow issues due to insufficiencies in client's ability to manage, client's inefficient use of funds, lacking of capital to manage the project, client's lack of success in generating revenue in cases where the houses are not being sold at a rate that was targeted by the client and poor cash flow due to lack of appropriate process application, delay in payment evaluation and delay in certification for the interim certificates and final payment certificate (Ye and Rahman, 2010). Therefore, CIPAA has gazetted in order to tackle the issues of payment in the construction industry. The following entails the preliminary findings of the research in regards to the factors contributed to the payment issues, and limitations of CIPAA implementation.

Factors Contributing to Payment Problems in Malaysian Construction Industry

Ye and Rahman (2010) found that there are eight (8) factors that may lead to payment problems. Meanwhile Sahab and Ismail (2011) identified twelve (12) factors that may lead to the late and non-payment in Malaysian construction industry which are derived from six researches conducted by various researchers. In addition, Azman et al. (2013) identified ten (10) factors that may lead to the late and non-payment in Malaysian construction industry. Table 2 entails the identified factors contributed to the payment issues.

Table 2. Factors that Contribute to Payment Problems

Factors that contribute to payment problems	Source(s)		
	Sahab & Ismail (2011)	Azman et al. (2013)	Ye & Rahman, (2010)
Paymaster poor financial management	/	/	/
Paymaster withholding payment	/		/
Conflict among contracting parties	/	/	
Usage of pay when paid provision	/	/	
Culture and attitude	/	/	
Delay in certification	/	/	/
Disagreement on valuation of work done	/	/	
Inequality of contractual bargaining powers	/	/	
Dissatisfaction of litigation and arbitration	/		

Factors that contribute to payment problems	Source(s)		
	Sahab & Ismail (2011)	Azman et al. (2013)	Ye & Rahman, (2010)
Pyramidal manner or contractual chain	/		
Errors in submitting claims	/	/	
Short of current year's project	/	/	
Technical problems		/	
Paymaster's failure to generate income from sales of houses			/
Delay in releasing retention money			/
Delay in evaluation			/
Scarcity of capital to finance the project			/
Paymaster's ineffective utilization of funds			/

Limitations of CIPAA in the Malaysian Construction Industry

CIPAA stated that the unpaid party will be permitted to proceed to adjudication for any payment issues which is inclusive of payment regarding variation works. Various guidelines have been made known to the public in order to promote compliance with CIPAA provisions. Despite the guideline existence, limitations of CIPAA in managing issues regarding payment are still apparent (Arzlee Hassan et al., 2019). Under Section 15, Section 26 (7) and Section 31 of CIPAA, it is stipulated that court have the ability to allow a stay of the adjudicator's decision in cases where the adjudicator's decision is doubted under various grounds. The following is the situations where an adjudication decision can be dismissed;

- The influence of fraud or bribery in making the adjudication decision
- Natural justice being breached during the proceedings of adjudication
- The adjudication made were partial and biased towards one side of the parties involved
- Excess of jurisdiction by the adjudicator during the proceeding

This concludes that an adjudication jurisdiction is not final. Its non-finality may be open to abuse as parties may use CIPAA to eventually enter litigation by challenging the decision as an attempt to drag out the case (Hassan, Mohammad Kamil and Ejau, 2019). This puts a question on the actual authority and integrity of the adjudication institution as a better way of resolving disputes among construction players (Arzlee Hassan et al., 2019). In addition to that, the grounds as mentioned above can also be considered as a limitation to CIPAA in settling payment issues. An adjudicator may be influenced with fraud or bribery in making his decisions which will lead to a partial and biased decision leaning towards only one side of the parties involved. An adjudicator may also act outside of his jurisdiction during the proceeding which will also lead to biased and partial decisions.

CIPAA's function in the construction industry is seen as mainly to decrease amount of time the parties involved being in a dispute which is unfavourable as there will be wastage of resources being used to solve the dispute (Mohd and Ismail, 2014). Therefore, the biggest purpose of CIPAA is to minimize the impact on the construction project as compared to arbitration or litigation. However, despite that, CIPAA's effectiveness in handling payment disputes highly on depends the adjudicator's competency (Mohd & Ismail, 2014). An incompetent adjudicator will end up wasting resources from the parties involved which defeats the core idea of CIPAA itself.

METHODOLOGY

The selection of the respondents is chosen among G7 contractors based in Klang Valley. The total population consist of 268 contractors as listed on the CIDB website. The emails of each respondent are also obtained from the CIDB website. The sampling method used is by using purposive sampling. Purposive sampling is a non-probability sampling method used to collect data from groups of specific characteristics which in the case of this research, the G7 contractors from Klang Valley. The researcher has divided the collection of data in two levels. During Level 1, the researcher searched keywords such as "CIPAA", "payment delays" and "construction disputes" to gather data during the literature review stage. Meanwhile, during Level 2, the data is collected by distributing questionnaire forms to the respondents.

ANALYSIS OF RESULTS

The data was analysed from the questionnaire responses that was retrieved by the respondents comprises of G7 contractors in Klang Valley. A set of questionnaires had been designed based on the literature review and distributed to the respondents. The questionnaires were distributed to the respondents via email. Data analysis discusses the findings obtained from the questionnaire survey and the division of each section consists of; i) demographic of the respondents, ii) factors that contribute to payment disputes, iii) the implementation of CIPAA in settling payment disputes, and iv) the limitations of CIPAA in settling payment disputes.

Table 3. Response rate of the Distributed Questionnaire

	Number of Distributed Questionnaire Forms	Number of Answered Questionnaire Forms	Precentage of Response Rate
Total	268	112	42%

Table 3 presents the percentage of the survey response rate. Out of 268 distributed questionnaire, 112 questionnaires were returned by the respondents, amounting to 42% of response rate. Overall, the percentage of response rate is within the acceptable percentage and viable to be used in this research. The number of responses received for this questionnaire may be affected by the occurrence of the recent virus outbreak pandemic called Covid-19 countrywide causing an unprecedented situation where all sectors were halted from operating and the people were forced to stay at home. The actual effect of the pandemic on the response rate for research questionnaires may be concluded by other researchers in the future.

Demographic

In terms of profession in the construction industry, the majority of the respondents are among Quantity Surveyors (QS) at 76% while the rest are Project Managers at 20%, Site Supervisors at 2% and Engineers at 2%. The high number of Quantity Surveyors (QS) involved in answering the questionnaire is very favorable and parallel with the topic of this research as in the construction sector, Quantity Surveyors (QS) are involved directly with the process of payment claims and contractual disputes. In terms of years of involvement and experience in the construction industry, close to half of the respondents has 5 to 10 years working experience with 49.1%. Meanwhile, the lowest number of respondents came from respondent with 11 to 15 years of experience amounting to 15.2% in total. However, none of

the respondents have more than 15 years working experience. The results were shown in Table 4.

Table 4. Years of Involvement in the Construction Industry

Working Experience	Frequency (N)	Percentage
Less than 5 years	40	35.7%
5 - 10 years	55	49.1%
11 – 15 years	17	15.2%
More than 15	-	-
Total	112	100

The respondents were also asked in terms of their involvement in CIPAA related matters. Table 5 shows the results of frequency of the respondents' involvement in the area. Based on Table 5, the highest number of respondents have been involved with CIPAA related matters is 53 respondents at 1 time who make up for 47% of the total respondents followed by respondents with 2 times involved with CIPAA related matters at 32 respondents which contributed to 29% of the total respondents. The respondents with 1 time and 2 times involved with CIPAA related matters make up for 76% of the total respondents. Meanwhile, the lowest number of respondents came from the respondent with 6 times of involvement with CIPAA related matters which makes up for 2% of the total number of respondents.

Table 5. Number of Times Involved with CIPAA Related Matters

Number of Times Involved with CIPAA Related Matters	Frequency	Percentage (%)
1	53	47.3
2	32	28.6
3	15	13.4
4	7	6.3
5	3	2.7
6	2	1.8
Total	112	100

Results on the Factors and Limitations of CIPAA

The next section of the questionnaire were entailed to the items on the factors contributed to the payment problems, the implementation of CIPAA and limitations of CIPAA. The respondents were asked in terms of their agreement level on the items based on five Likert-scale (1: Strongly Disagree – 5: Strongly Agree). The results were shown in Table 6, Table 7 ad Table 9 resepectively.

Table 6. Factors Contributing to Payment Problems

Ranking	Factors	Average index
1	Disagreement on the valuation of work done	4.29
2	Delay in valuation and certification of interim payment.	4.07
3	Conflict among parties involved.	4.05
4	Client's withholding of payment.	3.93
5	Local culture/attitude in making payment.	3.82
6	Technical problem.	3.77
7	Client's poor financial arrangement.	3.77

Table 6 shows factors that contributing to payment problems where the highest rank is the factor of disagreement on the valuation of work done at 4.29. This is followed by the factor of delay in valuation and certification of interim payment at 4.07 and the factor of conflict among parties involved at 4.05.The fourth rank is for the factor of client's withholding of payment at 3.93. The factor of local culture/attitude in making payment is 3.82. Meanwhile the factor of client's poor financial management and the factor of technical problems are both the lowest at 3.77.

Table 7. The Implementation of CIPAA in Settling Payment Disputes

Ranking	Implementations	Average index
1	CIPAA allows parties in dispute to remain confidential	4.05
2	CIPAA helps improve the cashflow in the construction industry	3.87
3	CIPAA offers lower fees by having adjudication as a method of dispute resolution	3.79
4	CIPAA ensures fairer risk allocation between the employers and the contractors	3.78
5	CIPAA allows for a swifter dispute resolution.	3.77
6	CIPAA provides legal remedy to non-payment	3.73

In terms of implementation of CIPAA as shown in Table 7, majority of the respondents agreed that CIPAA allows parties in dispute to remain confidential at 4.05. This is followed by CIPAA helps improve the cashflow in the construction industry at 3.79 and CIPAA offers lower fees by having adjudication as a method of dispute resolution at 3.78. The fifth rank is for CIPAA allows for a swifter dispute resolution at 3.77. Meanwhile, CIPAA provides legal remedy to non-payment is the lowest at 3.73.

Table 8. Limitations of CIPAA in Settling Payment Disputes

Ranking	Limitations	Average index
1	Non-finality of an adjudication jurisdiction	4.39
2	Competency of the adjudicator	4.31
3	Biased and partiality in the conduct and judgement	3.79
4	Excess of jurisdiction	3.78
5	Breach of natural justice	3.67

Table 8 shows the highest rank is for non-finality of an adjudication jurisdiction at 4.39. This is followed by competency of the adjudicator at 4.31 and biased and partiality in the conduct and judgement at 3.79. The fourth rank is for CIPAA allows for a swifter dispute resolution at 3.78. Meanwhile, breach of natural is the lowest at 3.67.

DISCUSSION OF RESULTS

As the construction industry involves multiples parties namely contractors, clients and various consultants, the valuation of work done on behalf of the client may be argued by the contractor for being undervalued in comparison to the contractor's own valuation. As shown in Table 6, disagreement on the valuation of work done is the main factor that contributes to payment problems from contractors' perspective. To them, the entitlement of payment upon completing their contractual obligations is highly important to ensure a healthy cash flow (Mohd and Ismail, 2014). Cash flow issues will affect contractor's performance as undervaluation of work done can impose a significant impact on contractor's ability to roll

the money to purchase materials. The progress of the construction project on site also becomes less optimal with the inability of the contractor to hire more workers due to financial constraints.

Valuation of work done is done periodically as agreed beforehand by the parties involved in the contract for the construction project. Typically, a representative of the client evaluates the amount of work done within 15 days of receiving interim claim from the contractor. The valuation of the work done is then processed by the client in order to release the payment to the contractor in the form of interim certificates within 15 days of valuation. Therefore, a typical valuation of claims and certification of interim payment process takes about 30 days. Contractors are obligated to pay to their suppliers for the materials, labors, sub-contractors and their own staff handling the construction project. Most of these are paid on a monthly basis and have been thoroughly calculated by the contractor of his ability to keep afloat by depending on timely payment by the client. A delay in valuation and certification of interim payment will disturb the flow of cash for the contractor. In extreme cases, the contractor may have to resort to bridge financing to accommodate for delay of payment which will inflict unnecessary cost upon the contractor especially in terms of interest.

In the construction industry, every parties involved have differences in terms of interests and specific targets to be achieved in a construction project. Therefore, conflict between stakeholders are inevitable (Mitkus and Mitkus, 2014). In the presence of conflict, when it comes to payment, client may withhold payment as leverage. This is unfair to the contractors as they are entitled to the work done in accordance to their contractual obligations. The only solution for the situation is for both parties to undergo dispute resolution process as conflict between parties can be managed (Mitkus and Mitkus, 2014).However, the dispute resolution process may take a long time to be resolved causing delay in payment thus contributing to payment problems. The minimalization of conflict among parties involved will improve the chances for the construction project to be successful as the contractor will receive payments in timely manner without having to worry about financial issues.

Table 7 shows that parties being able to remain confidential during disputes is the most significant implementation of CIPAA in settling payment disputes. Unlike litigation, disputes between parties can be resolved without attracting unnecessary public attraction as the identities of parties involved will remain confidential. Therefore, this implementation of CIPAA allows the parties to resolve disputes behind closed doors without exposing the names as parties prefer to maintain their good business reputation as it is one of the main traits of a good construction player (Hadi, Othman & Dadi, 2018). Parties may experience bad publicity when choosing the litigation path as the details of the case can be accessible. This may hurt their chances of winning future tenders if there exists a written history of dispute between the parties and may become the dealbreaker when choosing for a tender winner. Thus, CIPAA offering confidentiality is a prominent attraction for parties who want a quiet settlement during disputes.

In Part II of CIPAA, a decision must be provided by the adjudicator handling the case within 45 days. This ensures that the whole process is done in quickly. Improving cash flow is CIPAA's main objective in the construction industry. CIPAA provides a way of resolving dispute without having to go through litigation that will generally take a lot of time thus affecting the flow and quality of construction works as the parties involved cannot focus

effectively on their works and services. As having a good cash flow is of utmost importance for contractors, its ranking position in the table is expected. Going through litigation costs all parties too much resources to the point that one party will end up having to suffer loss. By accelerating cash flow during disputes, CIPAA is recognized of its function in helping to improve cash flow in the construction industry. In comparison to litigation, CIPAA offers lower fees as a method of dispute resolution. Therefore, in contrast with the findings by past researchers where this implementation were ranked last (Hadi, Othman and Dadi, 2018), it seems that throughout the years, contractors are more familiar and aware of the lower cost and short time frame provided by CIPAA.

Under section 28 of the Act, a party who is satisfied with an adjudicator's decision can have them enforced in High Court. Under section 26 (7), section 31 and section 15 also recognized that, if the decision is contested in arbitration or by the court by other procedural rules, the court may also grant a stay of adjudication decision (Arzlee Hassan et al., 2019). Therefore, the admissibility of any challenges to an adjudication decision is made possible thus concludes that an adjudication jurisdiction is not final. In the present, the use of CIPAA since its introduction in 2012 has been well accepted by construction stakeholders. However, its non-finality may be open to abuse as parties may use CIPAA to eventually enter litigation by challenging the decision as an attempt to drag out the case. This puts a question on the actual authority and integrity of the adjudication institution as a better way of resolving disputes among construction players (Arzlee Hassan et al., 2019). The dependency of CIPAA's effectiveness on the competency and integrity of the adjudicators can be considered as a limitation to the statutory adjudication (Mohd and Ismail, 2014). The reasoning behind respondents feeling that the competency of the adjudicator as a major limitation of CIPAA in resolving disputes perhaps come from the lack of explanation in CIPAA's act on the qualifications of an adjudicator. In CIPAA, under section 21, the requirements of someone to become an adjudicator is not specifically mentioned other than with the agreement of the parties in dispute or by the Director of the AIAC.

Therefore, parties in dispute may question the adjudicator's competency if his qualifications on becoming an adjudicator for the case is unclear. Under section 25 of CIPAA, adjudicator's duties and roles can be summarized as (i) overseeing the structure, time and conduct of the proceedings, (ii) managing the production and delivery of all relevant documents within the proceedings, (iii) ordering and carrying out the inquiries and inquisitions required, (iv) awarding costs and other acts deemed important to the proceedings, (v) providing fair and impartial decisions. However, despite impartiality and unbiased being listed among adjudicator's duties and roles, respondents feel that an adjudicator may still be biased and partial in his conduct and judgement thus being considered as a limitation of CIPAA. This may be stemmed from the possibility of foul play between the parties involved when the elected adjudicator is familiar with either of the party which may cause inclinations favoring one side when making decisions.

CONCLUSION

In this research the disagreement on the valuation of work done and delay in valuation and certification of interim payment are the key factors that contributes to payment problems. The finding highlighted that CIPAA allows parties in dispute to remain confidential and helps to improve the cashflow in the construction industry as well as offering lower fees as a method

of dispute resolution. The respondents believe that the introduction of CIPAA gives them confidentiality which is of great importance in order to preserve their good public image which is important for them to bid for future tenders. However, according to Asian International Arbitration Centre (AIAC), more than half adjudication cases are eventually being re-arbitrated and re-litigated, causing more delay in payment. This possibly due to the non-finality of an adjudication jurisdiction and the competency of the adjudicator that might involved element of self-interest such as biased and partiality in the conduct and judgement.

REFERENCES

Ahmad Abdul Jalil, Mastura Jaafar, Md Azree Othuman Mydin, and Azlan Raofuddin Nuruddin (2017) How Industry Players Perceived Payment Issues In Industrialised Building System (IBS) Housing Projects. *Malaysian Construction Research Journal (Special Issue)*, 2(2): 22-35

Arzlee Hassan, A., Hamimah, A., Izz, M. K. A., & Aisyah, A. M. N. (2019) Challenges against Adjudication Decisions on Payment Disputes within the Construction Industry. *IOP Conference Series: Earth and Environmental Science*, *233*(2), 1-10

Azman, M. N. A., Dzulkalnine, N., Kamar, K. A. M., Hamid, Z. A., & Nawi, M. N. M. (2013) Payment Scenario in the Malaysian Construction Industry Prior to CIPAA. *Proceedings of 19th CIB World Building Congress* . Brisbane, 1-10

Fong, C. K., Fong, L. C., & Kheng, O. C. (2014) *Adjudication of Construction Payment Disputes in Malaysia*. LexisNexis.

Hadi, N. A., Othman, M. K. F., & Dadi, A. M. (2018) The Perception on the Importance of Construction Industry Payment and Adjudication Act (CIPAA) 2012 Towards Remedying Payment Disputes: A Research on Subcontractors in Kuching, Sarawak. *IOP Conference Series: Materials Science and Engineering*, *429*(1).

Hassan, A. A., Mohammad Kamil, A., & Ejau, R. L. (2019) A Study on Current Dynamics in Adjudication Implementation in Malaysian Construction through Law Cases Analysis. *IOP Conference Series: Earth and Environmental Science*, *385*(1).

Loo, S.K., Kamarazaly, M.A., Hashim, N., Md Yaakob, A. and Man, N.H. (2019) Analysis On The Issues Of Construction Disputes And The Ideal Dispute Resolution Method, *Malaysian Construction Research Journal (Special Issue)*, 7(2):153-165

Che Munaaim, M.E. (2012) Is Late Or Non-Payment A Significant Problem To Malaysian Contractors? *Journal of Design and Built Environment*, 3(1):35–49.

Mat Isa, C. M., Saman, H. M., & Preece, C. N. (2015) Determining significant factors influencing Malaysian construction business performance in international markets. *Journal of Construction in Developing Countries*, *20*(2):1–23.

Mazani, Q. A., Sahab, S. S., & Ismail, Z. (2019) Trends of Adjudication Cases in Malaysia. *MATEC Web of Conferences*, *266* (03001).

Mohd, D. N. D. N., & Ismail, Z. (2014) Construction Industry Payment And Adjudication Act (CIPAA) Remedying Payment Issues: CIDB G7 Contractor's Perspective. *Journal of Technology Management and Business*, 1(1):21-38

Nasir, N. I. I. M., Ismail, Z., & Muhd Fadlullah Ng, N. K. (2018) Comparative Analysis On Construction Adjudication Systems Towards Effective Implementation Of Statutory. *Malaysian Journal of Civil Engineering*, 30(2):202–216.

Seah, K. (2018) *CIPAA: Adjudication Leading the Way?* The Malaysian Lawyer. https://themalaysianlawyer.com/2018/09/05/cipaa-adjudication-leading-the-way/

Seng, H. and Susy F. R. (2019) Indonesian Contractor Professionals' Perception On Problems In Construction Claim Management, *Malaysian Construction Research Journal,* 27(1):69-78

Sahab, S.S., & Ismail, Z. (2011) Construction industry payment and adjudication Act; Enhancing security of payment in the malaysian construction industry. *Proceedings od 2011 International Conference on Business, Engineering and Industrial Applications (ICBEIA 2011)*, 153–159.

Ye, K. M., & Rahman, H. A. (2010) Risk of late payment in the Malaysian construction industry. *World Academy of Science, Engineering and Technology*, *65*(5):538–546.

THE ASSESMENT OF SIGNIFICANT PASSIVE DAYLIGHTING STRATEGIES IN EDUCATIONAL STUDIO (ES) OF UNIVERSITY BUILDINGS

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Abstract

Malaysian universities face numerous environmental issues in the Educational Studio (ES). This is happened due to varied activities and longer time of occupancy. Owing to unregulated use of artificial lighting, this will raise the electricity bill and generate more energy waste. Daylight Strategy is a method used to increase natural light penetration in ES. Thus, this paper aims to revitalise daylight strategies involving ES in the universities by using Velux Daylight Visualizer Software. The Interior Design Studio is chosen as the case study. This study is carried out in two phases. Phase one is a field study which takes measurement of the site and transforms it into a generic model. Phase two is model simulation through the use of Velux Daylight Visualizer software. The Velux Daylight Visualizer Software is used to demonstrate the state of natural lighting in the generic model with respect to the degree of illuminance and daylight factor. This study found four daylight strategies that were essentially used in universities. They are window, louver, light-shelf, and overhang. Based on the simulation analysis, light-shelf has achieved the best reading for daylight factor and illuminance, as well as meeting the typical educational lighting level standard. Integrating daylight strategies into the ES has allowed the studio to have a higher amount of illuminance as well as brightening the studio with daylight strategies being implemented.

Keywords: *Daylighting strategies; Educational Studio; simulation; Velux Daylight Visualizer.*

INTRODUCTION

In establishing green building design, the key concepts are to create an energy efficient and environmentally friendly building. This is significant with current sustainable concept of development (Zen et al., 2016). In Malaysia, the issue of energy consumption and sustainability has always been associated with lighting since lighting usage is identified to be the second highest reading in electricity consumption after the air conditioning consumption for government buildings (Zakaria et al., 2013). Therefore, in line with the government's initiative to reduce energy consumption for the buildings, many Malaysian institutional agencies, including public universities have started their green related campaign (UTM Sustainable Campus (2016); Centre for Global Sustainability Studies (2016); and IIUM Go Green Committee (2012)).

To achieve a greener university, it is wise to start a smaller step through a strategic phase by phase development. One of the phases is by introducing an efficient way of using lighting in the educational spaces Dahlan & Eissa (2015). One of the criteria to achieve it, is by have a good lighting standard. The good lighting standard is between 300- 400 lux and 1.0% - 3.5% Daylight Factor (DF) (GBI, 2015; MS 1525, 2014). It was mentioned in GBI (2015), the

impact of lighting assessment is significant towards controlling energy consumption in buildings.

Since the usage of artificial lighting during daytime in universities is reported to be the major contribution in increasing annual electricity bills (Tang, 2012), thus it is important to indentify the significant natural daylighting strategies for universities. At the moment, many universities in Malaysia are facing the issues of poor passive daylighting strategies (Abdelatia et al., 2010). This is because most of the windows are tinted or blocked with furniture Abdelatia et al. (2010) claimed that the increased of electricity consumption is due to the excessive lighting usage that will increase the utilities bills in universities.

Many studies have focusing on 'greening' classroom (Dahlan & Eissa, 2015; Beatriz, Moreno & Labarca, 2015; Healthy Schools Network Inc., 2012). However, there are still limited studies on the educational studio (ES) for public university buildings. High frequency of ES usage will lead to higher consumption of electricity energy to lighten the space (Husain et al., 2015). Since most activities are performed in ES more than 12 hours, it will lead to the increasing of electricity bills that will influenc the universities maintenance budget. Therefore, this paper aims to revitalise daylight strategies involving ES in the univesties by using the Velux Daylight Visualizer Software to access and identify the significant daylighting strategies that can help to control the wastage energy consumption.

LITERATURE REVIEW

In order to control the carbon footprints emissions, there is a need to optimise sustainable development and construct a building with green architecture design that have environmentally friendly features (Setyowati et al., 2013). Passive lighting emission is the important criteria in designing green design and it helps in enhancing the suitability and efficiency of the building (Masood et al., 2017; Setyowati et al., 2013). The passive design of educational studio (ES) needs to organise effectively on the daylight aspect in order to have an excellent quality environment for ES. Sufficient amount of daylight penetrated into ES can positively affect on health of the students (Hassanain & Mohammed, 2014). Besides, daylight element also enhances the students' performance and productivity in creating a creative design for their assignment (Abdelhakeem et al., 2015).

Educational studio (ES) is a space for design based-student gathered for implementing the process of design phase of the project given (Bakhshi et al., 2015). In this space, students will develop their learning process such as drawing projection, exercises on grammar of design, making model and visual composition. Moreover, ES will provide a place for students in sharing information, learning and interacting with their studio mates (Husain et al., 2015). ES is the most important space for students to develop their learning process (Othman et al., 2017). This is where the lighting aspect is crucial. High frequency of ES usage will lead to higher consumption of electricity energy to lighten the space (Husain et al., 2015). Al-mohaisen & Khattab (2015) has highlighted that the operation and maintenance cost will increase due to the high electricity usage in buildings. There is a need to empower daylight strategies for ES; in order to allow energy to be utilised effectively and ultimately, to achieve greener ES.

Good daylighting strategies can reduce the energy operating and maintenance costs, by extending the lamps and luminaries life. By reducing the use of electricity lights at 50%, their life span will be doubled and associated maintenance cost will be cut in half (Costanzo et al., 2017). Thus, daylighting strategies are the significant solutions for creating greener spaces and allowing energy efficiency in a university.

The used of daylight and integration of daylight strategies could be one of the sustainable design approaches which is specific for ES. This is because since the sunshine duration is relatively longer in Tropical region compared to other regions in the globe (Mangkuto, Rohmah, et al., 2016), different duration for sunshine can lead to diverse needs of daylight for each region. However, high tropical daylight will cause discomfort glare and non-uniform daylight distribution, which resulting to great contrast and visual discomfort (Lim et al., 2012). Due to this, the plethora of daylight has not been fully utilised especially in ES. Therefore, there is a need to access and recommend significant daylight strategies to ensure that daylighting can be fully illuminated in the ES space.

Based on data presented in Table 1, it is found that the most prominent daylight strategies for Asia are, (i) window, (ii) louver, (iii) light shelf, (iv) skylight, and (v) overhang. Daylight strategies are categories in four different criteria (Zain-Ahmed et al., 2002). The criteria are (i) penetration, (ii) distribution, (iii) protection, and (iv) control.Window is regarded as one of the most important parts in building architecture (Mangkuto, Asri, et al., 2016) . It is important to provide window in ES because window act as one of the methods for daylight penetrated in the ES (Supansomboon & Sharples, 2014). While Dahlan & Eissa (2015) state that window also plays significant roles which are to diffuse daylight, direct daylight entrance and view to the outside environment.

Table 1. Summary of Ranking for Natural Daylighting Strategies

Ref	Daylight Strategies Types	Country Types		Total	Rank
		Non-Southeast	Southeast		
1	Light shelf	9	17	26	3
2	Window	20	68	88	1
3	Skylight	10	15	25	4
4	Open / translucent balustrade	1	0	1	8
5	Radiant barrier at the roof	1	2	3	7
6	Louver	11	18	29	2
7	Sloping metal roof	1	0	1	8
8	Overhang	4	14	18	5
9	Laser-cut panels	1	0	1	8
10	Cutting-edge techniques	1	0	1	8
11	Tint	1	0	1	8
12	Tubular daylight devices	2	8	10	6
13	Exterior shading and control devices	1	2	3	7
14	Dormers	1	2	3	7
15	Innovative roofing system)	0	1	1	8

Louver is known as one of the daylight strategies that can be used as shading device. Li et al. (2016) acknowledge that the proper used of louvers as shading device in ES space will improve the thermal comfort, reduce the cooling energy consumption, protect building envelope and provide pleasant daylight and views in the ES. Light shelf is known as one of

the natural daylighting strategies used in the world. Light shelf has shown the best light-redirecting device installed on the outside and one of the methods for exploitation of daylight in educational institution especially studio (Meresi, 2016). Light shelf is used to allow daylight and redistributing it by reflection or bounce. The daylight will be distributed to the deepest area of the room (Kurtay & Esen, 2017).

Skylight is one of the most widely used daylight strategies around the world. Daylight penetrated through skylight is more uniform distributed (Al-Obaidi et al., 2014). This is because it is less obstructed due to it is placed at the upper part of the building. It also has higher light intensity and could read the middle space of the studio (De Luca et al., 2017). Overhang is part of roof structure projected on the vertical wall of the building (Comfortable Low Energy Architecture, 2004). Overhang is the most reliable daylight strategies to be used especially in tropical climate condition (Sghiouri, Mezrhab, Karkri, and Naji, 2018). The overhang is functionable to provide shade and shield direct daylight penetrate in the studio (Department of Education, 2010). It is also suitable to reduce, minimise and adjust the amount of direct daylight and heat gain that reaches indoor spaces (Lee et al., 2018).

THE RESEARCH METHODOLOGY

This study is carried out in two phases. Phase one is a field study that takes measurement of the site and transforms it into a generic model. Phase two is model simulation through the use of Velux Daylight Visualizer Software. The selected case study is UiTM Perak (see Figure 1). For this case study, it has been reported that the highest electricity consumption has been recorded in the case study came from the Faculty of Architecture, Planning and Surveying (FSPU). This buildings are reported to use artificial lighting for 24 hours per day. This is due to the factor that the faculty has design studios. Therefore, the ES of the Interior Design department is chosen as the case study.

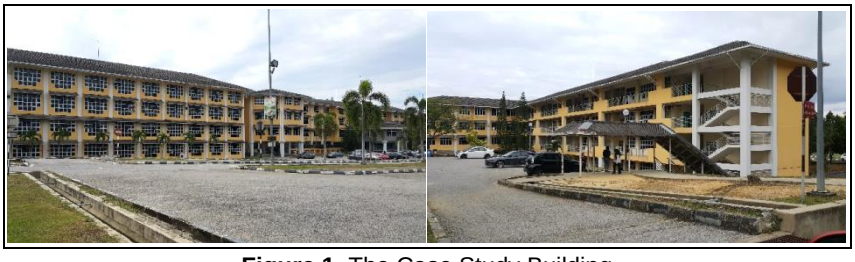


Figure 1. The Case Study Building

Phase 1: Field Study

The measurements were taken using measurement tape and manual sketches. Drawing measurement has been performed by taking every single dimension of the model. The dimension component that has been measured for the model is based on the following:

i. Studio layout plan (size and area)
ii. Studio ceiling height
iii. Studio window (size, height from the floor and opening area)

All components dimensions have been composed in the AutoCAD software and technical drawings have been produced. The technical drawings are, (i) floor plan drawings, (ii) elevation drawings and (iii) window openings drawing. Figure 2 presents the plan and elevation of the Model, including the types and quantity of openings inside the model.

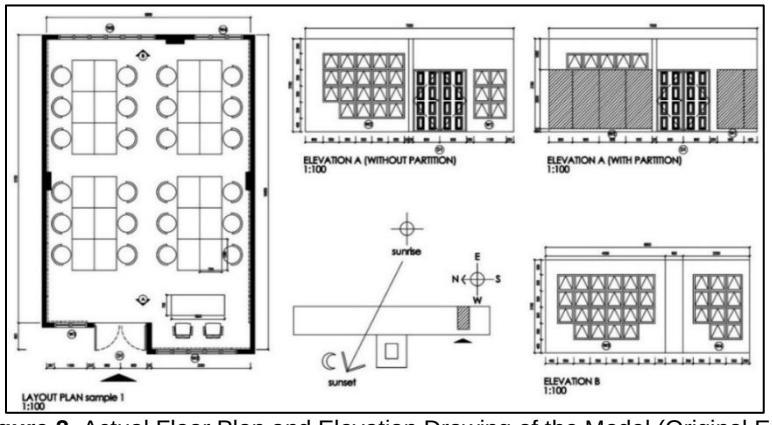


Figure 2. Actual Floor Plan and Elevation Drawing of the Model (Original ES)

The total floor area for this Model is 100.08 m2, with approximately 24 pax of students per studio in one semester. The ceiling height is 3150 mm. The furniture in this studio are the (i) students' drafting table with the drafting chair, and the (ii) lecturer's table with normal chair. There are two (2) types of openings, (i) a two-panel door and (ii) top hung windows. The quantities of the openings in the Model are listed as below:

i. Door - One (1) with the size of 1800mm X 2100mm.
ii. Window – 58 numbers, with size of 550mm X 550mm. The window set is categorised as Type 1, Type 2, Type 3 and Type 4.
iii. Type 1 has 6 windows set,
iv. Type 2 has 19 windows set,
v. Type 3 has 22 windows set,
vi. Type 4 has 11 windows set.

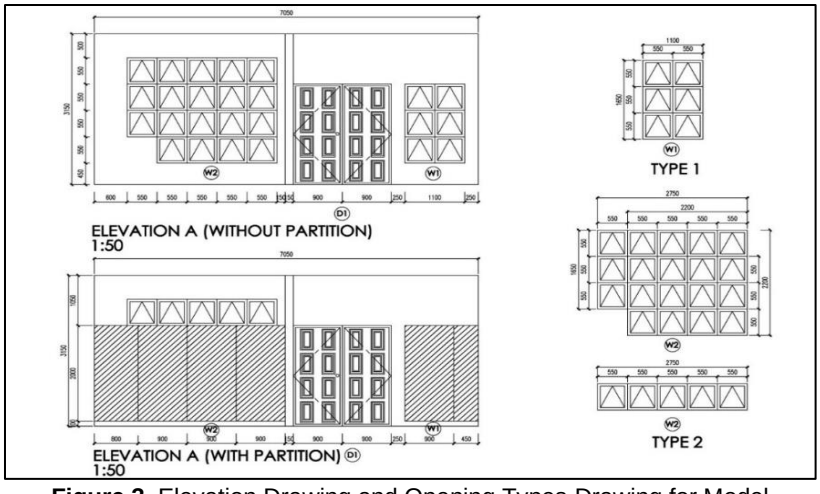


Figure 3. Elevation Drawing and Opening Types Drawing for Model

However, the fully functional window set is only for Type 3 and Type 4 windows. Type 1 and Type 2 were blocked with presentation partition boards (See Figure 3 and 4).

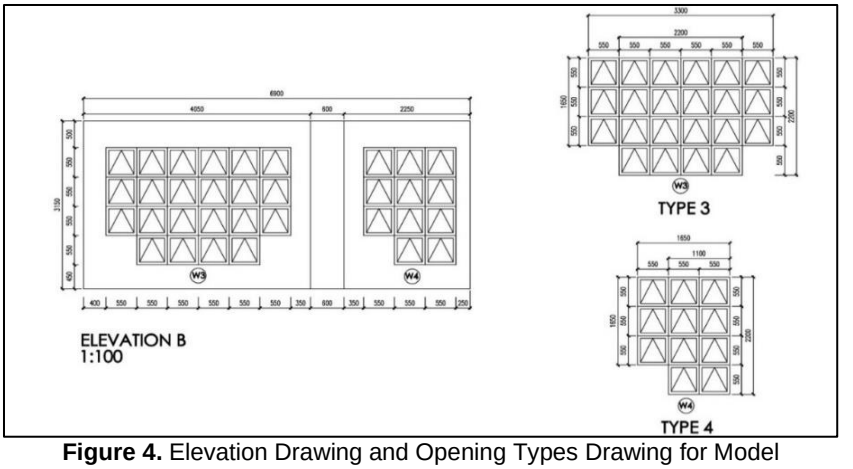
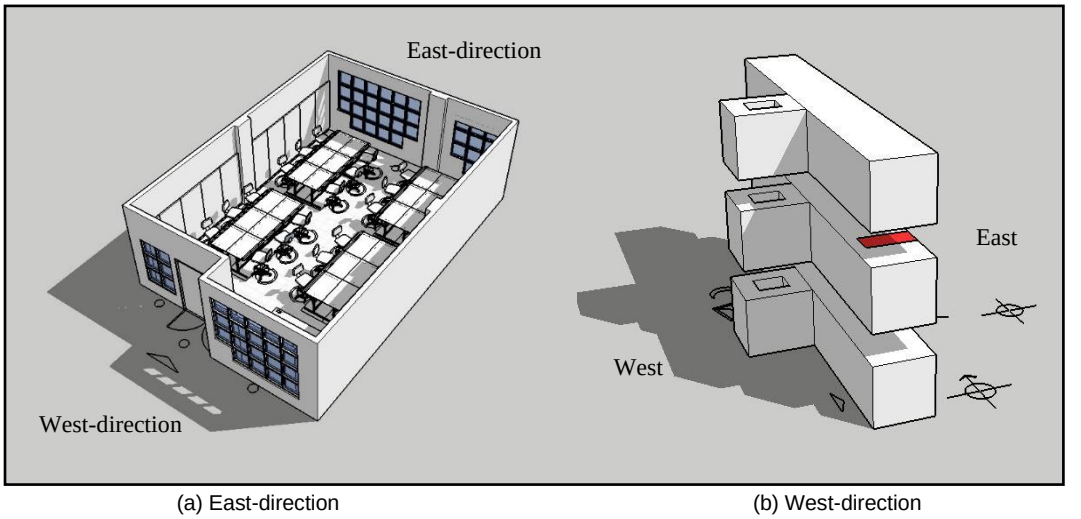


Figure 4. Elevation Drawing and Opening Types Drawing for Model

Phase 2: Model Simulation

The modelling stage is performed by building up the typical generic modelling for the model. The model is constructed in Sketch Up software based on the technical drawing produced in previous field study measurement (floor plan drawing and elevation drawing). The case study modelling is produced to highlight the natural daylighting penetration and the shadow assessment inside the model on the existing environment that is oriented based on East and West direction (refer Figure 5).



(a) East-direction (b) West-direction

Figure 5. Isometric View for the Model

Figure 6. Interior View for the Model

Figure 6 shows the interior view of the Model that has been constructed in the Sketch Up software modelling. The model received highest natural daylighting penetration through the east-direction window of the model. The windows (Type 3 and Type 4) (refer Figure 4) are facing direct to the sunrise which received maximum sunlight intensity from 8 am until 12 pm. At the same time, Window (Type 2) (refer Figure 3) only received slight amount of sunlight intensity during the evening, since it is located at the West-direction of the building.

For the simulation purposes, the model is being tested and simulated by using Velux Daylight Visualizer software. All design variables are shown In Figure 7.

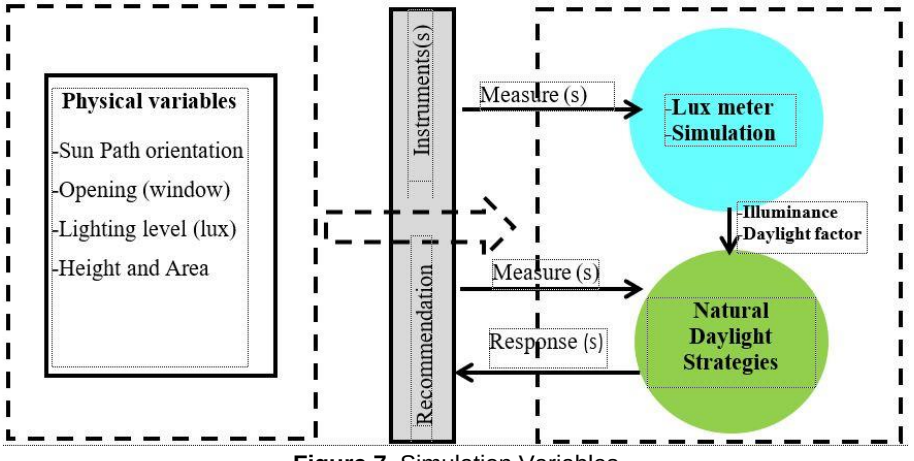


Figure 7. Simulation Variables

The simulation for the generic model has been simulated in Velux Daylight Visualizer software based on the location of placement (refer Figure 8)The Velux Daylight Visualizer software is used to demonstrate the state of natural lighting in the generic model with respect to the degree of illuminance and daylight factor. Velux Daylight Visualizer software is recommended by several scholars (Mardaljevic & Christoffersen, 2017; Vishwas & Soori, 2012). The generic model has been simulated with four (4) daylight strategies such as the (i) Window Base Case (WBC), (ii) Light Shelf (LS), (iii) Louver device/ Egg- crate device (LO) and (iv) Overhang (OV).

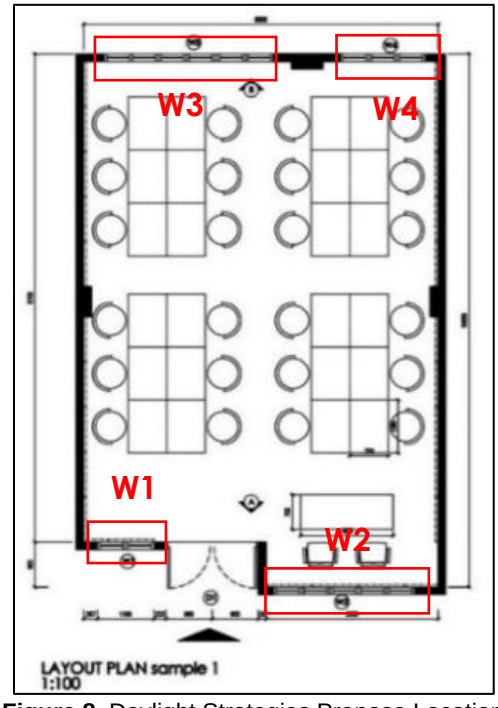


Figure 8. Daylight Strategies Propose Location

RESULTS AND DISCUSSION

The simulation process has been conducted for 7 days. The result for the simulation is been shown through (i) daylight factor (DF) aspect and (ii) illuminance aspect. This simulation process has shown types of daylighting strategies that can gain optimum daylighting and types of strategies that have less lighting penetration capability.

In the simulation process, there are three (3) types of indicators used to aid the illuminance and daylight factor (DF) results, as shown in Figure 9a, 9b and 9c. For the illuminance result; 1) blue is perceptible, 2) green is acceptable, 3) yellow is tolerable and 4) red is intolerable. For the DF simulation results, 1) blue is acceptable, 2) green is acceptable, 3) yellow is tolerable and 4) red is intolerable. The simulation analysis is shown in Table 2.

Figure 9(a)
Illuminance Iso Contour Indicator

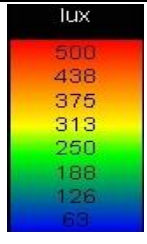


Figure 9(b)
Illuminance False Colour Indicator

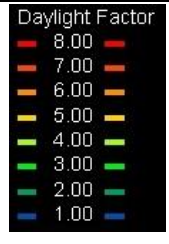


Figure 9(c)
Daylight Factor Indicator

Figure 9. Simulation Indicators

Based on Table 2 and Table 3, it appeared that among four daylighting strategies, LS strategy obtains the highest illuminance receive in the model compared to another daylight strategies. This can be seen based on the amount of red colour indicated during the simulation.

In addition, among the three-time phases (morning, afternoon and evening) assessment, afternoon time phases received the highest amount of illuminance in the model with 1530lux at the location near to the Window 3 and 4 (see Figure 8). The second strategy that receives highest illuminance is the WBC strategy. WBC strategy also recorded the highest illuminance during afternoon time phase with 1300lux at the location near to the Window 3 and 4 (see Figure 8).Third is the OV strategy. It also obtains the highest illuminance during afternoon time phase with 1140lux at the location near to the Window 3 and 4 (see Figure 8). Lastly, is the LO strategy. It obtains the least amount of illuminance recorded at all three-time phase studied with 100lux at the location near to the Window 3 and 4 (see Figure 8).This can be seen from Table 2 and Table 4, where there is only blue colour indicator presented in the simulation model.

Table 2. The Result of Window Base Case and Another Significant Strategies

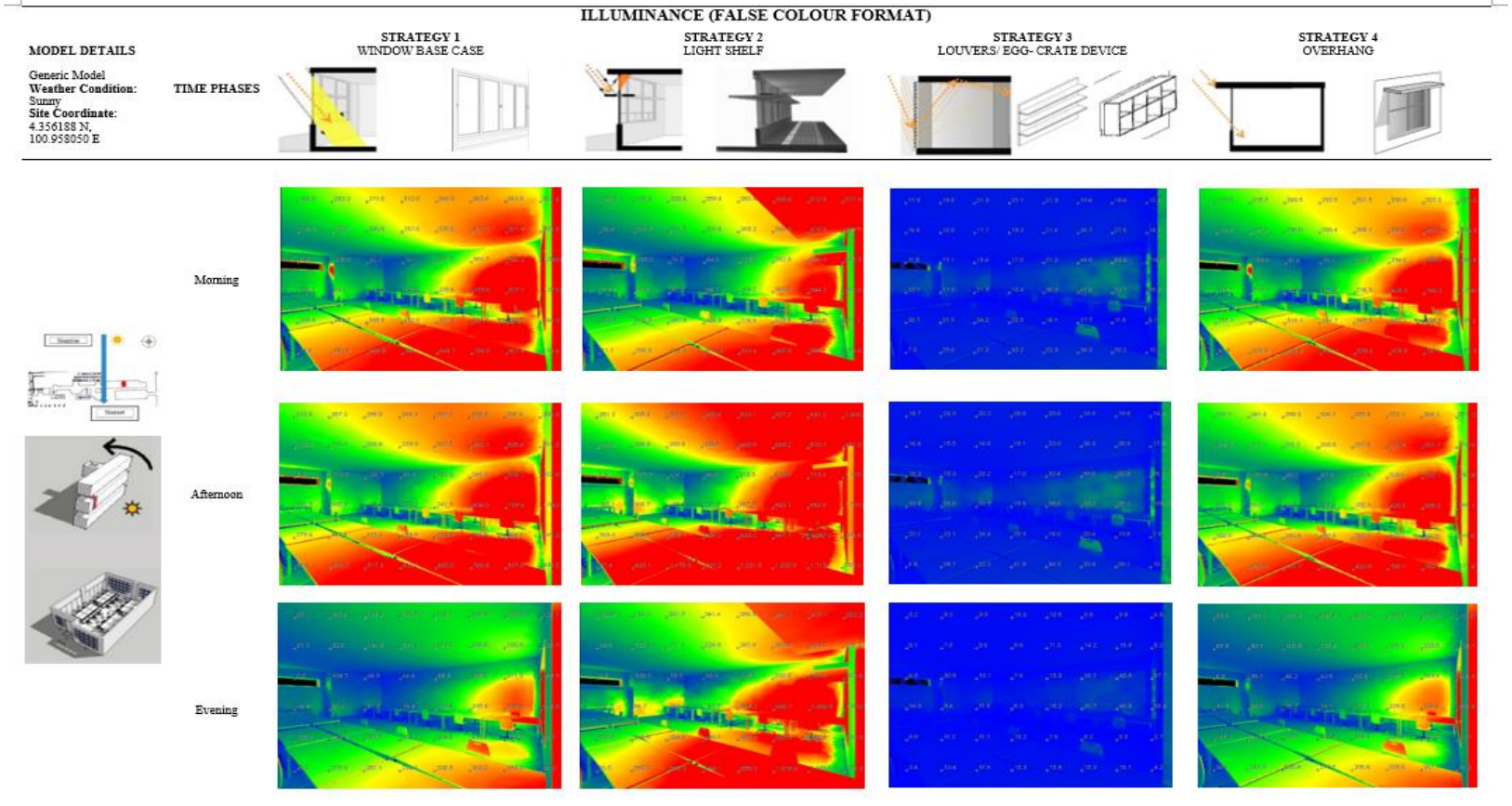


Table 3. Simulation Analysis Illuminance (ISO Contour Format)

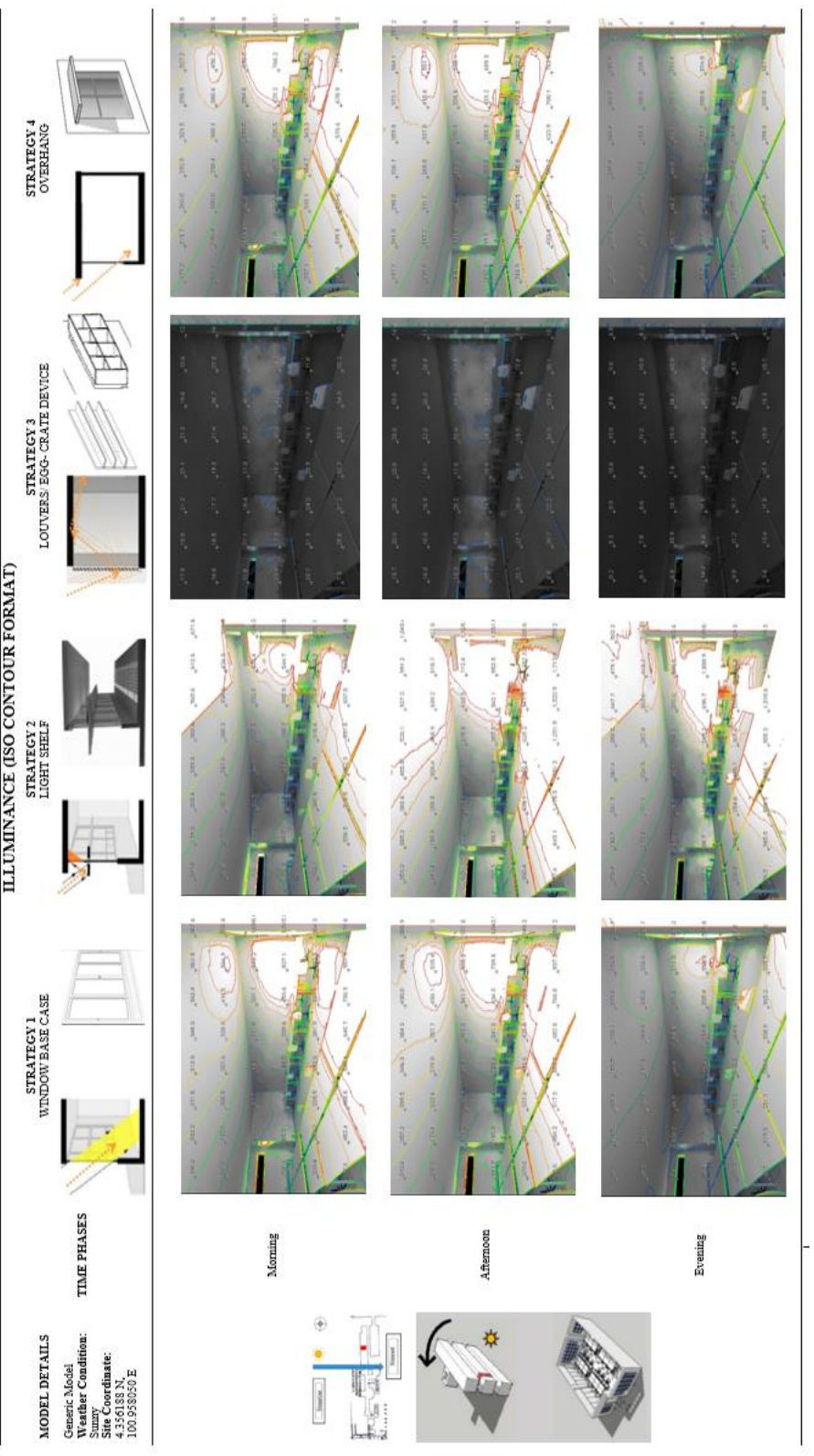


Table 4. Simulation Analysis DF (Iso Contour Format)

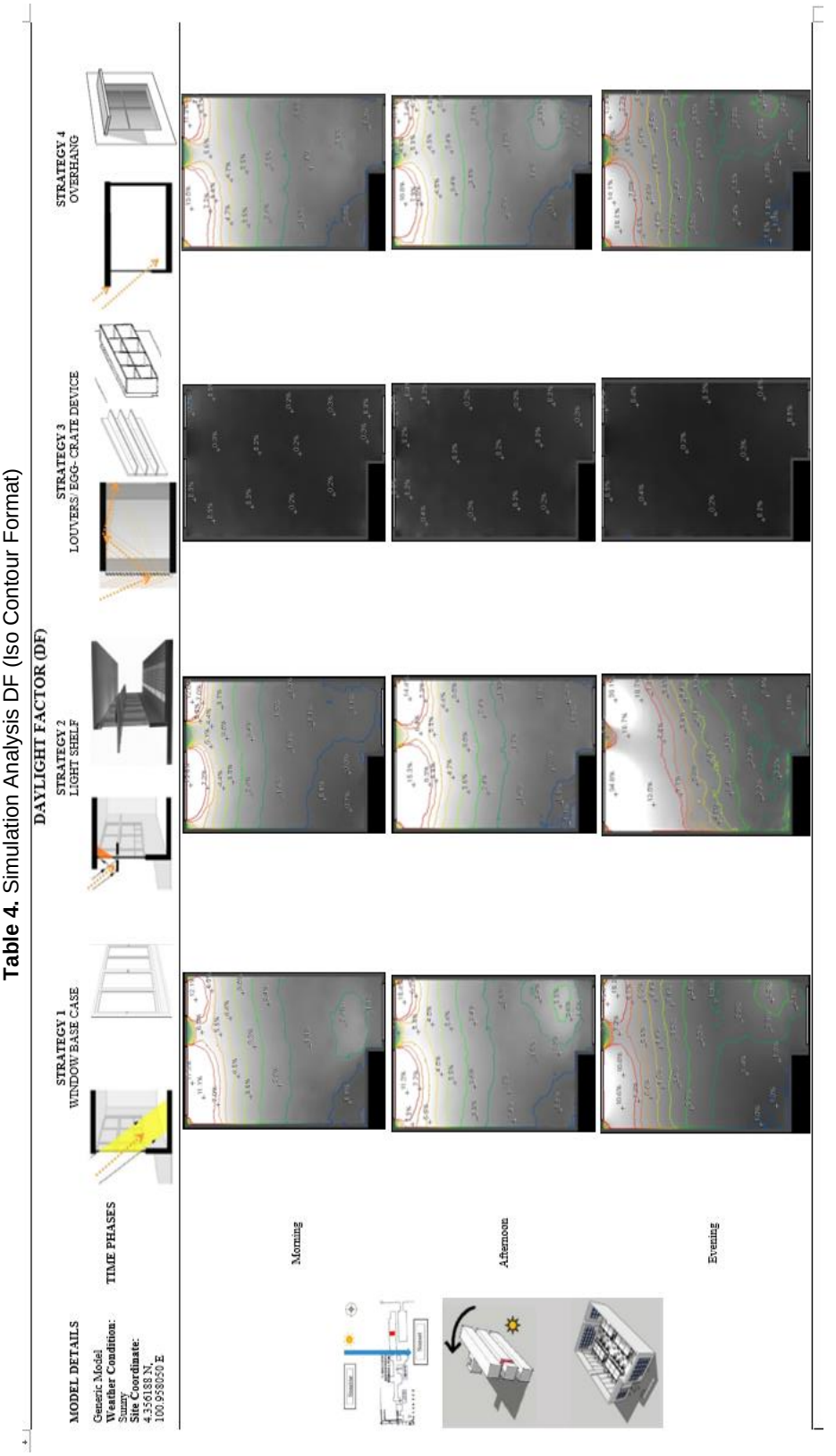


Figure 10. Visual Description

Based on the result in Table 2 and Table 4, it shows that there is a significant relationship between illuminance and daylight factor (DF) level with the daylight strategies simulation. On the other hand, as for the DF simulation, it is also found that LS strategy gains the highest DF value among the three-time phase, as shown in Table 4. This result implies that LS strategies is the significant passive daylighting strategies that can be used in this building. However, during morning time-phase, the DF value is low rather than readings recorded during afternoon and evening time-phase. The second highest DF value is WBC strategy followed by OV strategy and lastly, the LO strategy. Figure 10 shows the final result of the visual description of the suggested daylight strategies for ES in UiTM Perak.

CONCLUSION

Based on the simulation analysis, light-shelf has achieved the highest reading for daylight factor and illuminance of this research, as well as meeting the typical educational lighting level standard. Integrating daylight strategies into the ES has allowed the studio to have a higher amount of illuminance as well as brightening the studio with daylight strategies being implemented. This will subsequently reduce the carbon footprint in the ES and eventually reduce carbon footprint for the university. Finally, this research intends to highlight to other researchers on the study of the passive natural daylighting for ES by using various types of natural daylighting strategies towards achieving a sustainable university.

REFERENCES

Abdelatia, B., Marenne, C., & Semidor, C. (2010) Daylighting Strategy for Sustainable Schools : Case Study of Prototype Classrooms in Libya. *Journal of Sustainable Development*, 3(3):60–67.

Abdelhakeem, M., Aminu, D. Y., & Kandar, M. Z. (2015) Investigating Use of Daylight in a Typical Algerian Public Classroom Typology. *Jurnal Teknologi (Sciences & Engineering)*, 77(15):21–30.

Al-mohaisen, A., & Khattab, O. (2006) Green Classroom : Daylighting-conscious Design for Kuwait Autism Center. *Global Built Environment Review (GBER)*, 5(3):11–19.

Al-Obaidi, K. M., Ismail, M., & Abdul Rahman, A. M. (2014) A study of the impact of environmental loads that penetrate a passive skylight roofing system in Malaysian buildings. *Frontiers of Architectural Research*, 3(2):178–191. https://doi.org/10.1016/j.foar.2014.03.004

Bakhshi, M., Othman, N., & Wahab, M. H. (2015) Green campus in promoting green open spaces in University Technology Malaysia Kuala Lumpur campus. *Proceedings of International Joint Conference Senvar-Inta-Van*, 24–26.

Centre for Global Sustainability Studies (2016) *Green approach*. Retrieved June 20, 2016, from http://www.usm.my/index.php/en/

Comfortable Low Energy Architecture. (2004) *Use of Overhangs*. Retrieved June 20, 2016, from https://www.new-learn.info/packages/clear/visual/buildings/elements/exterior/overhang.html

Costanzo, V., Evola, G., & Marletta, L. (2017) A Review of Daylighting Strategies in Schools: State of the Art and Expected Future Trends. *Buildings*, *7*(2)(41):1-21

Dahlan, A. S., & Eissa, M. A. (2015) The Impact of Day Lighting in Classrooms on Students ' Performance. *International Journal of Soft Computing and Engineering*, 4.1.6*:* 1–4.

De Luca, F., Simson, R., Kurnitski, J., & Voll, H. (2017) Daylighting and energy performance design for single floor commercial hall buildings. M*anagement of Environmental Quality An International Journal*, 29(4):722-736

Department of Education (2010) *Educational Facilities Manual - Revised Edition of the 2007 Handbook on Educational Facilities - Integrating Disaster Risk Reduction in School Construction*. Retrieved 15 August 2020, from from http://geocities.ws/depedoroquieta/2010%20Educational%20Facilites%20Manual.pdf

Green Building Index. (2015) *GBI Assessment Criteria Contents* (Issue January).

Hassanain, M. A., & Mohammed, M. A. (2014) A multi-phase systematic framework for performance appraisal of architectural design studio facilities. *Facilities*, 30(7/8):324-342.

Huang, Y., Niu, J. L., & Chung, T. M. (2012) Energy and carbon emission payback analysis for energy-efficient retrofitting in buildings - Overhang shading option. *Energy and Buildings*, *44*(1):94–103.

Husain, F. H., Husri, Z., Amani, F., Campus, S. I., Darulridzuan, P., Campus, S. I., & Darul, P. (2015) Environmental Psychology : An Analysis on Lighting Efficiency of the Architecture Studio in UiTM Perak. *Proceedings of Postgraduate Conference on Global Green Issues (Go Green), Malaysia*, 113–118.

IIUM Go Green Committee (2012) *Go Green Campaign*. Retrieved 15 August 2020, from http://www.iium.edu.my/sports/events/go-green-campaign-2011

Kurtay, C., & Esen, O. (2017) A new method for light shelf design according to latitudes: CUN-OKAY light shelf curves. *Journal of Building Engineering*, 10:140–148.

Lee, H., Jang, H. I., & Seo, J. (2018) A preliminary study on the performance of an awning system with a built-in light shelf. *Building and Environment*, 131:255–263.

Li, L., Qu, M., & Peng, S. (2016) Performance evaluation of building integrated solar thermal shading system: Building energy consumption and daylight provision. *Energy and Buildings*, 113:189–201.

Lim, Y. W., Kandar, M. Z., Ahmad, M. H., Ossen, D. R., & Abdullah, A. M. (2012) Building facade design for daylighting quality in typical government office building. *Building and Environment*, *57*:194–204.

Mangkuto, R. A., Asri, A. D., Rohmah, M., Nugroho Soelami, F. X., & Soegijanto, R. M. (2016) Revisiting the national standard of daylighting in Indonesia: A study of five daylit spaces in Bandung. *Solar Energy*, 126:276–290.

Mangkuto, R. A., Rohmah, M., & Asri, A. D. (2016) Design optimisation for window size, orientation, and wall reflectance with regard to various daylight metrics and lighting energy demand: A case study of buildings in the tropics. *Applied Energy*, 164:211–219.

Mardaljevic, J., & Christoffersen, J. (2017) Climate connectivity in the daylight factor basis of building standards. *Building and Environment*, 113:200–209.

Masood, O. A. I., Al-Hady, M. I. A., & Ali, A. K. M. (2017) Applying the Principles of Green Architecture for Saving Energy in Buildings. *Proceedings of International Conference – Alternative and Renewable Energy Quest (AREQ 2017)*, 369–382.

Meresi, A. (2016) Evaluating daylight performance of light shelves combined with external blinds in south-facing classrooms in Athens, Greece. *Energy and Buildings*, 116:190–205.

MS1525 (2014). *Energy Efficiency Code of Practice. Malaysian Standards (MS) 1525:2014*.

Othman, M. A., Ahmad, N. A., & Md Ajis, A. (2017) Daylighting Strategies For A Green Design Studio In Malaysia University. *Proceedings of the 1st Green Environmental Energy and Building Science (GEEBS) International Conference 2017*, 41–50.

Setyowati, E., Rochma, A., & Nurul, Y. (2013) Green Building Design Concepts of Healthcare Facilities on the Orthopedic Hospital in the Tropics. *Procedia - Social and Behavioral Sciences*, 101:189–199.

Sghiouri, H., Mezrhab, A., Karkri, M., & Naji, H. (2018) Shading devices optimization to enhance thermal comfort and energy performance of a residential building in Morocco. *Journal of Building Engineering*, 18:292-302

Supansomboon, S., & Sharples, S. (2014) The Impact of Tropical Classroom Facade Design Alternatives on Daylight Levels and Cooling Energy Consumption. *PLEA 2014 - 30th International Plea Conference*, *December*, 16–18.

Tang, F. E. (2012) An energy consumption study for a Malaysian university. *International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering*, *6*(8):99–105.

UTM Sustainable Campus (2016) *Creating a Sustainable Campus Culture: Green and Sustainable Campus*. Retrieved 15 August 2020, from https://www.utm.my/sustainable/introduction/

Vishwas, M., & Soori, P. K. (2012) Simple Tool for Energy Analysis of Day Lighting and Artificial Lighting for a Typical Office Building Lighting System Design. *International Journal of Energy Engineering*, 2(6): 332-338

Zain-Ahmed, A., Sopian, K., Zainol Abidin, Z., & Othman, M. Y. H. (2002) The availability of daylight from tropical skies - A case study of Malaysia. *Renewable Energy*, *25*(1):21–30.

Zakaria, R., Amirazar, A., Mustaffar, M., Mohammad Zin, R., & Abd Majid, M. Z. (2013) Daylight Factor for Energy Saving in Retrofitting Institutional Building. *Advanced Materials Research*, 724–725:1630–1635.

Zen, I. S., Subramaniam, D., Sulaiman, H., Saleh, A. L., Omar, W., & Salim, M. R. (2016) Institutionalize waste minimization governance towards campus sustainability: A case study of Green Office initiatives in Universiti Teknologi Malaysia. *Journal of Cleaner Production*, 135: 1407–1422.

BUILDING ORIENTATION SELECTION FOR FIELDWORK MEASUREMENT ON THERMAL COMFORT IN RESIDENTIAL BUILDING

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Abstract
Building orientation is a critical consideration of architecture, primarily concerning solar radiation and wind. In terms of thermal comfort, building orientation has a significant influence. Buildings should be oriented to reduce solar gain and optimise comfort mainly in hot, humid regions, such as Malaysia, receiving sunlight throughout the year. Therefore, because most people spend their time inside the house, residential buildings must be oriented in the best direction to get more comfort for their occupants. The study aims to determine the effects of orientation towards thermal comfort condition and occupant satisfaction in low-cost detached housing. Meanwhile, this paper aims to review the research method to determine the orientation for the fieldwork measurement of thermal comfort. There are various orientations used by previous researchers. This study will provide strong evidence that there is a method for selecting building orientation for thermal comfort fieldwork measurement. Thus, this paper employed the Systematic Literature Review (SLR) to get the best solution to determine the orientation for the fieldwork experiment on thermal comfort.

Keywords: *Building orientation; low-cost house; method of orientation; residential building; Systematic Literature Review (SLR).*

INTRODUCTION

Building orientation is essential to its overall comfort and occupant satisfaction of the building. A properly oriented building may reduce heating and cooling while maintaining comfort to its occupants (EcoWho, 2017). Building orientation strongly correlates with wind direction and sun radiation (Al-Obaidi & Woods, 2016). Every region in the world has a specific climatic behaviour; some places may be too hot or too cold and between for others. Prior to every construction, there is a crucial decision to determine the building location; the orientation.

Malaysia is a tropical country described as warm and humid within the Capricorn and Cancer Tropics, with the latitude of 1° - 7°N and longitude 100° - 119°E. Malaysia is considered a tropical rainforest climate in which low-pressure systems mainly characterise it because doldrums dominate it; thus, receiving rainfall throughout the year. It is a hot and humid country, particularly in major cities and towns (Al-Tamimi et al., 2011). The climate elements are categorised as high temperature and uniform diurnal pattern throughout the year. It will turn the building to its most important side to ensure occupants (users) will have the best living conditions even when the weather outside is not too conducive (Anumah & Anumah, 2017). In the tropics, buildings should maximally avoid direct sun and try to make a barrier between it and living space.

In most of the time, people spend 90% of their time indoor than outside the building (Juangjandee, 2017). Therefore, building orientation is important that need to be taken into consideration when determining the orientation of the building because the orientation of the building will affect the thermal performance of the building by reducing the direct sunlight in the building (Al-Tamimi et al., 2011). Hence, directly it will affect the occupant's satisfaction inside the building.

Building orientation is an important parameter affecting the degree of solar radiation obtained on a building façade, and solar radiation is a primary factor influencing the cooling load in buildings (Alshayeb et al., 2015). The amount of solar radiation which the building envelope receives depends on its orientation (Al-Obaidi & Woods, 2016). Building orientation also a parameter to express the correlation of a building's front facade relative to the sun's trajectory, which has a significant impact on the performances of indoor air temperature and also the comfort (Fallahtafti et al., 2015).

Many of the research studies were studied on the building orientation for the energy saving, but not many on the research were reviewed on the method how to determine the correct way of building orientation. There are still lack of research on the building orientation. Therefore, in this paper, the method of determining the orientation of the building and the best selection of orientation for fieldwork measurement were reviewed. There are many researchers used different orientation towards their studies, however, the purpose of this paper is to determine the best selection of orientation for the fieldwork measurement. In addition, this paper will show the method of previous researchers used to determine the orientation for their studies. This factor will be discussed and explore using systematic literature review.

LITERATURE REVIEW

Residential Building

In most urban areas of developed nations, the world's population is growing and increasing. Therefore, the need for sufficient shelter has been an issue requiring urgent attention. Hence, shelter constitutes one of the basic needs of humanity that must be covered. The shelter should be not only sufficient but qualitative too. Residential efficiency is fundamentally a vital part of well-being because it impacts people's well-being, profitability, productivity, lifestyle, and decencies of their lives. Housing is a dynamic commodity that serves as a shelter and is important in economic and welfare growth at a national level (Sale, 2013).

Nowadays, the trend is to design and realise residential buildings that will be desirable in design, with low buying and operating costs, which are also energy-efficient. There is a need to build quick, efficient, and environmentally friendly buildings. One of the basic human needs - the need for accommodation - should be fulfilled by residential houses. This reality raises the question of what future owners want from their new houses for buyers or developers (Sirochmanová et al., 2016).

Low Cost House

A low cost house for low rise building comprise of terraced houses, detached house and the building that consist of two storey (Ibrahim et al., 2014). A low cost housing also called as affordable house. Housing affordability is a concept that interprets socioeconomic and development environments. It is considered as a household selection decision function between housing and non-housing product expenditure (Suraya, 2015). Housing affordability is referred to as the rent-to-benefit ratio or the house-to-income ratio known as the affordability of property; more complex metrics are affordability of sales, affordability of repayments and affordability of life-time profits (Zainon et al., 2017). Families are provided with affordable housing that can be afforded by a range of very low to middle income-earner groups. Housing is considered sustainable because it is able to consume more than 30 per cent of its income without spending (Osman et al., 2017). Ling and Almeida (2016) describe affordable housing as a low-cost accommodation with an appropriate place and condition in which the price does not surpass or preclude the residence's basic everyday needs.

The standard of low-cost housing in Malaysia has not been upgraded compared with other housing categories. One reason for implementing affordable housing in Malaysia was the residents' dissatisfaction with the quality of low-cost housing (Musa et al., 2015). Despite the efforts of the government, the quality of low-cost housing is still unsatisfactory, but there are still complaints about Malaysia's housing indoor environmental quality. The causes include the building standards, planning layouts, materials' quality and thermal comfort (Hanafi 2014; Isnin et al., 2012). However, the rapid growth of affordable housing development does not guarantee the quality of life within the affordable housing community. Several aspects of the affordable housing especially on the indoor environmental quality especially related to thermal comfort are still under research and are not considered during the design process (Hanafi, 2014).

Building Orientation

In Malaysia, the east and west facades expostulate each morning and evening to direct sunlight. Meanwhile, the north façade faces sunlight during May, June, July, and August, and the south façade faces it during November, December, January, and February. Therefore, building orientation should be taken seriously, especially in the tropical region, in terms of its interaction with solar radiation and wind direction (Al-Tamimi et al., 2011). As mentioned by Kamali (2014), the efficient cross-ventilation under local wind direction in hot, humid regions is the primary factor affecting building orientation.

The amount of solar radiation, depends on its orientation which the building envelope receives. Knowledge of solar radiation propagation due to its orientation is an important clue in creating energy-efficient facades. Buildings must be scheduled to benefit from shaded indoor and outdoor living areas when the weather is hot. The sun's high angle makes it easy to shade the house through a generous overhang to the roof. The sun is much lower in the sky and favours the vertical surface during the day (Al-Obaidi & Woods, 2016).The façade orientations with different zones are typically divided into east-facing, south-facing, west-facing, and north-facing; however, few studies focus on multiple orientations (Kwon et al., 2019).

The orientation of a building is a contributing factor on how much energy it would use to provide thermal comfort for its occupants. The amount of sunshine that enters an interior space is affected by the building orientation. Therefore, the level of productivity and human health is strongly influenced by local climatic conditions. Building orientation also take a significant effect to help the house to be comfortable as not much direct solar radiation penetrating the house (Rilatupa, 2019).

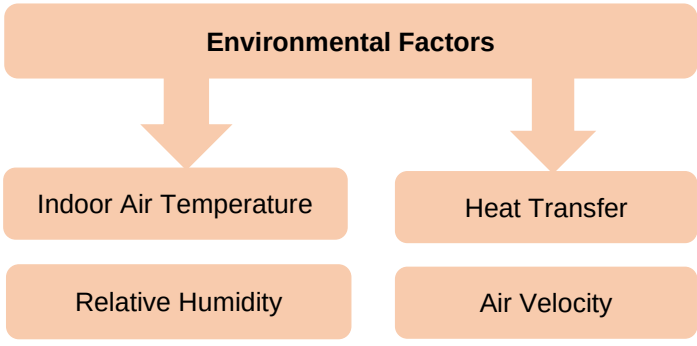
Thermal Comfort

Thermal comfort is challenging to measure because it is very subjective and can vary person to person and requires contextual reaction (Singh et al., 2016; Attia & Carlucci, 2015). Thermal comfort is also known as human comfort, it is the level of satisfaction of the inhabitants from the thermal conditions surrounding it and is an important factor to consider when designing a building (Mahar, Amer & Attia, 2018). In general, thermal comfort is used to mean whether a person is not feeling too cold or too hot in relation to certain thermal conditions (Roshan et al., 2017). Thermal comfort is the subjective state of mind satisfaction with the thermal environment and is assessed subjectively (ASHRAE, 2017). This condition can also be assessed through objective investigations looking at the human body as a thermodynamic system exchanging heat with the surrounding physical environment. In physiological terms, we experience thermal comfort when the body works well, with a core temperature of around 37°C and a skin temperature of 32-33°C. It represents the most extended studied IEQ parameter and a very significant one. When people feel thermally relaxed, then only they can produce entirely. A person experiences cognitive processes to achieve this feeling connecting physical, physiological, and psychological factors (Hou, 2016).

In a building, hot and humid weather can create a state of thermal discomfort. Thermal comfort can be an issue for residents of many hot and humid residential buildings, especially if they are not equipped with air conditioning. Malaysia is one of the tropical countries that can be hot throughout the year, much like most countries that have the temperature. There is no significant difference between seasons in Malaysia, including winter and summer. Days are warm and typically moist but nights are pretty cool. The most significant climate impact in the buildings in Malaysia is high solar radiation intensity and a high daily air temperature (Sadafi et al., 2011; Al-Tamimi et al., 2011). Investigation by other local researcher such as Ibrahim and Tinker (2005); Rajeh (1994); Nugroho (2011); Kamar et al. (2012); Azhaili et al. (2011) as well as Normah et al. (2012) have showed that typical Malaysian residential house including low-income house failed to provide the minimum thermal comfort target (Muhammad Syukri et al., 2018). To date, several studies have been conducted on thermal comfort, yet, the problem remained un solved in several parts of the world (Mahar, Amer & Attia, 2018).

Hussin (2016) described thermal comfort as a topological six-dimensional solid with at least six parameters giving basic thermal condition dimensions. Activity and clothing are two parameters specific to an individual, while air temperature, humidity, air velocity, and radiance are the environment's properties. Under conditions of isothermal and steady-state, these six vital variables can define the body's heat balance. Moreover, several other minor parameters, such as health and light, also influence thermal comfort. In particular, ASHRAE (2017) identified four main parameter affecting comfort; environmental conditions, which

consist of air temperature, radiant temperature, humidity, and air velocity are the most important environmental factors contributing to thermal comfort.



Source: (ASHRAE (2017))

Figure 1. Parameters of Thermal Comfort

Parameters of Thermal Comfort

Indoor Air Temperature

The air temperature, with respect to location and time, is the average temperature of the air surrounding the occupant. The spatial average takes into account the ankle, waist and head levels according to the ASHRAE 55 standard (2010), that varies with occupants who are sitting or standing. Air temperature is the most important element influencing the thermal comfort. This supported by Maarof (2014) described the air temperature has been considered the major influencing factor to the thermal comfort and many of the indexes produced are mainly focusing to the determination of the comfort temperature. The air temperature is a measure of how hot or cold the air is, and the weather parameter most commonly measured. Temperature describes the kinetic energy, acceleration strength, and air-forming gasses. When gas molecules travel more quickly, the air temperature will increase. In comparison, nearly all other environmental conditions are also influenced by the air temperature.

Relative Humidity

Relative humidity is the ratio of the total volume of water vapour in the air and the average amount of water vapour at the air temperature that the air can bear. The higher the relative humidity, the less heat a person is able to lose heat through the evaporation of moisture on the skin, and so the hotter they will feel. High humidity conditions have plenty of air pollution, which keeps the skin from evaporating moisture. Humidity is important and necessary in hot environments because less sweat evaporates when there is high humidity (80 per cent +). The principal method of heat reduction is sweat evaporation (Enescu, 2017).

Air Velocity

The air velocity (V) is defined at one point as the rate of air movement, regardless of direction. It is measured in m/s. the faster the air movement, the greater the exchange of heat between the body and the air. It is important because it accelerates convection. It changes the

skin and clothing surface heat transfer coefficient (reduces surfaces resistance), as well as increases evaporation from the skin. The impact on the heat transfer rate between air and adjacent surfaces is air velocities. It happens where the higher the air velocity moves across a surface, the higher the transfer of heat. Higher speeds can be helpful where heat transfer is needed for example, in the transfer of heat between the thermal mass of a building and the air above it, but in other conditions, such as the exchange of heat with the cold inner surface of a window, may be undesirable (Atmaca & Gedik, 2020).

As mentioned by Ismail et al. (2014), indoor building air velocities affect people's thermal comfort within the space. The higher the air velocity in building spaces, the greater the exchange of heat between people in a space, and the air around them. In other occasion, a higher air velocity may be necessary for the example, a fan might be turned on during hot climate/weather to increase the rate at where the body is able to lose heat to its surroundings areas. However, under other circumstances, a fan may be undesirable in colder conditions, for example, where higher air velocities can be noticed as draught.

Heat Transfer

In ASHRAE Standard 55 (2010), the mean radiant temperature is defined as the uniform surface temperature of an imaginary black enclosure in which an occupant would exchange the same amount of radiant heat as in actual, non-uniform space. The Mean Radiant Temperature is the weighted mean temperature of the temperatures of the surfaces that form the border of the room, including the influence of incident solar radiation and its effects can be transmitted by radiation.

The radiant temperature is related to the amount of radiant heat transferred from a surface and depends on the ability or emissivity of the material to absorb or emit heat. This is generally expressed as mean radiant temperature (MRT, a weighted average of the temperature of the surfaces surrounding a person, which can be measured by a globe thermometer) and any strong mono- directional radiation such as radiation from the sun (Designing Buildings, 2015). In conjunction with air temperature, mean radiant temperature is the major factor affecting the sensation of warmth as the radiation that falls on the skin stimulates the sensory organs of the skin.

Occupants' Satisfaction

A building in tropics requires overlapping construction and operation with extreme climatic conditions. The tropical climate regions are characterized by high humidity, heavy rainfall, and plentiful sunshine. Typical tropical climate conditions adversely affect the architecture of the building and have a positive impact. Occupants often overheat during the day due to their poor nature and may be too cool at night for comfort. Previous studies have shown that low-income housing thermal design could be ineffective and, as a result, most of its occupants are not satisfied with the levels of thermal comfort provided (Ibrahim, 2014). While Ismail et al. (2016) stated that thermal comfort has a great influence on the productivity and satisfaction of indoor building occupants.

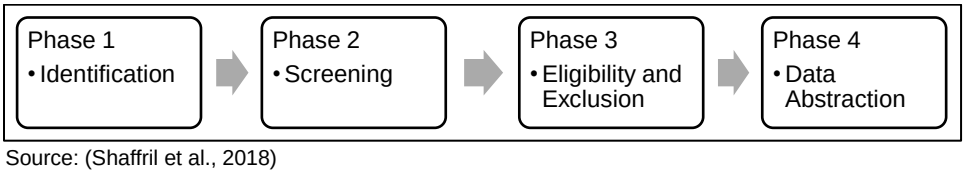
The standard of low-cost housing in Malaysia has not been upgraded compared with other housing categories. One reason for implementing affordable housing in Malaysia was the

residents' dissatisfaction with the quality of low-cost housing (Musa et al., 2015). Residents therefore often have many concerns about infrastructure and the quality of construction, although their views on indoor environmental quality have not been recorded in practice. Nevertheless, as living standards are rising in the near future, the issue of indoor comfort will, of course, be the main concern of these local residents (Singh et al., 2016).

The orientation of the building will affect the thermal performance of the building by reducing the direct sunlight in the buildings hence it will affect the comfort and disatisfaction inside the building (Al-Tamimi et al., 2011). Hence, this study is to identify the effect of orientation towards thermal comfort and occupants satisfaction in low cost housing.

METHOD OF USING SYSTEMATIC LITERATURE REVIEW

According to Nawi et al. (2014), literature review involved describing, summarizing, evaluating and clarifying the content of information. This paper employed a Systematic Literature Review (SLR) to obtain related literature on the effect of orientation towards occupant satisfaction. The reviewers used the SLR methodology to produce a suggested best orientation for field measurement. There are four phases in the SLR method.



Source: (Shaffril et al., 2018)

Figure 2. Phases Involved in SLR

Phase 1: Identification of Literature

First, a rigorous literature search of related topics or terms related to building orientation and occupant satisfaction were identified using queries searching, allowing systematic search via established publication databases. Scopus and Web of Science were two databases, covering more than 11,000 journals, chosen for the systematic literature search. The literature search focused on studies conducted in the last ten years (2010 to 2020). The reviewers finalised the literature search in August 2020. In this phase, related published papers were sought from the two databases search engines. English published articles were searched by including the keywords in their titles or abstracts: (“orientation” or “direction” or “side” or “position”) AND (“occupant” or “resident” AND “satisfaction” or “comfort”) AND (“residential building” or “urban” or “housing” or “house”).

Table 1. SLR Search String

Database	Keywords
Scopus	TITLE-ABS-KEY ((((“orientation” or “direction” or “side” or “position”) AND (“residential building” or “urban” or “housing” or “house*))) AND (LIMIT-2010-2020)
WoS	TS = (“orientation” or “direction” or “side” or “position”) AND (“residential building” or “urban” or “housing* or “house*).

Phase 2: Screening of the Identified Literature

The identified literature was screened to suit building orientation and occupant satisfaction. However, zero records were found concerning articles on occupant satisfaction. Since this paper aims to find the best selection of building orientation for fieldwork measurement on thermal comfort and the type of building, which is residential building or housing, the reviewers decided to stick with the building orientation term. From 45 literature, 19 literature suited this paper's topic: the building orientation selection for the fieldwork measurement on thermal comfort in the residential building. The screening excluded any literature duplicates, such as similar authors, similar research titles, and non-English publications.

Phase 3: Eligibility and Exclusion

The next phase was the eligibility and exclusion. The remaining 19 literature were reviewed thoroughly. After an extensive review, ten literature were removed because the literature did not have the information on the method of determining the building orientation and in a different building from a residential building. At this stage, nine literature were extracted and analysed using the SLR. The data was tabulated based on the Author(s), Year of Publication, Type of Building, Orientation Sides, and Method of Determining Building Orientation.

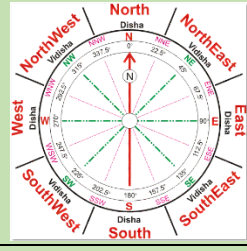
Phase 4: Data Abstraction

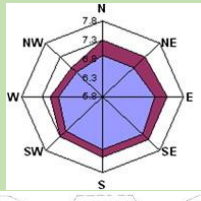
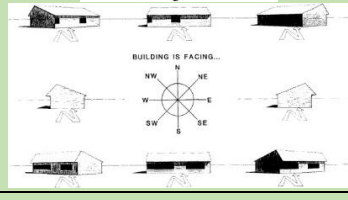
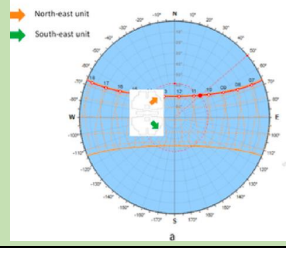
The final phase was the data abstraction. In this phase, building orientation was categorised into two groups; four sides building orientation and eight sides building orientation. The abstraction later formed the suggested building orientation selection for fieldwork measurement on thermal comfort. This paper only chose one group for the best building orientation selection to measure thermal comfort.

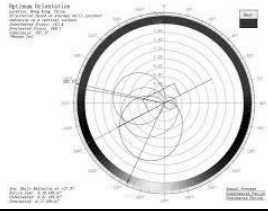
ANALYSIS AND DISCUSSION

Table 2 shows the literature review analysis concerning the orientation sides, type of building, and the method to determine building orientation.

Table 2. Analysis of Orientation, Type of Building, and the Method to Determine Building Orientation

No.	Author(S)	Orientation Sides	Type Of Building	Method To Determine Orientation
1.	Vaca (2015)	Eight sides NE, E, SE, S, SW, W, NW, N	Residential Building	
2.	Rendon et al. (2016)	Four sides E, W, N, S	Residential Building	BO is the building layout on a horizon plane or the sun's path pointing at AZM angles between 0° and 360°. Typically, N is 0° or 360°, E is 90°, S is 180°, and W corresponds to the 270°.

No.	Author(S)	Orientation Sides	Type Of Building	Method To Determine Orientation
3.	Mulyani et al. (2017)	One side E	Institutional Building	Using Angle (Simulation)
4.	Madhani et al. (2015)	Four sides E, W, N, S	Office Building	IEV, SE (Simulation)
5.	Prasad et al. (2017)	Four sides N, S, W, E	Residential Building	Long Façade facing with Angle N – 0° - 90° E – 90° - 180° S – 180° - 270° W – 180° - 360°
6.	Anumah & Anumah (2017)	Two sides NE, SW	Residential Building	-
7.	Nie et al. (2015)	Four sides W, E., N, S	Residential Building	Angle Direction 90°=north, 180°=west, 270°=south, 0°=east
8.	Al-Tamimi et al. (2011)	Four sides N, S, E, W	Institutional Building	The results indicated that the best bay with the least sunlight penetration is with orientation 0º and the worst is with 240º; those with orientations 30º, 180º, 330º, 60º, 90º, 300º, 150º, 120º, 210º, and 270º follow in order.
9.	Al-obaidi & Woods (2016)	Eight sides N, NE, E, SE, S, SW, W, NW	Residential Building	North = 0 North-East = 45 East = 90 South-East =135 South = 180 South-west = 225 West =270 North-West = 315
10.	Kim et al. (2016)	Four sides N, S, E, W	Residential Building	-
11.	Morissey et al. (2011)	8 Sides N, NE, E, SE, S, SW, W, NW	Residential Building	 
12.	Bekkouche et al. (2013)	Four sides S, E, W, N	Residential Building	Angle Direction
13.	Aflaki et al. (2016)	Eight sides N, NE, E, ES, S, SW, W, WN	Residential Building	

No.	Author(S)	Orientation Sides	Type Of Building	Method To Determine Orientation
14.	Sedki et al. (2013)	Three sides N, E, W	Residential Building	Angle Direction
15.	Faizi et al. (2011)	Two sides N, E	Residential Building	Angle
16.	Harahap et al. (2011)	Six sides W, E, SW, NE, SE, NW	Residential Building	The selected facades are the ones that are highly exposed to eastern and western sun, i.e., façades that are directed towards the northeast (NE), east (E), southeast (SE), southwest (SW), west (W), and northwest (NW)
17.	Albatayneh et al. (2018)	Four sides N, E, W, S	Residential Building	
18.	Susorova et al. (2014)	Four sides N, S, W, E	Institutional Building	-
19.	Haase (2009)	Two sides N, S	Residential Building	

Based on the reviewed articles, building orientation has been carried out in many types of buildings, which are institutional building, office building, and residential building, by previous researchers. As stated in the figure 3, many of the researches were conducted in residential building (79%) while institutional building (16%) and office building (5%). Nevertheless, this paper focuses on a residential building. Based on the Figure 3 below, residential buildings are the most reviewed by previous researchers other than other buildings.

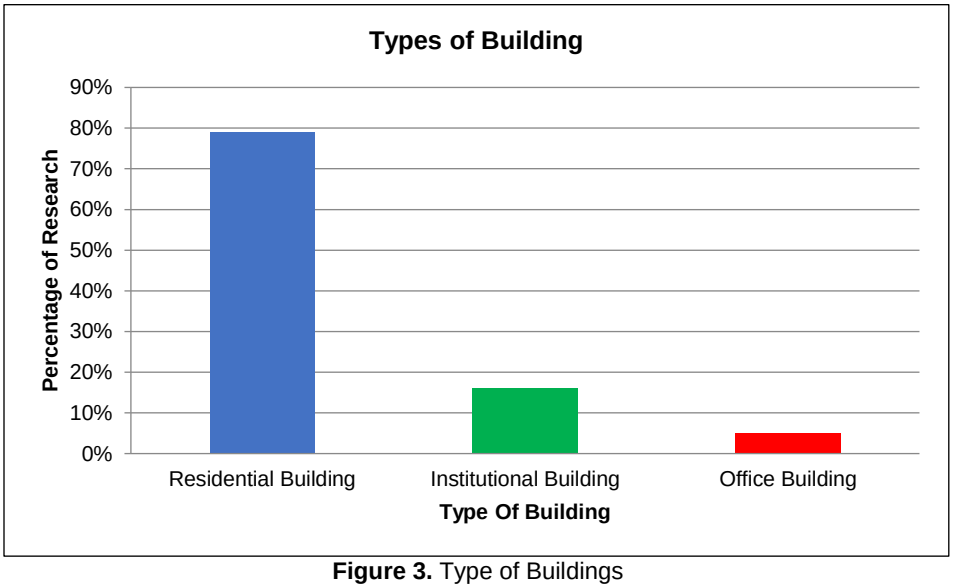


Figure 3. Type of Buildings

Previous researchers used many directions in their studies, namely one side, two sides, three sides, four sides, six sides, and eight sides of orientations. The orientation sides include north, northeast, east, southeast, south, southwest, west, and northwest. Based on the analysis, this paper chose the best orientation sides as shown in Figure 4.

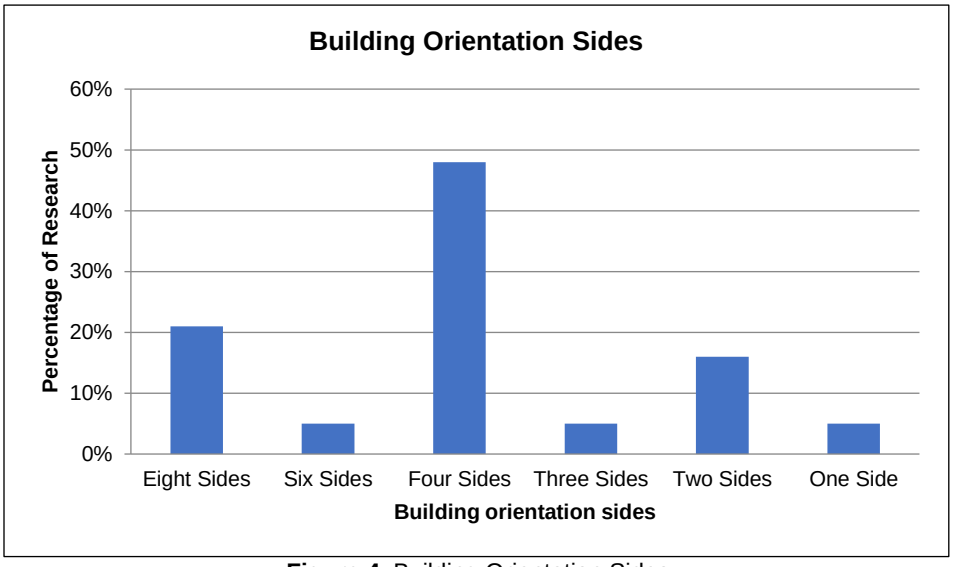


Figure 4. Building Orientation Sides

From the Figure 4 above, it can be seen that the orientation of four sides is the most reviewed by the previous researchers which is 48% and the eight sides of orientation is 21%. From all the reviewed articles above as in Table 2, only nine selected articled were reviewed deeply. The researcher then grouped into two building orientation group which are for the first group is four sides while for the second group is eight sides.

The orientation for the first group was north, south, west and east which consist of four sides while the orientation for the second group was north, northeast, east, southeast, south, southwest, west and northwest which consist of eight sides of building orientation. As shown in the Figure 5, more researchers used four side orientation in the nine selected literature than those using eight sides of building orientation. Those researchers using four orientation sides are Albatayneh et al. (2018); Prasad et al. (2017); Valladares-Rendon et al. (2016); Nie et al. (2015); and Bekkouche et al. (2013). Therefore, it is suggested that four sides building orientation which is North, South, East and West orientation, is the best orientation selection because these four sides of orientation are the most used. There were also investigate the method to determine the orientation of building.

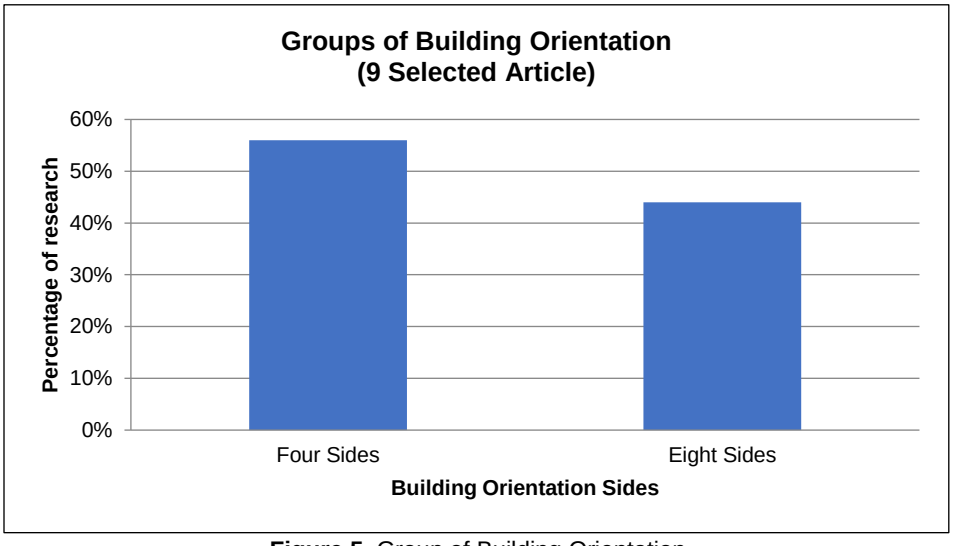
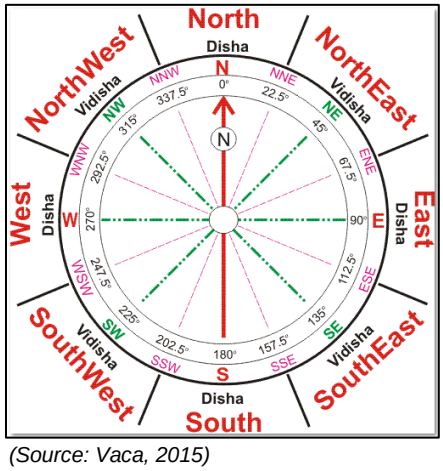


Figure 5. Group of Building Orientation

From the nine selected literature in the Table 2, all the researchers used the method in determining the orientation by using angle direction. This method were used by nine previous reserachers in order to determine the direction of the building orientation. Based on the paper reviewed, the angle direction for each sides of orientation; N – 0° - 45°, NE – 45° - 90°, E – 90° - 135°, SE – 135° - 180°, S – 180° - 225°, SW – 225° - 270°, W – 270° - 315°, and NW – 315° - 360° (see Figure 6). Hence, for this paper, the method that will be used in order to determine the direction of building orientation is by using angle direction. The angle that will be used in order to determine the orientation of building for this research is; N–0°- 45°, E – 90° - 135°, S – 180° - 225°, W – 270° - 315° because only four sides of building orientation is the best selection for this paper.



(Source: Vaca, 2015)

Figure 6. Angle for Orientation

Upon completing the analysis, this paper decided to use the four sides orientation to conduct the fieldwork measurement on thermal comfort parameter as the method to select the building orientation because it is the most reviewed by previous researchers rather than other sides orientation in residential building. Previous researchers Albatayneh et al. (2018); Prasad

et al. (2017); Valladares-Rendon et al. (2016); Nie et al. (2015); and Bekkouche et al. (2013) conducted their studies on a residential building. They used angle direction as the method to determine building orientation. Therefore, this study followed the method to determine the building orientation employed by previous researchers. Besides, it was found that all these researchers used the same method to determine the orientation but different used of study. This study will use this orientation selection method to determine the building orientation during the fieldwork measurement on thermal comfort in residential building. However, studies on methods to determine the orientation sides are still minimal.

This paper highlights the method and the orientation sides that will be used in the study; using angle direction as used by previous researchers and four orientation sides (North, South, West, and East) as used by Prasad et al. (2017). All these become the best selection for the researchers to complete the study; the fieldwork measurement on the residential building's thermal comfort condition. Many studies were conducted to determine the building orientation method, but not all the studies were used for the fieldwork measurement on the residential building's thermal comfort condition. Mostly, the researchers used this method to determine the building's energy consumption and design the building. Therefore, other researchers need to conduct more studies to determine the building orientation method for the fieldwork measurement in residential building.

CONCLUSION

This systematic literature review highlights the best selection of building orientation that should be considered for fieldwork measurement on thermal comfort in residential building. As discussed earlier, the building orientation can be determined using angle direction, as many previous researchers used. Most of the researchers used the same method, either for four or eight orientation sides. Therefore, this method will help the researchers to identify the building orientation direction during the fieldwork measurement. Studies also showed that building orientation selection is important to determine the building orientation because it has a significant effect on the thermal comfort in the building directly effect to the occupants satisfaction as the amount of solar radiation depends on its orientation. This is the best method and a better way for the researchers to use in the study in order to choose the best selection building orientation hence it can be as a reference to the future researcher in determining the building orientation. Nevertheless, it demands more research quantifying on the orientation towards thermal comfort and occupants satisfaction.

For this paper, it can be concluded that the best building orientation selection for fieldwork measurement on thermal comfort is four orientation sides (North, South, West, and East) with the angles of each orientation are N – 0° - 45°, E – 90° - 135°, S – 180° - 225°, W – 180° - 315°.

REFERENCES

Aflaki, A., Norhayati, M., Baharum, M. R. (2016) The influence of single-sided ventilation towards the indoor thermal performance of high-rise residential building: A field study, *Energy and Buildings*, 126:146-158

Albatayneh, A., Alterman, D., Page, A., and Moghtaderi, B. (2018) The significance of the orientation on the overall buildings thermal performance-case study in Australia, *Energy Procedia*, 152:372-377

Al-Obaidi, M. A. A. H., & Woods, P. (2016) Investigations on effect of the orientation on thermal comfort in terraced housing in Malaysia, *International Journal of Low Carbon Technologies*.1(2):167-176

Al-Tamimi, N. A. M., Syed Fadzil, S. F. & Wan Harun, W. (2011) Thermal Performance Analysis for Ventilated and Unventilated Glazed Rooms in Malaysia (Comparing Simulated and Field Data). *Indoor and Built Environment*, 20(5):534–542

Alshayeb, M., Mohamed, H., and Chang, J. D. (2015) Energy Analysis of Health Center Facilities in Saudi Arabia: Influence of Building Orientation, Shading Device, and Roof Solar Reflectance, Procedia Engineering, 118:827-832.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) (2017). Handbook Fundamentals; American Society of Heating, Refrigerating and Air-Conditioning Engineers: USA:Volume 30329

American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) (2010) Guideline 10P, Interactions Affecting the Achievement of Acceptable Indoor Environments.Atlanta:USA.

Anumah, J. J., and Anumah, L. (2017) Building Orientation; Enhancing Nature with Nature, Journal of Applied Sciences & Environmental Sustainability, 3(7):29 – 35

Atmaca, A.B., Gedik, G.Z., (2020) Determination of thermal comfort of religious buildings by measurement and survey methods: Examples of mosques in a temperate-humid climate, Journal of Building Engineering 30:1-10

Attia, S., and Carlucci, S. (2015) Impact of different thermal comfort models on zero energy residential buildings in hot climate. Energy and Buildings, 102:117-128.

Bekkouche, S. M. E. A., Benouaz, T., Cherier, M. K., Hamdani, M., Yaiche, R. M., and Khanniche, R. (2013) Influence of building orientation on internal temperature in saharian climates, building located in ghardaia region (Algeria), Thermal Science, 17(2):349-364

EcoWho (2017) The Importance of Building Orientation, Eco Friendly and Sustainable living. Retrieved from www.ecowho.com, Accessed date 8 September 2020

Enescu, D. (2017). A review of thermal comfort models and indicators for indoor environments, Renewable and Sustainable Energy Reviews, 79:1353–1379.

Fallahtafti, R., Mahdavinejad, M., (2015) Optimisation of building shape and orientation for better energy efficient architecture. International Journal of Energy Sector Management. 9(4):593–618.

Haase, M. and Amato, A. (2009) An investigation of the potential for natural ventilation and building orientation to achieve thermal comfort in warm and humid climates. Solar Energy, 83(3):389-399

Hanafi, Z. B. (2014) Environmental design in hot humid countries with special reference to Malaysia. PhD Thesis: University of Wales, College of Cardiff

Hou, G. (2016) An investigation of thermal comfort and the use of indoor transitional space, PhD Thesis: Cardiff University

Hussin, M. (2016) Thermal Comfort and Indoor Air Conditions in Laboratories At Universiti Sains Malaysia, PhD Thesis: Universiti Sains Malaysia

Ibrahim, S. H, Baharun, A., Mohd Nawi, M. N., and Junaidi, E, (2014) Analytical Studies on Levels of Thermal Comfort in Typical Low-Income Houses Design, UNIMAS e-Journal of Civil Engineering, 5(1):28-33

Ismail, A.R., Jusoh, N., Zulkifli, R., Sopian, K., and Deros, B.M., (2016) Thermal Comfort Assessment: A Case Study at Malaysian Automotive Industry, American Journal of Applied Sciences, 6(6):1495-1501

Isnin, Z., Ramli, R., Ezanee, H., A., and Irwan, M. A, (2012) Sustainable Issues in Low Cost Housing Alteration Projects, Procedia - Social and Behavioral Sciences, 36:393-401

Juangjandee, W. (2017) Analysis Thermal Comfort Condition in Complex Residential Building, Case Study: Chiangmai, Thailand, IOP Conference Series: Materials Science and Engineering, 245(5):1-5

Kamali, S. (2014) Improving Thermal Comfort in Building and Reducing the Indoor Air Temperature Fluctuation in Cyprus by Utilizing the Phase Change Materials, MSc Thesis: Eastern Mediterranean University.

Kwon, M., Remøy, H., Van, M., & Bogaard. (2019) Influential design factors on occupant satisfaction with indoor environment in workplaces, Building and Environment 157:356-365

Ling, C. S. and Almeida, S. J. (2016) "Demystifying the affordable housing issue in Malaysia, Outlook and Policy in 2017: Annual Report 2016, Bank Negara Malaysia", Kuala Lumpur, MY.

Maarof, S. (2014) Roof Designs and Affecting Thermal Comfort Factors In A Typical Naturally Ventilated Malaysian Mosque. PhD Thesis: Cardiff University

Mahar, W.A., Amer, M., and Attia, S., (2018) Indoor thermal comfort in residential building stock: A study of RCC houses in Quetta, Pakistan, European Network for Housing Research (ENHR) Annual Conference 2018, Uppsala, Sweden, 1-12.

Morrisey, J., Moore, T., and Horne, R. E. (2011) Affordable Passive Solar Design In A Temperate Climate: An Experiment In Residential Building Orientation, Renewable Energy, 36(2):568-577

Musa, A.R., Tawil,N. M., and Che-Ani, A.I. H. B. (2015) An Analysis of the Selection Criteria in Purchasing a House in Klang Valley towards the Quality Affordable Housing. Life Science Journal, 12(3):51–57

Nawi, M. N. M., Lee, A., Azman, M. N. A., & Kamar, K. A. M. (2014) Fragmentation issue in Malaysian industrialised building system (IBS) projects. Journal of engineering Science and Technology, 9(1):97-106.

Nie, P., Zhou, J., Tong, B., Zhang, Q., and Zhang, G. (2015) Numerical Study On The Effect Of Natural Ventilation And Optimal Orientation Of Residential Buildings In Changsha, China, Procedia Engineering, 121:1230-1237

Osman, M. M., Ramlee, M. A., Samsudin, N., Rabe, N. S., Abdullah, M. F., and Khalid, N. (2017) Housing Affordability In The State of Johor. Planning Malaysia Journal, 15(1): 347-356

Prasad, K. A., Anchan, S, S., Kamath, M., S., and Akella, V. (2017) Impact of Building Orientation on Energy Consumption in the Design of Green Building, International Journal of Emerging Research in Management &Technology, 6(2):8-11

Rilatupa, J. (2019) Factor Building Orientation Direction as Determinant The Thermal Comfort Quality, IOP Conference Series: Materials Science and Engineering, 620(1):1-13

Roshan, G., Farrokhaz, M., and Attia, S. (2017) Defining thermal comfort boundaries for heating and cooling demand estimation in Iran's urban settlements. Building and Environment, 121:168-189.

Sadafi, N., Salleh, E., Chin, L., and Jaafar, Z. (2011) Evaluating thermal effects of internal courtyard in a tropical terrace house by computational simulation. Energy and Buildings, 43(4):887–893.

Sale, M. I. (2013) Construction Of Residential Houses A Case Study Of Public Housing In Gombe State, Nigeria, Msc Thesis : Universiti Teknologi Malaysia.

Shafrill, H. A. M., Krauss, S. E., and Samsuddin, S. F. (2018) A systematic review on Asian's farmers' adaptation practices towards climate change, Science of the Total Environment, 644:683-695

Singh, M., Attia, S., Mahapatra, S., & Teller, J. (2016) Assessment of thermal comfort in existing pre-1945 residential building stock, Energy, 98:122-134

Sirochmanová, L., Kozlovská, M., & Bašková, R. (2016) The importance of the criteria of residential buildings from the perspective of future users, Journal Of Civil Engineering 11(1):97-106

Suraya, I. (2015) Making Housing Affordable, Khazanah Research Institute, Kuala Lumpur.

Susorova I, Angulo M, Bahrami P, Stephens B (2013) A model of vegetated exterior facades for evaluation of wall thermal performance. Building and Environment, 67:1–13.

Vaca, L. (2015) Architectural Form, Orientation, and Energy for Residential Design in The Southern Nevada region, MSc Thesis: University of Nevada

Valladares-Rendon, L. G., Schmid, G., and Lo, S. L. (2017) Review On Energy Savings By Solar Control Techniques And Optimal Building Orientation For The Strategic Placement Of Façade Shading Systems, Energy and Buildings, 140: 458-479

Muhammad Syukri, I., Azhaili, B., Siti Halipah, I., and Wan Azlan, W. Z. A, (2018) Bioclimatic Home Cooling Design For Acceptable Thermal Comfort In Malaysian Climate, Malaysian Construction Research Journal, 25(2):1-12.

Zainon, N., Azli, F. M. R., Sulaiman, S., Bari, S. A. K., & Hamzah, A. (2017) Factors Affecting the Demand of Affordable Housing among the Middle-Income Groups in Klang Valley Malaysia, Journal of Design and Built Environment, Special Issue:1-10.

INITIAL CONCEPTUAL MATRIX ON THE DEVELOPMENT OF ROAD SAFETY ASSESSMENT TOOL (RSAT) FOR NEW ROAD PROJECT

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Abstract
There is an absence of self-assessment tools to determine the level of safety at the design stage of road projects in Malaysia. This paper is presented with the intention to develop the road safety assessment tool by determining the level of safety for new road design project. For this study, the conceptual matrix was initially constructed by focussing on the geometry design elements, based on various literature and precedent research. To initiate the tool, five (5) elements of road assessment were addressed in the matrix; i) sight distance, ii) design speed, iii) traffic signal, iv) cross section (surface type); and v) horizontal alignment. The initial conceptual will be a pre-basis guidance for the next phase of main survey. Road Safety Assessment Tool (RSAT) will be indicated as guidance towards the design element of the road that contributes greatly to the safety impact. It is expected that RSAT can be used as a complementary tool to assist in the implementation of Road Safety Audit. It is hoped that this study will provide a model for local agencies nationwide to implement road safety audit recommendations more effectively.

Keywords: *Road Safety Audit (RSA); multiplying factor; level of safety; road design project; Road Safety Assessment Tool (RSAT).*

INTRODUCTION

In Malaysia, road transport is an essential mode of transport which guarantees both the mobility of people and the transportation of resources. Since the introduction of the road network at the end of the 19th century, transport in Malaysia has been dominated by road transportation. In 1997, Public Work Department (PWD) has implemented Road Safety Audit (RSA). Since then, the introduction of the RSA has exposed problems which include inadequate management of the RSA, widespread repetitive errors by designers and the absence of a warrant application. The article addresses these problems and applies them to the research carried out. This research aims to equate local RSA activities with other countries in finding solutions to the abovementioned problems. It has been shown that having a policy, a clear role & responsibility and a proper management of the RSA is vital in ensuring that road safety is adequately addressed (Abu Mansor et al., 2019).

The RSA is a current road infrastructure technique intended to detect possible safety hazards during new road planning phase, design and construction (Hildebrand & Wilson, 1999). Adoption of the RSA procedure, including audits at different stages throughout the creation of a project will make a major contribution to the achievement of safe and effective road efficiency and also to ensure changes in road safety that are incorporated throughout the project in the planning and design phases (PWD, 1997). The implementation of RSA safety concepts in road design and road improvement is intended to avoid or mitigate the severity of accidents. The outcome of the audit is the identification of any possible safety concerns, along with recommendations about how to resolve these issues. The RSA method includes an

analytical approach to the evaluation of the probability of an accident. The most important way of achieving this goal is by an independent evaluation of the safety assessment of projects by individuals that are not involved with the original design. Experienced designers and planners are needed to conduct road safety engineering technique.

PROBLEM STATEMENT

Based on the ARIMA model produced predicting Malaysian road fatalities for year 2020 projected to rise to 10,716 number of fatalities. In order to avoid fatal traffic accidents, more efforts and successful strategies can be creatively developed to cut down fatalities (Sarani et al., 2013). It is in line with the two Sustainable Development Goal targets which are specifically related to road safety: SDG 3 with the target 3.6 aims to halve the number of global deaths and injuries from road traffic accidents by 2020 and SDG 11 with the target 11.2 seeks to provide access to sustainable and safe transport systems (World Health Organisation, 2017).

PWD has also taken a number of other steps to strengthen the application of RSA. These include RSA preparation, an accreditation scheme for the selection of eligible auditors, the development of guidelines for The Safety Audit of Roads and Road Project in Malaysia and guidelines on reporting. However, more improvisation is required, in particular by developing a hierarchy of safety deficiencies to allow faster decision-making, an improved documentation system to promote traceability and the retrieval of RSA decisions (Abu Mansor et al., 2019).

The development of this RSAT is to support insufficient number of Road Safety Auditors in Malaysia to evaluate the standard of safety for the road design project. There are also provisions in the Road Safety Audit to implement double inspection mechanisms for road designers, in particular for local authorities, to ensure that the safety element of the plan before construction has been taken care of. This research aims to explore the techniques in determining level of road safety and it can be one of the complementary tools to assist in the implementation of Road Safety Audit.

SIGNIFICANCE OF THE INQUIRY

This conceptual paper is very important since it varies somewhat from most of the previous studies. From previous research, most studies concentrated on the development of accident prediction models and the purpose of this study is to explore the best model for developing a road safety assessment tool in determining the level of safety for new road design. Data collected from the actual experience of informants may provide feedback to assist in the implementation of the Road Safety Audit to provide a more appropriate and more acceptable tool.

METHODOLOGY

This study uses qualitative approach by reviewing precedent research and literature review to develop the initial conceptual framework of the tool. Since the main survey is yet to carry out, the basis of elements in the proposed tool is developed based on the synthesis of literature. A pre-constructed framework is needed as the basis of main survey, hence, there

are five (5) elements allocated in the proposed developed tool. The elements comprises of, i) sight distance, ii) design speed, iii) traffic signal, iv) cross section (surface type) and v) horizontal alignment (PWD, 1986).

LITERATURE REVIEW

International Approaches in Road Safety Assessment Tool/Accident Prediction Models

The development of Austroads Road Safety Engineering Toolkit in Australia based on the Austroads Guide to Road Safety – Part 6: Road Safety Audit, 2009 (Karndacharuk & Hillier, 2019). The Road Safety Audit Toolkit has been developed to assist practitioners in the comprehensive and efficient completion of road safety audits (Austroads, 2009). These toolkits are used in Australia and New Zealand as a reference tool for road engineering practitioners in both state and local government. It outlined best-practice, low-cost, high-return road-environment initiatives to minimize road-trauma. The intention of the toolkit is to minimize the incidence and frequency of accidents involving road safety factors and to integrate established knowledge of road safety engineering as much as possible with one toolkit for easy access by practitioners. The computer-based 'expert' system is designed to support road safety auditors.

In Virginia, the Field Review Assessment Tool was created to provide a registry of information and evidence gathered prior to and during the field analysis and a checklist of site features and requirements for the review and guidance of the suggested safety counteraction steps (VDOT, 2008). In the United States of America, Box 9.5: Safety Analyst is a series of software tools used to apply state-of-the-art analytical techniques for use in decision-making to define and maintain a system-wide site-specific enhancement initiative to optimize highway safety through cost-effective means (AASHTOWare, 2001).

In New Zealand, accident prediction models (APMs) for two-lane rural roads were developed using the Generalised Linear Model (GLM) method for main crash categories like head-on, loss-of-control and driveway based accidents (Turner et al., 2012). The models quantified the statistical relationship between collisions and traffic numbers, road geometry, cross-section, road surfaces, roadside hazards and pavement density. These accident prediction models have made it possible to better understand how protection impacts these variables and to understand how they relate with each other. Cafiso et al. (2010) also aims to determine accident prediction models for two-lane rural road sections on the basis of a combination of exposure, design, accuracy and context variables directly related to safety performance. The proposed models are also based on the Generalised Linear Modeling (GLM) method, assuming a negative binomial distribution error structure. The research was based on an analysis of 168.20 km of two-lane rural roads with a 5-year accident review period to compensate for the low traffic flow and accident frequencies predicted on local roads. Three of the models studied were found to be acceptable, based on functional considerations, statistical significance and goodness of fitness measures.

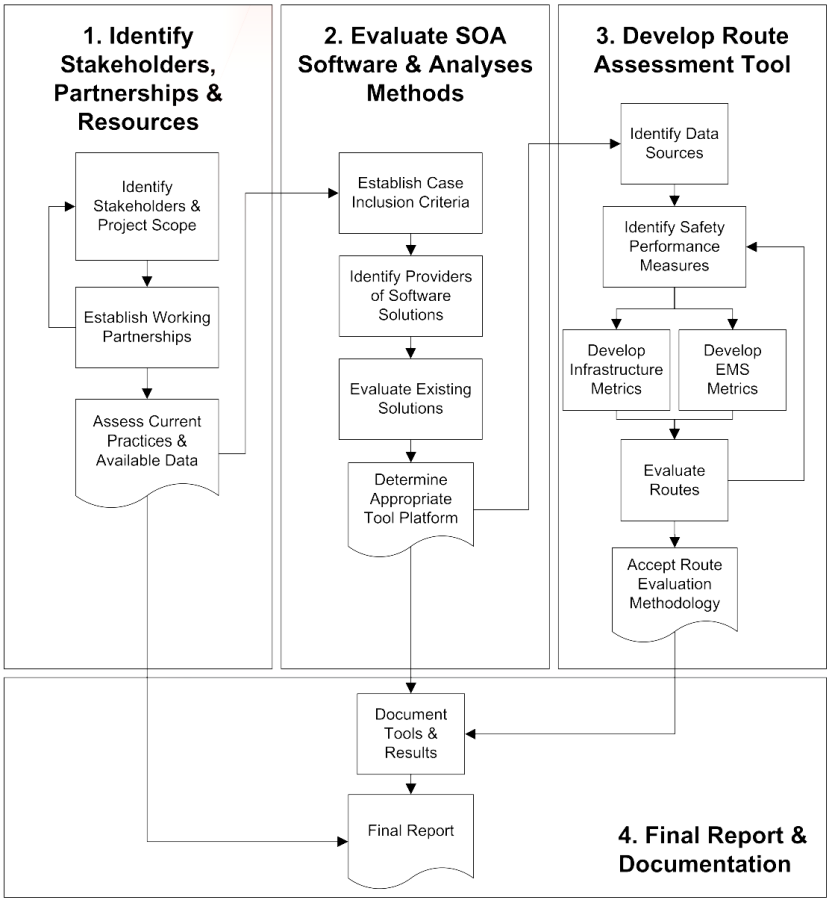
Caliendo, Guida, and Parisi (2007) developed a prediction model for Italian four-lane median-divided motorways. Based on the Generalized Likelihood Ratio Test (GLRT) and Maximum Likelihood Method, the model parameters were estimated to detect the significant

variables to be used in the model equation. The models built in this study for Italian motorways tend to be useful for a variety of applications, such as the identification of critical factors, the estimation of accident reductions due to infrastructure and road development, and accident predictions, while comparing different design options. Thus, this research may represent a reference point for engineers in adjustment or designing multilane roads.

Montella, Colantuoni, and Lamberti (2008) developed separate crash prediction models for total accidents and extreme (fatal plus all injuries) crashes on Italian rural motorways, using Generalized Linear Modelling techniques and assuming a negative binomial distribution error structure. The research used a dataset of 2,245 accidents that occurred between 2001 and 2005 on the A16 motorway between Naples and Canosa in Italy. The models were built in the step-forward procedure with explanatory variables related to traffic volume and composition, horizontal alignment, vertical alignment, design consistency, sight distance, roadside context, cross-section, speed limit and interchange ramps.

In Mexican Hat, Utah, research was done to build a Roadway Safety Assessment Tool (RSAT) for States to use to identify and evaluate the safety of rural roads used by motorcoaches in an easily accessible manner. In order to determine the relative safety of the roads, metrics were explored to quantify infrastructure and traffic-related risks along the road, as well as access to adequate medical or trauma treatment. This includes communication and response capabilities of the EMS, as well as proximity to hospitals and trauma centers. The research carried out in this project was divided into four main tasks: (1) identifying stakeholders and state-of-the-art research partnerships; (2) documenting the state-of-the-art software analysis for motorcoach travel and safety assessment; (3) developing a tool capable of identifying the routes used by motorcoaches and the ability to assess safety along that route; and (4) demonstrate the tool and include a user manual and a review of the results of the project. The relationship between these tasks is shown in Figure 1 below (Blatt et al., 2014).

Jurewicz and Excel (2016), introduced key aspects of the Australian National Risk Assessment Model (ANRAM) and showed how it can be used to drive the creation of the Road Safety Infrastructure Program. The study demonstrates how hybrid risk assessment and accident prediction methodology was used to measure the individual and cumulative risk of a major accident. A number of innovative uses tested by Australian road agencies have been identified, plus a number of possible future uses. The paper explains how ANRAM uses a crash-predictive approach to the first estimation of the mean road accidents by type of crash. It illustrates how ANRAM adjusts the evaluation using risk algorithms based on the protocols of the International Road Assessment Program (iRAP). These algorithms use comprehensive road feature data and research information on the potential for accident risks associated with road design/infrastructure, traffic speeds and the probability of vehicle conflicts. Finally, the model uses historical extreme crash evidence in the Empirical Bayes validation methodology to provide increased confidence in the estimates.



(Source: Blatt et al., 2014)

Figure 1. RSAT Task Structure and Workflow

From the previous study that has been discussed above, it can be concluded that most of the analysis technique was using the statistical method especially general model of linear regression. Researchers have attempted to investigate road safety by establishing statistical relationships between accidents and related factors. For an overview of the Road Safety Audit (RSA) Toolkit that have been used in other countries, it is an online tool that assists practitioners to carry out road safety audits. The Road Safety Audit Toolkit is not a replacement for a Road Safety Auditing course. Rather, it is a tool to assist in the comprehensive and efficient completion of road safety audits. The Toolkit seeks to reduce the severity and frequency of crashes involving road environment factors. Provision of safer roads and roadsides is a major area of gain under the National Road Safety Strategy and is a strategic priority area for researcher. It draws together existing road safety engineering knowledge for easy access.

Road Safety Measures Assessment and Other Related Research

Aghaabbasi et al. (2018), studied to decide if current walkability assessment methods take into account factors such as protection, attractiveness, disability issues and path conditions that are important for the sidewalk assessment. An in-depth analysis of the walkability audit tools is carried out in this article. This analysis reveals that a small range of audit tools

consider issues of disability, safety and attractiveness. The use of questionnaires is a common approach to capturing people's impressions of their walking and environmental experiences. Since sidewalk assessment deals with standards and specifications of sidewalk design, assessing the perception of people is not sufficient to illustrate sidewalk shortcomings. Geographic Information System (GIS) measures and audit tools can objectively be used to assess sidewalks. Tools reviewed primarily use path condition factors. In conclusion, suggestions are made for potential walkability audits that concentrate on accessibility factors as well as micro-scale design factors.

Useche et al. (2018), studied the validation of the Cycling Behavior Questionnaire (CBQ) as a tool for determining the behavior of cyclists on the road. This research had two important objectives to explain in depth the validation of risky and positive road user behavior measurements of CBQ-based cyclists and to compare the mean values of the validated version of the CBQ with demographic and cycling-related variables. The data was analysed using competitive Confirmatory Factor Analysis (CFA) to obtain basic psychometric values and an optimized scale structure. The findings of this research support the idea that CBQ could have important applications to improve road safety by researching the behavioral factors of cyclists and their relationship to demographic and cycling-related factors.

Several international approaches and initiatives are analysed, concerning handbooks and manuals but also research project results like SUPREME (European Commission, 2007, 2010), ROSEBUD (European Commission, 2006), PROMISING (SWOV Institute for Road Safety Research, 2001) and other studies report. These comprehensive manuals, handbooks and other tools have been developed in recent years, aiming to gather, harmonize and improve the existing knowledge on the effectiveness of road safety measures (Yannis et al., 2012). The Norwegian researchers Elvik and Vaa (2004), the authors of The Handbook of Road Safety Measures provide a systematic overview of current knowledge regarding the effects of road safety measures.

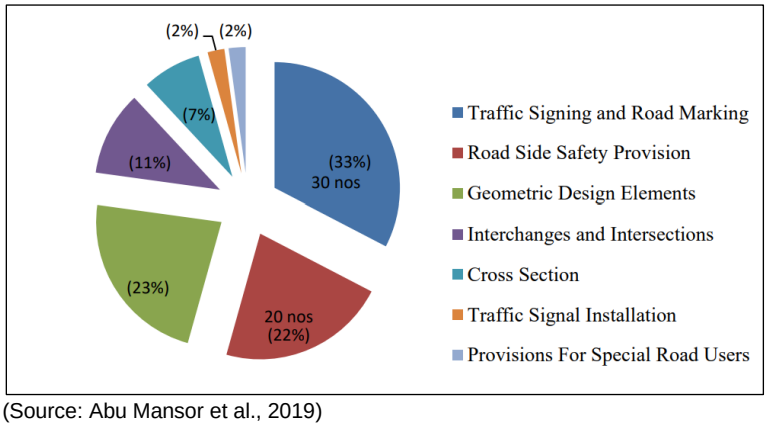
In 2019, the International Road Assessment Programme (iRAP) announced the launch of the Malaysian Road Assessment Programme (MyRAP), in collaboration with the Malaysian Institute of Road Safety Research (MIROS) and local agencies, attempts to highlight the highest risk roads across the country(MIROS, 2019). The development of Road Attribute Data-logger and Inspection System (RADIS) was a collaborative effort between MIROS and Universiti Teknikal Malaysia Melaka (UTeM) which provide a portable survey system for road assessment work (MIROS, 2017).

The experiences in Europe and Australia have shown that RSA's as a constructive safety enhancement tool are both effective and cost beneficial. Studies in the United Kingdom have shown that the total number of fatal and injurious accidents at 19 audited project sites fell by 1.25 accidents per year while crashes at 19 equivalent non-audited sites fell by 0.26 crashes per year (Wilson & Lipinski, 2004).

Factors Affecting Road Safety

There are many factors that contribute to the road safety impact. Abu Mansor et al. (2019) have indicated that 92 number of safety deficiencies were found in Road Safety Audit Report Stage 3 involving various issues. It was found that issues involving traffic signing and road

marking are 33%; and geometric design elements are 23% which contributed to 56% of the total deficiencies as shown in Figure 2. These issues were repeatedly reported in RSA reports and need to be looked into to minimize further occurrences.



(Source: Abu Mansor et al., 2019)

Figure 2. Deficiencies Audit item in Design Stage

Conceptual framework and hypothesis development is one of the major tasks in analyzing the road safety performance and the impact of interrelation of latent contributing factors. For this study, the detailed hypothesis is explained as follows which focus on geometric design elements that are derived from the previous study:

Design Speed

Speed limit is one of the main factors in road safety issues (Elvik et al., 2004). Reducing speed limits has a huge effect on the reduction of deaths and injuries (Balkin & Ord, 2001). The efficacy of speed-related variables is connected to the implementation of limits. The sector's wise influence of speed limits has an impact on urban and rural roads, especially on motorways. Elvik et al., 2004 carried out a detailed study of the effects of speed on accidents again using the Power Model. They concluded that there was a significant correlation between changes in speed and changes in road accidents.

Sight Distance

Adequate distances of sight have been described as a function of operating speeds and are achieved by designing non-restrictive horizontal and vertical alignment and avoiding visual obstructions (vegetation, embankments, walls, etc.) in intersection quadrants and on the inside of horizontal curves (Glennon, 1984).

Horizontal Alignment

In the design of horizontal curves, it is important to create a proper relationship between design speed and curvature, as well as their joint relationship with superelevation and side friction. Haynes et al., 2007 studied road curvature and its connection with road accidents at district level (Census Tract) in England and Wales. Their study created a range of road curvature measures and found that, at district level, road curvature is a protective factor, which means that the presence of more curved roads in the area result in less road accidents.

Cross Section (Surface Types)

Pavement material (bituminous rather than concrete) is associated with a higher number of injury and property damage incidents. Again, the causality may not be that bituminous causes collisions, but rather that concrete highways, which appear to serve higher levels of traffic, are designed to a different or more modern standard (Yokoo et al., 2014).Pavements can be considered as three general types-high, moderate and low. High-type pavements are justified for high-volume traffic for which it is appropriate that the surface has smooth riding properties and strong non-skid properties in all weather conditions. The intermediate type of pavement differs from those slightly less expensive and slightly less durable than the high type of pavement to the surface treatment. Low-type pavements vary from surface-treated and stabilized earth roads to loose-surface materials such as earth and gravel. The important characteristics of the surface form in relation to the geometric design are the ability of the surface to maintain its shape and proportions, the ability to drain and the effect on the behaviour of the driver.

Traffic control signals are devices that control vehicle and pedestrian traffic by granting the right of way to different movements for some pre-determined or traffic-adjusted time intervals. They are one of the main elements in the running of many urban roads and should be combined with the geometric design in order to achieve maximum operating performance.

One of the potential explanations for the high number of incidents and injuries is the beating of traffic lights. There is also a need to examine this worrying issue. Kulanthayan, Phang, and Hayati (2007) studied that traffic light violation has a relationship with all five factors: day (weekday or weekend), camera enforcement, vehicle type (two-wheel or four-wheel vehicles), cycle time of traffic light (long or short) and type of traffic lights (timer or normal).

PROPOSED INITIAL CONCEPTUAL MATRIX OF ROAD SAFETY ASSESSMENT TOOL (RSAT)

This section presents an initial conceptual matrix of the development of a road safety assessment tool that aims to measure the level of safety for new road design project. As described in the methodology section, there are five (5) elements allocated in the conceptual mtraix table, as a basis of safety rating guidance. The safety rating for these elements allocated in range of 1 to 5, where 1 represents very low safety and 5 represents high safety rating. Table 1 shows the initial conceptual matrix of Road Safety Assessment Tool (RSAT), which is initially constructed as a pre-basis guidance for this study.

Table 1. Initial Conceptual Framework of Road Safety Assessment Tool (RSAT) for New Road Project

Safety Rating / Element of The Road Design	1	2	3	4	5
	Total Response				
Sight Distance					
Design Speed					
Traffic Signal					
Cross Section					
Horizontal Alignment					

Based on the above conceptual matrix, the data will be analysed to obtain multiply factor for road design element. The multiply factor is evaluated based on the total numbers of response in Safety Rating 4 and 5 against total numbers of question in one element of road design. The study considers the Safety Rating 4 and 5 because both ratings are the critical road safety impact based on road user perception. The RSAT will be validated by implementing the Matrix Concept in constant validation. The best constant obtained from the total of multiply factors of road design element is identified from the analysis to represent the safety impact. From the result of the constant, scoring for Level of Safety is set by implementing validation process of constant using matrix concept. The constant were chosen on a 0 to 1 scale to represent JKR Standard Compliance. An equation formula will be used to obtain percentage scoring for Level of Safety for each project:

$$\text{Calculation of Level of Safety: } \frac{\text{Total Index Ratio}}{\text{Total of Multiply Factor}} \times 100\%$$

Table 2. Example of Implementation of Matrix Concept in Constant Validation

Element Of Road Design	Multiply Factor	Constant					Index Ratio				
Sight Distance	0.9	0	1	1	1	1	0	0.9	0.9	0.9	0.9
Design Speed	0.84	1	0	1	1	1	0.84	0	0.84	0.84	0.84
Traffic Signal	0.88	1	1	0	1	1	0.88	0.88	0	0.88	0.88
Cross Section	0.9	1	1	1	0	1	0.9	0.9	0.9	0	0.9
Horizontal Alignment	0.9	1	1	1	1	0	0.9	0.9	0.9	0.9	0

Table 2 shows the example of validation process for constant to get the percentage scoring of Level of Safety and develop it as an Assessment Tool. Since the main survey is yet to be executed, hence,the findings is expected to indicate the road design element that highly contributes to the safety impact. It is expected that there is a strong relationship between the level of safety and element of road design. It is also expected that the respondents are aware about the safety impact of complying with the element of road design and the result of validation using Road Safety Assessment Tool will show that the Level of Safety of new road design project is valid compared with the recommendation in the Road Safety Report.

CONCLUSION AND RECOMMENDATION

As roadway safety is being brought to the forefront of the transportation industry, RSAT will become a major tool in assessing the safety of existing roadways. RSAT is a proactive approach in determining the level of safety for the proposed road design. To improve the ability of decision makers in assessing the safety of the roadways, transportation professionals need a tool that can look at the complexity of the roadways. In this study, the validation of RSAT will prove that it can be one of the complementary tools to assist in the implementation of Road Safety Audit. This tool will help practitioners but this was the first step in quantifying RSAT while future investigations can look at ways to help calibrate the tool to actual benefits gained from the Road Safety Auditor (RSA) recommendations.

REFERENCES

AASHTOWare (2001). *Safety Analyst*. https://www.safetyanalyst.org/tools.

Abu Mansor, S. N., Ahmad Saman, M. S., Tengku Razman, T. M. S., & Masnel, H. (2019). Road safety audit - What we have learnt? *IOP Conference Series: Materials Science and Engineering*, *512*(1):

Aghaabbasi, M., Moeinaddini, M., Zaly Shah, M., Asadi-Shekari, Z., & Arjomand Kermani, M. (2018). Evaluating the capability of walkability audit tools for assessing sidewalks. *Sustainable Cities and Society*, *37*:475–484.

Austroads. (2009). *Road Safety Audit Toolkit*. Version 2.0. http://www.rsatoolkit.com.au/

Balkin, S., & Ord, J. (2001). Assessing the Impact of Speed-Limit Increases on Fatal Interstate Crashes. *Journal of Transportation and Statistics*, *4*(1):1-15.

Blatt, A., Kevin Majka, & Schock, S. (2014). *Motorcoach Roadway Safety Assessment Tool – Final Report*. Retrieved on 30th November 2020 from https://safety.fhwa.dot.gov/rsat/motorcoach_rsat_finalrpt.pdf

Cafiso, S., Di Graziano, A., Di Silvestro, G., La Cava, G., & Persaud, B. (2010). Development of comprehensive accident models for two-lane rural highways using exposure, geometry, consistency and context variables. *Accident Analysis and Prevention*, *42*(4), pp. 1072–1079.

Caliendo, C., Guida, M., & Parisi, A. (2007). A crash-prediction model for multilane roads. *Accident Analysis and Prevention*, *39*(4):657–670. https://doi.org/10.1016/j.aap.2006.10.012

European Commission. (2006). *Handbook of assessed road safety measures* (Issue July). United Kingdom.

European Commission. (2007). *Handbook For Measures At The European Level* (Issue June). United Kingdom.

European Commission. (2010). *Best practices in road safety - Handbook for measures at the country level*. United Kingdom. https://doi.org/10.2832/16225

Elvik, R., Christensen, P., & Amundsen, A. (2004). Speed and road accidents: An evaluation of the Power Model. *TOI Report 740*, *740*(December), 134. http://www.trg.dk/elvik/740-2004.pdf

Elvik, R., & Vaa, T. (2004). Book Review: The Handbook of Road Safety Measures. In *European Journal of Transport and Infrastructure Research*, *4*, pp. 445-446.

Glennon, J. C. (1984). *Effect of Sight Distance on Highway Safety*.

Haynes, R., Jones, A., Kennedy, V., Harvey, I., & Jewell, T. (2007). District variations in road curvature in England and Wales and their association with road-traffic crashes. *Environment and Planning A*, *39*(5), 1222–1237. https://doi.org/10.1068/a38106

Hildebrand, D. E., & Wilson, D. F. (1999). *Road Safety Audit Guidelines for Canada by UNB*.

Karndacharuk, A. & Hillier, P. (2019). *Guide to Road Safety Part 6: Managing Road Safety Audits*. Australia: Austroads Ltd.

Jurewicz, C., & Excel, R. (2016). Application of a Crash-predictive Risk Assessment Model to Prioritise Road Safety Investment in Australia. *Transportation Research Procedia*, 14:2101–2110.

Kulanthayan, S., Phang, W. ., & Hayati, K. (2007). Traffic Light Violation Among Motorists In Malaysia. *International Association of Traffic and Safety Sciences*, *31*(2):67–73. https://doi.org/10.1016/S0386-1112(14)60224-7

MIROS (2017). 2017 MIROS Annual Report. Malaysia: Malaysian Institute of Road Safety Research,1-208

MIROS (2019). *MyRAP for Malaysia*. Retrieved on 15th December 2020 from https://www.irap.org/2019/10/myrap-programme-launched-to-address-malaysia-road-safety/

Montella, A., Colantuoni, L., & Lamberti, R. (2008). Crash prediction models for rural motorways. *Transportation Research Record*, *2083*, 180–189. https://doi.org/10.3141/2083-21

PWD. (1986). *A Guide on Geometric Design of Roads*. Kuala Lumpur: Public Works Department

PWD. (1997). *Guideline for The Road Safety Audit of Roads and Road Project In Malaysia*. Kuala Lumpur: Public Works Department

Sarani, R., Syed Mohamed Rahim, S. A., & Voon, W. S. (2013). Predicting Malaysian Road Fatalities for Year 2020. *Road Safety and Simulation International Conference*. Rome, Italy, 1–11.

SWOV Institute for the Road Safety Research (2001). *Cost-Benefit Analysis of Measures for Vulnerable Road Users.* Project Report for European Commission. Retrieved from https://ec.europa.eu/transport/road_safety/sites/default/files/pdf/projects_sources/promising_deliverable_5.pdf

Turner, S., Singh, R., & Nates, G. (2012). The next generation of rural road crash prediction models : final report. In *New Zealand Transport Agency Research Report 509* (Issue December 2012).

Useche, S. A., Montoro, L., Tomas, J. M., & Cendales, B. (2018). Validation of the Cycling Behavior Questionnaire: A tool for measuring cyclists' road behaviors. *Transportation Research Part F: Traffic Psychology and Behaviour*, *58*:1021–1030.

VDOT (2008). *VDOT Road Safety Assessment Guidelines*. *May 2008*, 1–11. http://www.virginiadot.org/business/resources/traffic_eng_hsip/VDOT_RSA_Guidelines_200804.pdf

Wilson, E. M., & Lipinski, M. E. (2004). Road Safety Audits- A Synthesis of Highway Practice. *Transportation Research Board, Washington*. Retrieved on 12th November 2020 from https://trid.trb.org/

World Health Organization (2017). Fact sheets on sustainable development goals: health targets, Road Safety. *World Health Organization (WHO) 2017*, 8. https://doi.org/10.1201/b16346

Yannis, G., Weijermars, W., & Kauppila, J. (2012). A review of International Sources for Road Safety Measures Assessment. *Procedia - Social and Behavioral Sciences*, *48*:2876–2886.

Yokoo, T., Levinson, D., & Marasteanu, M. (2019). Pavement condition and crashes. *Transport Findings.* (November 2018), 1–9. https://doi.org/10.32866/5771.

PERSONAL PROTECTIVE EQUIPMENT AND COSTS INCURRED BY THE CONTRACTORS OF MASS RAPID TRANSIT PROJECTS IN MALAYSIA

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Abstract
The construction of rail infrastructure projects such as the Mass Rapid Transit (MRT) is expanding in Malaysia to enhance and integrate urban public transportation services. However, fatalities, serious injuries, and damage to property occur every year due to the rapid construction of this project. Previous research revealed the most common cause with a 32% death rate is falling from a high place due to negligence and not following the proper personal protective equipment (PPE). The costs of these injuries to an organisation are crucial in establishing how much it should spend on safety control. Most contractors had some problems with the safety budget. The budget always overruns due to a lack of systematic calculation during the construction stage. Thus, the safety budget required is not clearly defined and specified in the existing contract document. Most contractors are unable to identify the safety items clearly and do not know the requirements of the project, which causes them to estimate safety budgets using their experience. The effect causes a defective budget system for the construction project. This research aims to analyse the Personal Protective Equipment (PPE) costs that are most incurred by MRT project contractors. The PPE costs are one of the main items in safety budget. A quantitative method was used in this research. The questionnaires were distributed to the Work Packages Contractors (WPC) who were involved in the guideway (viaduct) package works in MRT projects. The findings show that types of PPE like steel toe safety shoes, traffic vests and earplugs (>85 dBA) accounted for the highest costs incurred during MRT projects. These findings could assist contractors to allow for a reliable safety budget during the pre-contract stages.

Keywords: *Personal Protective Equipment (PPE); cost incurred; contractor; Mass Rapid Transit (MRT) projects.*

INTRODUCTION

Workplace accident rates are very high in the construction sector compared to other sectors (Hola & Szostak, 2017; Martinez Aires et al., 2010; Loosemore & Andonakis, 2007; Mitropoulos et al., 2005; Abdelhamid & Everett, 2000). Construction is a complex activity in which various stakeholders are present and working under constant challenges from the demands of the job. It stands unique compared to other industries because most of its activities take place outdoors and under conditions that are not conducive to safety and health (Misnan & Mohammed, 2007). Each job entails several safety and risk factors, requiring quality and safety management systems to be established, as indicated by Mehta and Agnew (2010). This view is supported by Imriyas et al. (2007) who argued that construction site conditions are hazardous due to the scope of works and location of the projects. Higher project hazard levels tend to be associated with higher risk levels on site.

Recently, Malaysia has reached another milestone in its urban rail infrastructure with the completion of the MRT 1 (SBK Line) Project in July 2017. Other rail infrastructure projects that are currently under construction are the MRT 2 (SSP Line) Project and the Light Rail Transit (LRT) 3 (Bandar Utama to Klang Line) Project. These developments indicate that

Malaysia is in line with other developed countries that have high-speed and modern public transportation. The projects generally have a large investment, long development cycle, high technical requirements and a complex construction environment complex. Many risk factors are involved during the period of the construction project, such as economic, political, legal, physical site, scope of work, construction contract, design materials, financial and human resource risks (Sangsomboon & Yan, 2014).

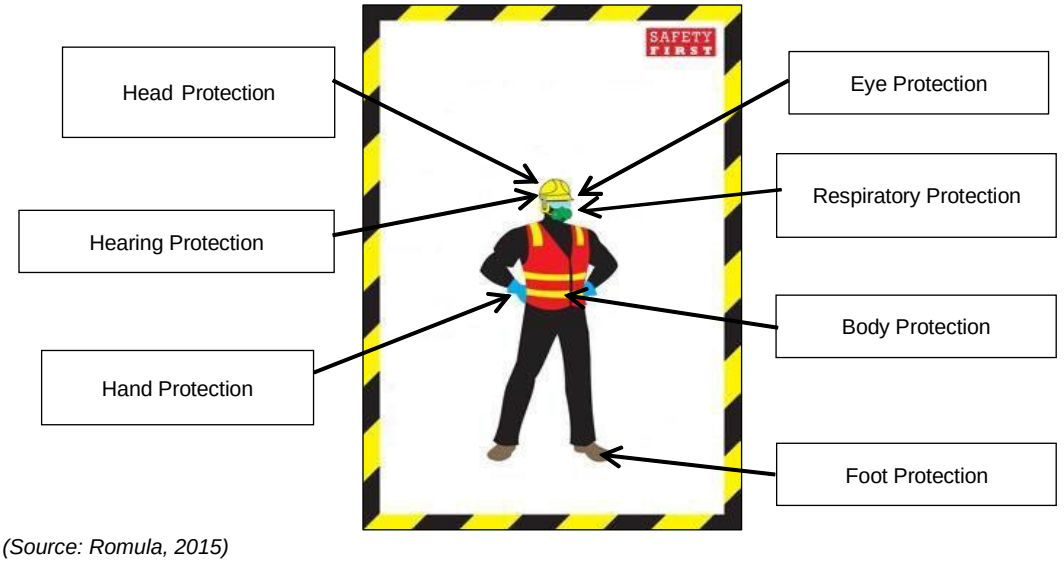
Personal Protective Equipment (PPE) is the first priority regarding safety protection to prepare before other forms of safety protection are concerned. In addition, PPE is designed to protect employees from serious workplace injuries or illnesses resulting from contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazards. PPE equipment includes face shields, safety glasses, safety helmets, safety shoes, gloves, eye protection, ear protection, safety harnesses, vests, high-visibility clothing, and respirators (OSHA, 2014).Moreover, the main function of PPE is to protect employees against health or safety risks at work and it is also designed for job-related occupational safety and health purposes, to protect the body from injury from electrical hazards, heat, chemicals, and infections (Ahmed & Azhar, 2015). Different types of PPE are used for each type of construction, but the most common are used are head, hand, face, eye, foot, and body protection.

Therefore, the implementation of PPE for the construction workers becomes highly essential (Nipun et al., 2020). The necessary of PPE include Safety Goggles, High Visibility Vests, Safety Boots, Gloves, Hard Hats/Construction Helmets, Safety Harnesses, Communication Radios, Knee/Elbow Pads, Hearing and Sound barricading aids, Chemical Face Shields, along with Electronic Gadgets which assist during the routine choirs on-site (Mansour et al., 2019; Martina et al., 2019; Marcin, 2013). In addition to the PPE, the Safety Devices, which include Signboards, Warning Lights, and Information Chalking, also play a vital role in directing the individuals towards safe zones on construction site (Syed et al., 2021).

The Occupational Safety and Health Act (OSHA) requires employers to allocate PPE to comply with OSHA standards (OSHA, 2014) in safety budget. Chuing & Abdul (2011) revealed that the implementation of safety measures during the conceptual design phases is substantially lower in cost than the implementation of systems during or after construction. However, many clients and contractors did not allocate resources towards the cost of PPE and safety becomes more ineffective due to an insufficient safety budget (Ahmed & Azhar, 2015). Most of them estimate the safety budget using their experience but with a lack of systematic calculation (Barlow, 2009). Thus, it will effect the allocation of PPE items in construction project. They were not able to identify the safety items clearly in the safety budget, which includes the cost of PPE. As a result, it will lead to a defective budget system, especially for safety equipment. Therefore, the project's safety budget can exceed the actual cost. There are no competency or reliable systems for estimating the safety budget. This significant gap, which is highlighted in this research, means there is a need for an empirical study of the types of PPE which are considered important in terms of costs incurred by MRT project contractors.

TYPES OF PERSONAL PROTECTIVE EQUIPMENT (PPE)

Personal Protective Equipment (PPE) is anything used or worn by a person to minimise risk to the person's health or safety and includes a wide range of clothing and safety equipment (OSHA, 2014). PPE is considered the first line of defence against hazards and in preventing work injuries (Ahmed & Azhar, 2015). PPE is also designed to protect employees from serious workplace injuries or illnesses resulting from contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazards (Tanko & Anigbogu, 2012).PPE should be chosen carefully according to what the hazard is, the extent of its use, and the suitability of the PPE for the task intended. Many types of PPE are used by individual workers to protect them from hazards. These types vary depending on the worksites of the construction industries and the level of hazards at the workplace (Romulo, 2015). Figure 1 shows the allocation of PPE for an employee at the workplace and Table 1 shows the categories of PPE commonly used in construction site.



(Source: Romula, 2015)

Figure 1. Allocation of Personal Protective Equipment (PPE) for Employee at the Workplace

Table 1. Categories of Personal Protective Equipment (PPE)

Category	Descriptions	Types of Tools	Sign of Protection
Head Protection	A head injury can impair a worker for life, or it can be fatal. Wearing a safety helmet or hard hat is one of the easiest ways to protect a worker's head from injury.		
Eye Protection	Workers can be exposed to a large number of hazards that pose danger to their eyes and face. Examples of tools: safety glasses with side shields, goggles with face shields, goggles, eyecup and cover types, welding goggles, welding helmet or shields with safety glasses & side shields, chemical goggles or face shield and unvented chemical goggles.		

Category	Descriptions	Types of Tools	Sign of Protection
Hand Protection	Potential hazards to hands and arms include skin absorption of harmful substances, chemical or thermal burns, electrical dangers, bruises, abrasions, cuts, punctures, fractures, and amputations. Example of tools: gloves, finger guards and arm coverings or elbow-length gloves.		
Hearing Protection	All workplaces generate noise and sometimes the level of noise may lead to temporary or permanent loss of hearing. Example of tools: earplugs and earmuffs.		
Respiratory Protection	Respiratory protection is designed to give protection to an employee against inhalation hazards such as lack of oxygen, particulate contaminants (dust, fibres, mists, fumes, or dirt), hazardous gases, vapors and contaminants - solvents.		
Body Protection	• The workplace hazards that could cause bodily injury is temperature extremes, hot splashes from molten metals and other hot liquids, potential impacts from tools, machinery and materials and hazardous chemicals. • Examples of tools: laboratory coats, coveralls, traffic vests, jackets and full-body suits, cut resistance sleeves, static control coats or overalls, flame- resistant jacket or aluminium fire suits, chemical apron or suits, body harnesses and lanyards.		
Foot Protection	• Employees who face possible foot or leg injuries from falling or rolling objects or from crushing or penetrating materials and whose work involves exposure to hot substances or corrosive or poisonous materials must have protective gear to cover exposed body parts, including legs and feet. • Examples of tools: steel toe safety shoes, leather boots or safety shoes with metatarsal guards, slip resistant soles, puncture resistant soles and electrical shoes. • Types of hazards: water (slip), chemical, hot splashes, penetration to the underside of the foot and ankle twist injuries from rough terrain.		

METHOD

This research was conducted on the work packages contractors (WPC) from the viaduct (guideway) package of the MRT 1 (SBK Line) Project and the MRT 2 (SSP Line) Project. The respondents, who were the safety personnel for both projects were required to answer the questionnaire survey based on their experience of being involved in those projects. A cover letter was attached to inform them of the importance of the survey. The letter also informed them of the confidential nature of the study by ensuring anonymity. A total of 60 questionnaires were distributed to the contractors for both projects. A total of 40 questionnaires were returned by the safety personnel. Based on their experience, respondents were asked about their knowledge regarding the types of PPE costs which are most often incurred by contractors involved in the MRT projects. The survey was divided into three (3) parts: 1) Organisational background; 2) Respondent particulars; and 3) Types of PPE cost

most often incurred by MRT project contractors. Seven (7) categories of PPE we assessed in this section using a five-point Likert scale; foot protection, body protection, ear protection, respiratory protection, eye protection, hand protection and eye protection.

RESULTS AND DISCUSSION

Table 2 presents the respondents' profiles of the research. The majority (46.3%) were assigned to those in a Site Safety Supervisor position followed by a Safety & Health Officer (26.8%) and a Safety Manager (24.4%) position. The designation that someone holds in an organisation portrays their employment experience. Thus, it shows most respondents (36.6%) had working experience ranging from 10 years to 20 years, and only 12.2% had experience in construction safety of more than twenty (20) years.

Table 2. Respondent's Profiles

Items	Sub-Items	Frequency (N)	Percentage (%)
Job Position	Safety Manager	10	24.4
	Safety & Health Officer	11	26.8
	Site Safety Supervisor	19	46.3
Works Experience	< 5 years	11	26.8
	5-10 years	10	24.4
	10-20 years	14	36.6
	> 20 years	5	12.2

Table 3 shows the mean rank score for the types of foot protection that incurred costs to MRT project contractors. Based on the table, the highest cost incurred was for steel toe safety shoes (mean=4.63, SD=.536). The second highest was for leather boots (mean=3.95, SD=1.431), followed by the cost of puncture resistant soles (mean=3.85, SD=1.352). Meanwhile, the lowest foot protection cost incurred was for insulated boots or shoes (mean=2.29, SD=1.764).

Table 3. Mean Rank Score for Foot Protection Costs

No.	Types of PPE	Mean	Std. Deviation	Rank
1.	Steel toe safety shoes	4.63	0.536	1
2.	Leather boots or safety shoes with metatarsal (top of foot) guards	3.95	1.431	2
3.	Puncture resistant soles	3.85	1.352	3
4.	Slip resistant soles	3.63	1.545	4
5.	Electrical hazard shoes	3.34	1.622	5
6.	Rubber boots or closed top shoes	2.80	1.833	6
7.	Conductive footwear	2.78	1.710	7
8.	Insulated boots or shoes	2.29	1.764	8

Table 4 shows the mean rank score for body protection costs. The result shows that the highest cost of PPE incurred by the contractors to pay for body protection was for traffic vests with a mean=4.56 (SD=.594). The second highest was for body harnesses and lanyards (mean=4.39, SD=.862), followed by flame-resistant jacket or aluminium fire suit costs (mean=3.63, SD=1.561). The lowest cost incurred by the contractors was for chemical aprons or suits (mean=2.76, SD=1.609).

Table 4. Mean Rank Score for Body Protection Costs

No.	Types of PPE	Mean	Std. Deviation	Rank
1.	Traffic vests	4.56	0.594	1
2.	Body harnesses and lanyards	4.39	0.862	2
3.	Flame resistant jackets or aluminium fire suits	3.63	1.561	3
4.	Long sleeves	3.32	1.753	4
5.	Cut-resistant sleeves	3.07	1.738	5
6.	Static control coats or coveralls	2.95	1.774	6
7.	Chemical apron or suits	2.76	1.609	7

Table 5 shows the mean rank score for the ear protection costs required during MRT projects. The highest cost of ear protection was for earplugs or earmuffs >85 dBA 8-hour TWA (mean=4.49, SD=.746). The second highest was for earplugs or earmuffs >105 dBA 8-hour TWA (mean=3.76, SD=1.463) and the lowest was earplugs or earmuffs which reduce exposure to sparks with a mean=3.59 (SD=1.612).

Table 5. Mean Rank Score for Ear Protection Costs

No.	Types of PPE	Mean	Std. Deviation	Rank
1.	Earplugs or earmuffs (>85 dBA)	4.49	0.746	1
2.	Earplugs or earmuffs (>105 dBA)	3.76	1.463	2
3.	Earplugs or earmuffs (exposure to sparks)	3.59	1.612	3

Table 6 shows the mean rank score for the costs of respiratory protection elements. There were seven types of respiratory protection costs incurred by contractors. Disposable dust or mist masks contributed the highest cost, with a mean=4.48 (SD=.711), followed by the cost for respirators with a P100 filter (mean=3.54, SD=1.675) which is to protect against the hazards of welding fumes and asbestos. Meanwhile, the second lowest cost was for respirators with OV/P100 (mean=2.85, SD=1.769) which it is used as protection against hazardous paint spray. The lowest cost for types of respiratory protection is that for respirators with organic cartridges (mean=2.34, SD=1.637).

Table 6. Mean Rank Score for Respiratory Protection Costs

No.	Types of PPE	Mean	Std. Deviation	Rank
1.	Disposable dust or mist mask	4.48	0.711	1
2.	Respirator with P100 filter	3.54	1.675	2
3.	Respirator with cartridges as per pesticide label	3.27	1.761	3
4.	SCBA or Type C airline respirator	3.05	1.830	4
5.	Respirator with acid gas cartridges	2.90	1.744	5
6.	Respirator with OV/P100	2.85	1.769	6
7.	Respirator with organic cartridges	2.34	1.637	7

Table 7 shows the results of the mean rank score for head protection costs and shows that the highest rank mean score (mean=4.39, SD=.833) was for Type 1 ANSI Z89.1-1997 head protection costs, followed by the safety helmet Class B/E (mean=4.15, SD=1.062). Both PPE items are to protect against impact to the side of the head. Meanwhile, the lowest cost incurred was for the Type 2 ANSI Z89.1-1997 (mean=3.83, SD=1.430).

Table 7. Mean Rank Score for Head Protection Costs

No.	Types of PPE	Mean	Std. Deviation	Rank
1.	Type 1 ANSI Z89.1-1997	4.39	0.833	1
2.	Safety helmet Class B/E	4.15	1.062	2
3.	Safety helmet Class A/G	3.85	1.333	3
4.	Type 2 ANSI Z89.1-1997	3.83	1.430	4

Table 8 represents the mean rank score for types of hand protection that incurred costs to contractors. The chemical resistant gloves cost was the highest incurred by contractors (mean=3.98, SD=1.214), followed by the cost of leather or cut resistant gloves (mean=3.68, SD=1.507). The lowest cost incurred was for insulated gloves, with a mean=2.27 (SD=1.613).

Table 8. Mean Rank Score for Hand Protection Costs

No.	Types of PPE	Mean	Std. Deviation	Rank
1.	Chemical resistant gloves	3.98	1.214	1
2.	Leather or cut resistant gloves	3.68	1.507	2
3.	Fabric and coated fabric gloves	3.66	1.315	3
4.	Metal mesh gloves, Kevlar gloves, heavy leather gloves	3.44	1.598	4
5.	Heat flame resistant gloves	2.85	1.667	5
6.	Using plastic, cotton, nylon	2.85	1.824	6
7.	Using insulated rubber gloves	2.80	1.778	7
8.	Nitrile gloves	2.49	1.660	8
9.	Insulated gloves	2.27	1.613	9

Table 9 shows the use of PPE for eye protection on MRT projects. The highest cost incurred was for protection against hazards caused by UV light welding, cutting, torch brazing or soldering, which are welding helmets or shields with safety glasses and side shields (mean=4.17, SD=1.223). The second highest was the costs of laser goggles or glasses (mean=3.66, SD=1.575). The lowest cost types of eye protection was unvented chemical goggles (mean=1.80, SD=1.382).

Table 9. Mean Rank Score for Eye Protection Costs

No.	Types of PPE	Mean	Std. Deviation	Rank
1.	Welding helmet or shields with safety glasses and side shields	4.17	1.223	1
2.	Using laser goggles or glasses	3.66	1.575	2
3.	Goggles, eye cups and cover types	3.61	1.656	3
4.	Welding goggles	3.37	1.577	4
5.	Safety goggles with face shields	3.37	1.757	5
6.	Goggles with face shields	3.32	1.695	6
7.	Chemical goggles or face shield	3.32	1.836	7
8.	Safety glasses with side shields	3.10	1.729	8
9.	Safety goggles with face shield	3.10	1.744	9
10.	Shaded safety glasses	2.90	1.800	10
11.	Unvented chemical goggles	2.78	1.754	11
12.	Safety glasses with side shields	1.80	1.382	12

Table 10 shows a summary of the mean rank score for all types of PPE that incurred costs to MRT project contractors. Based on the table, the highest cost incurred was for foot protection, which was steel toe safety shoes (mean=4.63). The second highest was the cost of traffic vest (mean=4.56) for body protection, followed by the cost of earplugs or earmuffs (>85 dBA) (mean=4.49) for ear protection and disposable dust or mist masks (mean=4.48)

for respiratory protection. Meanwhile, the lowest PPE cost incurred was for safety glasses with side shields for eye protection (mean=1.80).

Table 10. Summary of Mean Rank Score for All Types of PPE

Categories of PPE	Types of PPE Costs	N	Mean	Rank
Foot Protection	Steel toe safety shoes	41	4.63	1
Body Protection	Traffic vests	41	4.56	2
Ear Protection	Earplugs or earmuffs (>85 dBA)	41	4.49	3
Respiratory Protection	Disposable dust or mist masks	41	4.48	4
Head Protection	Type 1 ANSI Z89.1-1997	41	4.39	5
Hand Protection	Insulated gloves	41	2.27	6
Eye Protection	Safety glasses with side shields	41	1.80	7

The results obtained agree with previous work carried out by OSHA (2007), which OSHA addressed several items of PPE that employers are required to provide for their employees such as safety-toe protective footwear. Moreover, according to the Health & Safety Policy (2014), steel toe shoes or boots have a protective covering to safeguard the wearer from an injury that results from impact and or compression by heavy objects. It is generally accepted as best practices and most effective for types of protection to be fully integrated into construction operations.

However, the lowest mean rank (mean=1.80) was the eye protection category, which was safety glasses with side shields. This PPE is used against the hazard of impacts like flying objects, chips, sand, or dirt. The lower cost was incurred the hazards are beyond expectations. They could happen outside the project site. Meanwhile, the second-lowest mean rank was the insulated gloves hand protection (mean=2.27). They provide the protection and warmth for employees on cold winter days. This type of PPE is neither used in nor appropriate for MRT projects due to the year-round hot and humid weather in Malaysia.

Syed et al. (2021) also highlighted the quality and usage of PPE are considered as an essential factor in construction projects. The equipment is equipped with the standards already specified, or it will give the protection up to the mark. These standards are set by authorised bodies such as OSHA, NIOSH, DOSH. The equipment's quality and efficiency should be up to the standards as specified by the legislative authorities. It should be implemented by all organisations to follow with the government rules and regulations.

CONCLUSION

In conclusion, the construction project success also depends highly on the safety provisions. These safety provisions are further linked to the PPE engagement in construction projects. The on-site workers are less productive if they do not feel safe on site. In this study, the types of PPE in which are considered important in terms of costs incurred by MRT project contractors has been reviewed. The study found that steel toe safety shoes for foot protection were the highest cost incurred by MRT project contractors, while the eye protection category, which was safety glasses with side shields, was the lowest costs incurred. Overall, the presented results could enrich awareness among contractors and help them plan their investment in safety measures appropriately according to the related PPE categories. Proactive steps on the allocation of safety and health costs are required to overcome the safety issues in the construction sector.

REFERENCES

Abdelhamid, T.S., & Everett, J.G. (2000) Identifying root causes of construction accidents. *Journal of Construction Engineering and Management*, 126(1): 52–60.

Ahmed, S. M., & Azhar, S. (2015) Addressing the Issue of Compliance with Personal Protective Equipment on Construction Worksites: A Workers' Perspective. *ASC 45th (2009) Conference*. Florida International University Miami, Florida, United State.

Barlow, P. (2009) Cost of Quality in the Construction Industry. *Journal of Construction Management and Economics*, 21(2): 175-185.

Chuing, S., & Abdul, R. H. (2012) Malaysian Contractors in Gulf Construction: A Preliminary Study on Financial and Economic Risks. *International Journal of Engineering and Technology*, 4(4): 437-450.

Health and Safety Policy (2014) Personal Protective Equipment. [Online]. Available: https://intranet.birmingham.ac.uk/hr/documents/public/hsu/hsupolicy/PersonalProtective-Equipment.pdf. Acessed: 5 January 2017.

Hola, B., & Szostak, M. (2017) Methodology of analysing the accident rate in the construction industry. *Procedia Engineering*, 172: 355–362.

Imriyas, K., Low, S.P., & Teo, E.A.L. (2007) A fuzzy knowledge-based system for premium rating of workers' compensation insurance for building projects. *Construction Management Economics*, 25: 1177–1195.

Loosemore, M., & Andonakis, N. (2007) Barriers to implementing OHS reforms–the experiences of small subcontractors in the Australian construction industry. *International Journal of Project Management*, 25(6): 579–588.

Marcin, J. (2013). Electrostatic Properties of Selected Personal Protective Equipment Regarding Explosion Hazard. *Journal of Sustainable Mining*. 12 (1) (2013) 27–33.

Martina, L., Sandra, H., Gerold, S., Andrea, B., Kurt, Z. (2019). Limiting Factors for Wearing Personal Protective Equipment (PPE) in a Health Care Environment Evaluated in a Randomised Study. PLOS One. 14 (1) (2019) 1–16.

Martinez Aires, M.D., Rubio Gamez, M.C., & Gibb, A. (2010). Prevention through design: the effect of European directives on construction workplace accidents. *Safety Science*, 48(2): 248–258.

Mehta, R. K., & Agnew, M. J. (2010). Analysis of individual and occupational risk factors on task performance and biomechanical demands for a simulated drilling task. *International Journal of Industrial Ergonomics*, 40(5): 584–591.

Misnan, M. S., & Mohammed, A. H. (2007). Development of safety culture in the construction industry: A conceptual framework. In *23rd Annual ARCOM Conference.* Belfast, UK. 13-22.

Mitropoulos, P., Abdelhamid, T.S., & Howell, G.A. (2005). Systems model of construction accident causation. *Journal of Construction Engineering and Management*, 131(7), 816–825.

Nipun, D.N., Amir, H.B., Stephanie, G.P (2020). Deep Learning for Site Safety: Real-Time Detection of Personal Protective Equipment. *Automation in Construction Journal*. 112, 103085.

OSHA (2007). Safety Practices on Personal Protective Equipment. [Online]. Available: https://www.osha.gov-Publications-osha3151.pdf. Accessed: 17 August 2016.

OSHA (2014). Issues in the Personal Protective Equipment. [Online]. Available: https://www.osha.gov-Publications-osha3151.pdf. Accessed: 17 September 2016.

Romulo, R. N. (2015). Human Factors in Issues Responsible for Use or Disuse of PPE in Construction – Case Study. *International Journal of Scientific Research and Innovative Technology*, 2(8): 25-36.

Sangsomboon, P. & Yan, S. (2014). Analysis of Risk-Response based on Railroad Construction Project. *International Journal of Management Sciences and Business Research*, 3(1): 81-91.

Syed, A., Wesam, S.A., Syed, S., Abdul, H.Q. (2020). Personal Protective Equipment (PPE) Usage in Construction Projects: A Scientometric Approach. Journal of Building Engineering. 35 (2021), 102086.

Tanko, B. L. & Anigbogu, N. A. (2012). The Use of Personal Protective Equipment (PPE) on Construction Sites in Nigeria. *4th WABER Conference*. Abuja. 1341-1348.

PRELIMINARY FINDINGS ON THE CRITERIA AND REQUIRED PROCESS IN IMPLEMENTING GREEN PROCUREMENT (GP) FOR CONSTRUCTION WORKS

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Abstract

The construction industry inevitably plays a vital role in Malaysia's economic growth; however, it can have an adverse impact on environmental aspects. Green procurement initially helps to reduce the environmental issues in construction by considering green products and sustainable materials for construction. However, the procurement process in construction is relatively complex as it involves many activities and various stakeholders. This study investigates the criteria for construction works needed to implement green procurement for green projects in Malaysia's construction sector. Through extensive literature reviews and focus group discussion (FGD), the criteria were established. The FGD was used to get a better and more viable result as the participants are experts in the field. The participants mainly consist of experts in green and sustainable construction projects. The process was divided into five phases; i.e.; i) inception or planning phase, ii) design phase, iii) tendering phase, iv) construction phase, and v) operation phase. It was found that the project's green requirements should be initiated clearly in the planning phase from clients. The findings help to depict more precise guidance in adopting green procurement to achieve aims in green construction.

Keywords: *Green procurement; green projects; construction works; implementation criteria; focus-group discussion.*

INTRODUCTION

Due to the ever-increasing need to become a more developed country, Malaysian government has given a fair focus on its economy. One of the main contributors to this is the construction sector. Maskuriy et al. (2019) stated that the construction outcome shows that there is a solid connection between the economic growth and the construction field in all states of Malaysia. The national's gross domestic product is considerably supported by the construction benefit of financial outcomes. This proves the significance of the construction sector towards Malaysia's economy by reviewing the criteria and process for green procurement.

The value of construction work is increasing year by year, where the first and second quarter of 2017 recorded 35.1 billion and 33.8 billion respectably which was a huge growth of 11.2% compared to the previous years. All sub-sectors are leading the expansion in the value of construction work such: civil engineering (19.3%), special trades activities (11.6%), non-residential buildings (9.7%), and residential buildings (3.8%) sub-sector. In terms of contributions, the performance of value of construction work done is still dominated by the civil engineering sub-sector with 35.5%, followed by non-residential buildings (31.2%), residential buildings (28.5%), and special trades activities (4.8%). The construction activity

is predominated by the private sector with 64% share (RM21.6 billion) as compared to the public sector with only 36% share (RM12.2 billion). Hence, this proves that construction industry is one of the main focus of the Malaysian economy (Zid et al., 2019).

However, construction industry activities lead to greenhouse gas (GHG) and high carbon dioxide emissions, water pollution and also lead to high waste of materials to landfills. Concerns on the environmental adverse impact are significant to avoid destruction or damages of the natural resources. Therefore, the Malaysian government has promoted the awareness of green growth and the concept of green procurement (GP) as a method to maintain and minimize the environmental effects. The government has been serious in the highlights of green procurement as it was also shown in the National Green Technology (2009) that offered environmental-friendly and green products or services. In 2014, the Malaysian government has introduced a guideline for government procurers through the Ministry of Environment and Water (KASA) or previously known as KeTTHA and Malaysia Green Technology Corporation (MGTC). The government green procurement (GGP) guideline in 2014 was established as the first government green procurement and the purchasing is delineated to six (6) green products and services including cleaning services, ICT equipment, energy efficiency (EE) indoor lighting, paper, paints, and fibre cement (Kahlenborn et al., 2014). The GGP guideline is improvised through its latest issuance in the year 2018, where 20 products were incorporated. The GGP is intended to create demand for green products and services, encouraging industries to raise both the standards and quality of their products in order to meet green requirements.

In the context of sustainability in the built environment, the green growth has been addressed in the Construction Industry Transformation Plan (CITP) 2016-2020, and one of the thrusts in this strategy is environmental sustainability. The importance of green procurement is further addressed in the by the Sustainable Voluntary Reviews of 2017 (EPU, 2017) where it focuses on the government purchases of environmentally-friendly products and services to spur demand for green industries. Other than that, the promotion of green procurement and green growth is also announced in the 11th Malaysia Plan (2016-2020) whereby one of the plans is focusing on the pursuance of green for sustainability and community resilience. A lot of attention has been given to the construction industry due to the involvement of various parties within it such as the suppliers, manufacturers, owners, consultants, and contractors (Bohari et al., 2017).

Even though the green awareness in construction industry was addressed in the CITP (2016-2020) and also highlighted in the SDG No. 12 (Responsible Consumption ad Production), implementation of green procurement for construction works is yet to establish. Additionally, various procedures must be undertaken due to the involvement of various parties. This is to ensure that the project runs smoothly, and everyone is satisfied. One particular and important procedure is called procurement. This procedure is considered significant because construction of buildings cannot be legalised without undergoing the procurement process. Therefore, it is important to address green procurement in the construction industry.

PROBLEM STATEMENT

Due to the increase in the need for sustainable or green development, Malaysia has started its effort to supplement this need by implementing green procurement practices in the construction industry which is commonly known as green procurement (GP). Additionally, Malaysia had already established a government green procurement (GGP) guideline for products and services in 2014 and 2018 (KeTTHA, 2018; Bohari et al., 2017). Although this is the case, it only emphasizes the products and services for the government buildings. It does not cover the construction sector in any comprehensive way. This problem occurs due to the relative complexity of documentation and procedures in construction procurement. The problem does not only encompass the government itself. Chan et al. (2018) argued that procurement managers seldom consider the effects of procurement on the environment. This situation will cause many environmental problems such as carbon dioxide emissions, climate change, greenhouse effects, pollution, and deforestation. So, even the procurement managers are at fault, though not entirely, for not knowing about the repercussions of their projects (Kwok et al., 2016) that there is a lack of research addressing the issue in facilitating the successful implementation of green procurement in local construction industries.

Green procurement (GP) is still not well-reviewed and familiar among many organizations, firms or people in the sector of construction industry. Fischer (2010) argued that the GP's implementation and the success seem to be unclear even though the use of green procurement appears to be increasing globally. Several researches, for example, (Adham & Siwar, 2012; Bohari et al., 2017; Musa et al., 2013) addressed the significance of GP in their research from the aspect of products, services, constructions and others. However, it is also highlighted that the establishment of GP is still lacking in terms of legal, policy, framework, and standard guidelines. This is also supported by Musa et al. (2013) that there is no issuance of standard guideline or framework that can be used by the procurement officers in applying GP practices in their firms. Consequently, the analysis on the above issues has become major challenges for both government and private agencies on green procurement programs. If the industry is ready to implement GP for construction, there is a need to determine the possible strategies to overcome the challenges, especially for construction enablers. As supported by Yang et al. (2015), the key drivers of green technology should uptake and quality assurance that will enable the system to achieve sustainability goals. The result shows robust commitment and support from the government and implementation agencies are needed in the form of policies, initiatives and incentives, as key catalyst.

According to Adham et al. (2012), our government is serious toward adoption of green procurement whereby they have provide the initiatives to support GP's implementation. To ensure the project is oriented in green path, the relevant stakeholders and construction procurers need to determine the procedures and steps as criteria in developing the GP criteria for construction works. The implementation criteria are vitally required for further development of the GP best practice framework for construction works. Despite much previous research carried out on the green procurement studies in the Malaysian context (for example: (Bohari et al., 2020; Adham & Siwar, 2012; Adham et al., 2015; Bohari et al., 2017; Buniamin et al., 2016; Jaafar et al., 2016; Bohari et al., 2015; Musa et al., 2013) implementation criteria, documentations to address or requirements to adopt green procurement for construction works in each project phases is lacking.

Therefore, this paper is aimed to identify the criteria needed for the implementation of GP for construction works. Hence, this research is beneficial in facilitating the government stakeholders to address green criteria in construction works and achieving a sustainable country. This study shall also focuses to the requirements needed for green projects specifically to office buildings (non-residential category). Hence, the focus of requirements are narrowed to the procurement process of green projects for office or administration buildings, which may differ in other category buildings such as residential, educational or welfare buildings. Office buildings are the main contributor to the business activities and operations sectors (Jing et al., 2017). Energy is one of the enormous tractable emissions in office buildings, therefore, much green projects are more focussing to office buildings.

LITERATURE REVIEW: GREEN PROCUREMENT (GP) IN CONSTRUCTION

According to the Royal Institute of British Architects (RIBA), development in construction is divided into seven (7) stages, and under the stages, it is divided further into five (5) phases known as inception, design, tendering, construction, and operation phases. These are the main phases associated with procurement. There is fast growth in the field of green procurement (GP) in government organizations and sectors across the world. Green procurement is relatively a new concept and initiatives have been taken in Malaysia for improving sustainability (International Green Purchasing Network, 2010). Green procurement is effective in minimizing environmental impacts. Based on the International Green Purchasing Network (2010), there are some of the essential principles of green procurement include that consideration of necessity before purchasing, taken concern about environmental impact due to the entire product life cycle, and consideration of company and distributor environmental performance.

Besides, green procurement also promotes the growth of local companies by maximum use of local materials and resources (Kahlenborn et al., 2014). Therefore, this will enhance companies through technology and expertise transfer and encourage local companies to accelerate Malaysia's economic growth (EPU, 2017; KeTTHA, 2009). Thus, green procurement will support the development of a green economy (Kahlenborn et al., 2014). Based on previous studies, there are significant barriers to the development, adoption, and implementation of green procurement practices across countries and companies (Khairul Naim Adham & Siwar, 2012). According to Preuss (2009), the financial barriers in the form of cost or price, lack of budget, lack of resources were among the largest challenges faced by the construction stakeholders in implementing green procurement practices.

METHODOLOGY

A qualitative approach was employed in the current study to ensure the result is viable and generate better findings. Qualitative data can be used for exploring the content validity of an instrument from another perspective and for providing experts with the chance (Creswell, 2012). Hence, a semi-structured interview via focus group discussion (FGD) workshop was utilised as the methodology instrument. The participants were selected from various government organisations and private agencies related to government green construction projects. The invitation to participate in the interview session was then forwarded to 25 participants via email. The list of participants was drawn with the help of from GGP Core Team from Public Works Department (JKR), Construction Industry Development Board

(CIDB) and Green Tech Corporation. Out of 25 invited participants, 17 participants have agreed to participate in the FGD workshop session and reverted the email with attendance confirmation.

A predetermined set of interview questions was prepared earlier as a guide to the researcher and moderators during the FGD session. The content of interview questions were validated by the ethics committee and also several field experts before the FGD is carried out. Hence, the structure of interview questions are valid and reliable to be used for the FGD session. The workshop was carried out at Putrajaya on November 2019. It begins with welcome remarks by the researcher, followed by presentation on the overview of GP in construction works. The interview session starts after the overview presentation. The participants were seated in three separate round tables with one moderator at each table. During the session, the moderator(s) asked the interview questions and recorded the responses by the participants.

RESULTS AND DISCUSSION

The participants' responses was summarised through content analysis; presented in a tabular form. Figure 1 depicts the gender background of the participants. The majority that participated in the interview session were male participants with 65% (11 participants, while the rest was 6 participants or 35% of the participants were female. The demographic of participants in terms of designation and years of working experience are shown in Table 1. The participants were picked from various designations to get a more accurate and unbiased result.

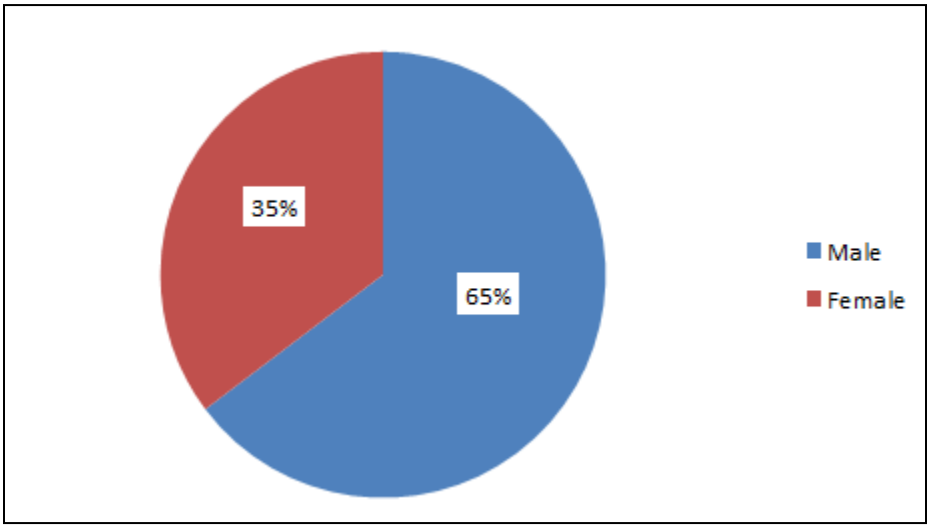

Figure 1. The Gender of Interview Participants

The participants were asked in terms of their agreement on the division of project phases, consisting of; i) inception or planning phase, ii) design phase, iii) tendering phase, iv) construction phase, and, v) operation phase. It was agreed upon unanimously by the participants on the GP implementation being based on their respective phases. By focusing on the specific project phases, input from participants is needed in terms of implementation criteria and process in the GP's implementation. As the target is towards having a low

environmental impact office buildings, it was found that the green elements are needed in the early stage of a project, i.e. starts from the planning phase. It was found that the initiation to have a green project must come from the client, as well as legal instruction from ministries to have a green project. From the instruction, all other processes are tailored to the procurement process in green orientation. The participants' responses to the requirements and implementation criteria are listed in Table 2.

Table 1. Demographic Background of the Participants

REF.	DESIGNATION	YEARS OF WORKING EXPERIENCE	YEARS OF INVOLVEMENT IN GREEN PROJECT
P1	Senior Mechanical Engineer	20	10
P2	Procurement Office / Quantity Surveyor	15	6
P3	Assistant Manager of Eco-Innovation	5	1
P4	Environmental Manager	8	2
P5	Head Architect	23	10
P6	Senior Architect	20	6
P7	Mechanical Engineer	10	6
P8	Manager/Quantity Surveyor	20	6
P9	Head of Green Catalyst	20	10
P10	Researcher	17	2
P11	Senior Auditor	15	8
P12	Senior Auditor	19	8
P13	Senior Quantity Surveyor	17	6
P14	Civil Engineer	6	2
P15	Senior Electrical Engineer	18	9
P16	Energy Officer / Electrical Engineer	19	6
P17	Senior Civil Engineer	8	9

Table 2. Participants' Responses on the Project Phases and Process in the Green Procurement

Participants' Reference	Agreement on GP implementation based on project phases (inception, design, tendering, construction and operation)	Requirements/ Criteria/Process that should be incorporated in each phase to implement GP
P1	Yes. It must be grouped into project phases.	First of all, the planning phase must have the client's brief. In the client's brief, must have a targeted tool; either the government green rating tools Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST), Penarafan Hijau JKR (pH JKR) or other rating schemes such as GBI, GreenRE. For government's project, Treasury Circular must also be included in this phase. What will be the targeted score? It should also be there. Other than that, must have project statement – in JKR for instance, the requirements are documented in separate volumes in accordance with the unit; architecture volume, structural, mechanical electrical, infra and energy efficiency work.
P2	Yes, I agree	The planning phase should be further divided into tangible and intangible elements to give a clearer picture. Other than that, the planning phase should look into tangible elements, for example, selection of procurement type must include UBBL requirements, state cost planning, and budget

Participants' Reference	Agreement on GP implementation based on project phases (inception, design, tendering, construction and operation)	Requirements/ Criteria/Process that should be incorporated in each phase to implement GP
P3	Yes	Elements that should have in the planning phase include a selection of the project team. They must have green knowledge and capability, targeted budget or finance, designer's selection. In the design phase, must state the requirements on the usage of JKR Material List (JMaL) or GGP MyHIJAU as a searching platform for certified green construction products. Must also have Value Management or Value Assessment exercise
P4	Yes, the inception phase is covered in the project planning, it then continued to the sequential phases; as you have highlighted here (design, tendering, construction, and operation).	In the planning phase, must address targeted building performance, initiation of green buildings, social aspects, and program input and output. Other than that, environmental and energy efficiency requirements to be incorporated in the project brief
P5	Yes, agree	In the design phase, ideally should specify the green elements, LCC exercise, carbon emission calculation exercise, cost checking exercise.
P6	Yes	In the inception phase, clients should state clearly the initiation to have a green project - including the targeted rating tool, the green elements, and energy consideration instruction to the designers (passive and active design)
P7	Yes, it is in line with the current phases adopted for the green project in JKR	The targeted rating tools or green rating schemes should be incorporated in the project statement. This is addressed in the inception or planning phase.
P8	Yes, I agree	I believe it is crucial to consider the confirmation of materials, detailed cost breakdown, especially during the inception and design phase. In the design phase also must conduct a feasibility study and analysis of green via design cost, construction cost, and operation and maintenance cost, enforcement of MS1525.
P9	Agree	In the tendering phase, must have green monitoring evaluation in the tender instruction. The contractor also should have the green capacity or at least attended green training.
P10	Yes, definitely. It covers the life cycle of a building as well	The instruction must be clear from the beginning… in terms of instruction of KPKR for instance, or treasury instruction from MOF to implement green building. In terms of procuring green construction materials, it should be decided in the design phase. If all policies and legal instructions are there, definitely all processes should follow towards greening the construction.
P11	I agree. Yes	In the design phase, detailed specifications by integrating all requirements of MyCREST, MyBIM library, MyHIJAU directory, or regulatory for having at least 80% of the materials to be green materials. It must also comply with JKR Standard Specification for Building Works 2020 for government green projects.
P12	Yes	In the tender documentation phase, must have a requirement of green rating tools such as IBS, QLASSIC, standard documents on products and services must be in accordance with MS1525, allow access to the MyBIM system and final cost checking exercise. Other than that, the requirements of PhJKR or MyCREST should be inserted in the planning phase.

Participants' Reference	Agreement on GP implementation based on project phases (inception, design, tendering, construction and operation)	Requirements/ Criteria/Process that should be incorporated in each phase to implement GP
P13	Yes, agree. For the final phase, it should also be known as the Occupancy phase	I elaborated on requirements that are a must-have in the tender documentation phase. It should have an evaluation, tendering and award of tender must specify the standards of the potential builders. For example, one must have experience in handling green projects, must have a certain amount of green personnel. Tender notice also should specify the requirement for GP
P14	Yes, all the phases are tally to building life cycle	The planning phase should clearly state the targeted tool, for instance, what is Building Energy Index (BEI), MyCREST, or pHJKR. In the tender documentation phase, create a tender evaluation team of green experts. In construction, must include site monitoring especially in the usage of green construction products, and comply to contract. In the occupancy phase, must conduct energy audit and monitoring, and comply with MycREST requirement during the operation phase.
P15	Yes, the procurement process should start as early as the inception phase	During the tender documentation phase, the tender evaluation team should consist of MyCREST facilitator, consultant's team, and certified financial personnel
P16	Yes, I agree	I will contribute input on the requirements during the construction phase. As for me, this is crucial since the building is emerged according to the intention. In the construction phase, the criteria should have monitoring on the QLASSIC as to comply with quality performance in green, compliance to MyCREST (construction phase), must also have project manager at site with green knowledge.
P17	Yes	In the construction phase, must monitor the specification's compliance. However, the operation phase is the longest period compared to other phases. Ideally, in the operation or occupancy phase, designers must issue tenants' guidelines for green building to users; and conduct energy monitoring and building performance evaluation.

DISCUSSION OF FINDINGS

The findings revealed the outcomes on the required capacity development of GP and highlighted the covered process, requirements, and criteria for implementing the GP for the construction sector. In addition, the findings also revealed that crucial elements of green procurement should be thoroughly allocated in the inception or planning phase. This is also in line with the findings from Ambler and Constantine, (2000) and Bohari et al. (2020) which stated that the inception phase is to set a firm foundation for the project by giving a thorough understanding. This is also supported by Ojo et al. (2014) and Bohari et al. (2017) that state establishing the project requirements for quality begins at the project inception. Therefore, to ensure the success of GP implementation, ideally the inception phase should give a clear explanation as to all the necessary information needed by the parties to incorporate the green elements in the project. For example, Kwok et al. (2016); Diabat and Govindan (2011); Salam (2008); and Bohari et al. (2017) described that effective standards and guidelines, such as evaluation criteria, green specifications, green label schemes, and ISO 14000 certification for suppliers, are considered as an effective way to enhance the implementation of green procurement in the industry.

Apart from that, Diabat and Govindan (2011) stated that mandatory environmental policies and regulations are of utmost importance to the successful implementation of green procurement. However, based on the responses of participants from the interview session, it was found that all of the involved processes are crucial in ensuring the success of green procurement implementation. Hence, the list of criteria, requirements, and processes that should be included in the GP is summarised in Table 2. The findings are differ to the previous studies of GP for the Malaysian context (for example, studies by: (Bohari et al., 2020; Adham & Siwar, 2012; Adham et al., 2015; Bohari et al., 2017; Buniamin et al., 2016; Jaafar et al., 2016; Bohari et al., 2015; and Musa et al., 2013), where the requirements are more focussing to the criteria or requirements that should be implemented for green construction projects. It involves key to address, documentations, activities, and process to achieve green projects for construction works.

The listed criteria are also vital towards the development of the next questionnaire for this research as there is a need to identify the significant rank of the criteria in the GP component. By listing all the requirements and processes as the outcome of the discussion, the items can be integrated into the establishment of the GP best practice framework. Ideally, it is noted that the procurers need to go through the learning process to enhance their understanding and knowledge of GP implementation.

Table 2. Summary of Criteria, Requirements, and Process towards GP Implementation

Project Phases	Criteria and Requirements Related to GP	Source / Participants Ref.
Inception Phase	Include targeted tool - Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST) Budget approval incorporating GP The project title states clearly as a green project Environmental and energy efficiency requirements to be incorporated in the project brief Energy consideration instruction to the designers (passive and active design) List of approved green materials as decided by the project team	P1, P3, P4, P6, P7
Design phase	Carry out LCC exercise and cost checking exercise. Carry out carbon emission calculation exercise Comply with green construction materials listed in the MyHIJAU directory Detailed specifications by integrating all requirements of MyCREST, MyBIM library, MyHIJAU directory, or regulatory for having at least 80% of the materials to be green materials Value Management/Assessment exercise Feasibility of study and analysis of green via design cost, construction cost, and operation and maintenance cost Enforcement of Malaysian Standards MS1525 (Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings)	P3, P5, P8, P11, P12
Tendering Phase	Green monitoring evaluation in the tender instruction Consideration of the contractor's capability that has the green capacity or at least attended green training Tender notice specified requirement for GP Include in the Instruction to Tenderers (ITT) as mandatory requirements (green project) Green compliance on criteria for evaluation of tender	P9, P13, P16

Project Phases	Criteria and Requirements Related to GP	Source / Participants Ref.
Construction phase	The project manager or site officer must be green experts or have green knowledge Verification of design and product compliance towards green materials Quality of workmanship to Quality Assessment System for Building Construction works (QLASSIC)	P14, P16
Operation phase	Meet compliance and approval of the green project from local authorities Carry out energy monitoring and building performance evaluation	P16, P17

CONCLUSION

Ideally, green procurement (GP) in the construction works should be looked at as a whole system. Therefore, relevant agencies and supporting partners play a significant role to drive the green growth for construction that is parallel to the initiative highlighted by the Construction Industry Transformation Programme (CITP) and 11th Malaysia Plan. As highlighted in the Sustainable Development Goals (SDG), the particular target that is related to green procurement is under goal number 12 (Responsible Consumption and Production), namely target 12.7, which is to promote public procurement practices that are sustainable and per national policies and priorities. By increasing the implementation of GP, in turn, will greatly benefit the country and help in achieving the SDGs. To cater to the sustainable concerns in the construction industry, the relevant stakeholders need to respond to the greater demand for social, economic, and environmental improvements of the industry. As the current practice is fragmented, ideally the GP criteria need to conform to the acceptable standards which enable specific provisions for the acquisition of eco-friendly sustainable construction. Hence, it is hoped that the findings would be a starting point for continuing the next agenda on the implementation of GP in Malaysia.

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REFERENCES

Adham, K.N., Siwar, C., & Atan, A. M. (2012). Pelaksanaan Perolehan Hijau Kerajaan : Isu , Cabaran dan Strategi Daripada Perspektif Pegawai Perolehan Kerajaan Malaysia Implementation of Government Green Procurement : Issues and Challenges from the Perspective of Government Procurement Officer. *Prosiding Perkem*, *1*, 291–304.

Adham, K.N., & Siwar, C. (2012). Empirical Investigation Of Government Green Procurement (Ggp) Practices In Malaysia. *OIDA International Journal of Sustainable Developmen*, *4*(4), 77–78.

Adham, K.N., Siwar, C., & Abdul Ghani Aziz, S. A. (2015). Kajian Empirikal Amalan Perolehan Hijau Kerajaan di Malaysia. In *Persidangan Kebangsaan Ekonomi Malaysia ke-10 (PERKEM 10)* (Vol. 10, pp. 338–349).

Ambler, S. W., & Constantine, L. L. (2000). *The Unified Process Inception Phase* (1st ed.). C M P Books.

Bohari, A. A. M., Skitmore, M., Xia, B., & Teo, M. (2017). Green oriented procurement for building projects: Preliminary findings from Malaysia. *Journal of Cleaner Production*, *148*, 690–700. https://doi.org/10.1016/j.jclepro.2017.01.141

Bohari, A. A. M., Skitmore, M., Xia, B., Teo, M., & Khalil, N. (2020). Key stakeholder values in encouraging green orientation of construction procurement. *Journal of Cleaner Production*, *270*, 122246. https://doi.org/10.1016/j.jclepro.2020.122246

Bohari, A. A., Skitmore, M., Xia, B., Teo, M., Zhang, X., & Adham, K. N. (2015). The path towards greening the Malaysian construction industry. *Renewable and Sustainable Energy Reviews*, *52*, 1742–1748. https://doi.org/10.1016/j.rser.2015.07.148

Buniamin, S., Ahmad, N., Rauf, F. H. A., Johari, N. H., & Rashid, A. A. (2016). Green Government Procurement Practices (GGP) in Malaysian Public Enterprises. *Procedia Economics and Finance*, *35*(16), 27–34. https://doi.org/10.1016/s2212-5671(16)00006-x

Chan, S. W., Tiwari, S. T. S., Ahmad, M. F., Zaman, I., & Sia, W. L. (2018). Green procurement practices and barriers in furniture manufacturing companies. *International Journal of Supply Chain Management*, *7*(6), 431–438.

Creswell, J. W. (2012). *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research* (4th Editio). Pearson Education.

International Green Purchasing Network. (2010). *Green Purchasing: The New Growth Frontier*.

Jaafar, M. R., Aziz, S. A., & Ramli, N. M. (2016). The roles of compliance with government procurement policy: Moderating the effects between explanatory factors and sustainable public procurement practice. *Jurnal Pengurusan*, *48*(2016), 89–98. https://doi.org/10.17576/pengurusan-2016-48-07

Kahlenborn, W., Mansor, N., & Naim, K. A. (2014). Government Green Procurement (GGP) short-term action plan 2013–2014. *Sustainable Consumption and Production (SCP) Policy Support Malaysia*, 1–25.

Kwok, J., Wong, W., Kit, J., Chan, S., & Wadu, M. J. (2016). Facilitating effective green procurement in construction projects : An empirical study of the enablers. *Journal of Cleaner Production*, *135*, 859–871. https://doi.org/10.1016/j.jclepro.2016.07.001

Maskuriy, R., Selamat, A., Ali, K. N., Maresova, P., & Krejcar, O. (2019). Industry 4.0 for the Construction Industry—How Ready Is the Industry? *Applied Sciences*, *9*(14), 2819. https://doi.org/10.3390/app9142819

Musa, N. D., Buniamin, S., Johari, N. H., Ahmad, N., Rauf, F. H. A., & Rashid, A. A. (2013). Key indicators towards the implementation of green government procurement in Malaysia. *World Applied Sciences Journal*, *28*(13), 127–135. https://doi.org/10.5829/idosi.wasj.2013.28.efmo.27020

Salam, M. A. (2008). An empirical investigation of the determinants of adoption of green procurement for successful green supply Chain management. *Proceedings of the 4th IEEE International Conference on Management of Innovation and Technology, ICMIT*, 1038–1043. https://doi.org/10.1109/ICMIT.2008.4654511

Yang, R. J., Zou, P. X. W., & Wang, J. (2015). Modelling stakeholder-associated risk networks in green building projects. *International Journal of Project Management*, *34*(1), 66–81. https://doi.org/10.1016/j.ijproman.2015.09.010

Zid, C., Kasim, N., Soomro, A. R., & Laidoune, A. (2019). The discrepancy in the construction industry of Malaysia: one of the most contributing industries in Malaysia's economy and the highest contributor of the fatal accidents. https://doi.org/10.1088/1757-899X/788/1/012034

THE ADOPTION OF BUILDING INFORMATION MODELLING (BIM) FOR BIM-BASED PROJECT CONTRACTORS DURING THE CONSTRUCTION PHASE

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Abstract
The trend towards automation, digitalisation and exchanges of data in manufacturing technologies and processes that comprises the elements of Internet of Things (IoT), artificial intelligence and cloud computing, was designed as the Fourth Industrial Revolution 4.0 (IR 4.0). Hence, as IR4.0 introduces digital technology, the Building Information Modelling (BIM) has become the main accelerator in producing digital information for construction projects. Through BIM, the construction information is stored, supplied and received in one single respiratory system which enables the BIM-based project team to interact and collaborate in real time throughout the project life cycle. Nevertheless, the adoption of BIM in the Malaysian Construction Industry and particularly for contractors is relatively low. This is due to the fact that contractors have no profound understanding of BIM and its' requirement. Hence, the aim of this study is to determine the significant uses of BIM from the contractor's perspective which covers six (6) uses during the construction phase. In this respect, the questionnaire survey was designed and administrated for the Malaysian Construction Industry particularly for BIM-based project contractors. The mode of sampling is purposive and analysis was carried out with IBM SPSS Statistics to test the mean score of the study. As a result, from 340 distributed surveys, 114 responses were collected for this study. The findings show that the 3D coordination and the record model was remarked as the top significant uses in the construction phase. This shows that the uses of BIM are to minimize the discrepancy of drawings and visualizations and to create a record model for facility management purposes. Thus, the results of the study also provide insight to the project teams especially contractors, client, consultants and other stakeholders to take into consideration the uses of BIM for future BIM-based projects.

Keywords: *Building Information Modelling (BIM), adoption, uses of BIM, contractor, BIM-based projects.*

INTRODUCTION

The industry 4.0 is interchangeable with the fourth industrial revolution that emphasises on the digital transformation of production/ manufacturing. It is also recognised as a 'digital revolution' as it transitions from mechanical devices, analogue electronics to digital technology (Rojko, 2017;Alaloul et al., 2018; Othman et al., 2020). It represents a new stage in the organisations related to industries and the value chain processes. Consequently, a cyber-physical system (e.g. smart machines) becomes a foundation of the industry 4.0. It uses a modern control system which encompasses software systems and internet usage to connect and address the Internet of Things (IoT). With this in mind, the production of the products will be networked and communicated which empowers new production manners, optimizing real-time process as well as creating added value during the process. Moreover, with this cyber-physical system, connection of technology and people, IR4.0 aims to become viable and sustainable in the manufacturing sector which allows the integration of the technical and business process and thus allows smart factories. As the concept of IR4.0 emphasises in the construction industry, the Malaysian Government has conscripted the National agendas such

as the "Construction 4.0 Strategic Plan (2021-2025)", "Construction Industry Transformation Programme" (CITP) by the Construction Industry Development Board (CIDB) (2016-2020) in 2015. Several initiatives and activities are conscripted as an act of awareness for the construction industry to embrace IR4.0. Consequently, the Building Information Modelling (BIM) is one of the initiatives in CITP which is emphasised under thrust 3 (productivity). The leveraging of BIM adoption by CIDB is to promote efficiency in the construction methodology as well as to support IR4.0 (CIDB, 2016b; CIDB, 2019).

The former and well-known definition of BIM is defined by The National Building Information Modeling Standard (NBIMS) Committee (2007) that defined BIM as a digital representation of physical and functional characteristics of a facility which emphasises on knowledge sharing of the facilities information throughout its lifecycle process. Similarly, BIM also has an IT enabled approach which involves the integral digital representation of all building information in the form of repository for various phases of the projects lifecycle (Gu & London, 2010). BIM encompasses a process to produce, communicate and analyse digital information throughout the construction life-cycle in the form of 3D modelling (CIDB, 2014).

Apart from this, BIM with the processing and integrated tools of the project data, can reshape the way of construction teams to work together in order to achieve the ultimate project outcome (i.e., time, cost, quality and safety) (Rohena, 1999: Hadzaman et al., 2015). Despite the advantages of BIM, the adoption of BIM among contractors has been reported to be low as compared to others stakeholders in Malaysia. This is shown in BIM reports produced by the Construction Industry Development Board of Malaysia, (CIDB, 2016a) which revealed that contractors have the lowest adoption rate which is 13%, while architects have the highest adoption rate which is 42% and followed by engineers (21%) (CIDB, 2016a). This percentage also remain stagnant as reported by Idrus & Bahar (2018) that the level of adoption of BIM by contractors is still less than 20%.

According to George (2015), many stakeholders especially contractors do not have a profound understanding of what BIM is and also its requirements. Added to that, contractors have not taken note of the abilities and benefits offered by BIM. Furthermore, BIM is also perceived to be expensive by many stakeholders and a high difficulty rate in using with uncertain outcome (Khosrowshahi, and Arayici, 2012). Hence, the adoption rate among the contractors become slow. Furthermore, the project outcomes such as cost, time, quality and safety also depend on the uses of BIM which involve contractors. Clear BIM uses which are determined during the early phases will aid the contractors to reap the benefits of BIM. Hence, the objective of this paper is to determine the significance of BIM uses towards the contractor's perspective by adopting BIM during the construction phases.

BIM USES IN BIM-BASED PROJECTS

BIM uses are defined as methods applied in BIM-based projects to achieve specified objectives (The Computer Integrated Construction Research Program, 2010); The Computer Integrated Construction Research Program, 2019). It also defines BIM service and function which consist of task and procedures to support the project's planning, design, construction, and operational processes (Won & Lee, 2016). Added to that, The Computer Integrated Construction Research Program, (2010) and The Computer Integrated Construction Research Program, (2019) listed 25 uses of BIM across the project life cycle, consists of planning to

operation and maintenance. Nevertheless, due to the scope of contractors in this study that are involved in the construction phase, BIM uses from Planning, Design and Operation and Maintenance phases are excluded. As a result, six (6) uses of BIM are described as follows:

Table 1. Description of BIM Uses

BIM Uses	Description
3D Coordination	Coordination process that occurs between trades such as Architectural, Structural and MEP models of a project by means of clash detection.
Site Utilising Planning	A graphic representation of permanent and temporary facilities on site showing labour resources, materials and equipment locations.
Construction System Design	Virtual mock-ups of building systems such as formwork system, glass veneers and anchor systems served by a 3D model.
Digital fabrication	The digital information used to facilitate the fabrication of construction materials and assemblies.
3D Control and Planning	The process by using the digital information model to layout facility assemblies or automate control of an equipment's movement and location.
Record Model	The process to record the information related from the architectural, structural and MEP elements in order to provide record data for facility managers or owners during the operational and maintenance phase.

(Sources: The Computer Integrated Construction Research Program (2010); Chou & Chen (2017); The Computer Integrated Construction Research Program (2019).

As BIM-based project contractors, they are required to choose the most reasonable and achievable uses of BIM in respective to each project as a goal for the early stages of a project (Chou & Chen, 2017). This is because it will affect the selection of software, hardware, team expertise and processes. Moreover, the right BIM goals and uses of BIM will help to achieve the targeted project performance which can reduce the project duration, project cost saving and increase the project quality (Brahim, 2018).

METHODOLOGY

The study applied a cross-sectional survey design by using a purposive sampling. This sampling allows non-probability samples to be selected based on specific characteristics of the population to answer a survey question (Hatmoko et al., 2019). The target population of this study was the BIM-based project contractors of CIDB G7 grade qualification. Consequently, the total number of the BIM-based project contractors was 340 individuals. Thus, a questionnaire was designed to quantify the uses of BIM from the BIM-based projects contractors' perspectives.

A developed item- questions from questionnaire surveys were reviewed for content validity thoroughly by five (5) BIM specialists, two (2) BIM- based project contractors and ten (10) academicians from similar and different fields of study including the statistical department. The questionnaire set consist of two parts: 1) The respondents' background; and 2) Uses of BIM. The respondents were asked to indicate their level of agreement and disagreement which begins from "never used" to "always used" by using seven-point Likert scale. The purpose of a seven-point Likert scale is to gather the information as well as to indicate their agreements based to their experience (Sarpin et al., 2019). The descriptive statistics involving mean and standard deviation values were used to analyse the data and thus describe the phenomenon of the studies by using the IBM SPSS Statistics version 23.0.

This survey was administrated and was sent to the G7 Contractor's office from June until September of 2018. For the first three (3) months, postage was used while self-distribution of questionnaire surveys was administered for next one (1) month. In total, 114 questionnaires were finalised and returned which makes up to a response rate of 33.53% (as per Table 2) and is acceptable in the construction research as suggested by Fellows & Liu (2003). Respondents within the organisations who have experience in BIM-based projects with different designations were selected such as CAD/managers, Project managers, BIM modelers, Project engineers, Estimators Principals/Directors/VPs (Top management) and others. The variation in types of designations were recommended by Mutai (2009) and Monko et al. (2017) in order to produce various results.

Table 2. Acquisition of Questionnaires Data

No	Distribution	Total	Percentage (%)
1	Questionnaires distribution	340	
2	Questionnaires received	129	37.94%
3	Unusable questionnaires	15	4.41%
4	Usable questionnaires	114	33.53%
	Overall response rate	**33.53%**	

RESULTS AND DISCUSSION

The following section discusses the results and the discussion of respondents' profiles, statistical results and also to analyse the descriptive and inferential analysis.

Respondent's Profile

Figure 1 – 3 shows the demographic background of the respondents. The participants come from various backgrounds, positions (professions) and experience in construction as well as BIM. As a result, based on Figure 1, it indicates that most of the respondents are BIM Modellers (37%), followed by Project Engineers (26%), Project Managers (12%), CAD/BIM Managers/IT Managers/ Technical Managers (11%), Estimators, other positions (5%) and lastly Principals/directors/VPs (Top Management) with 4%. This implies that most of the respondents are BIM Modellers which implies that these respondents have great knowledge of BIM compared to the Top Management which contributes the lowest percentage of filling the questionnaire survey. This is supported by Mutai (2009) in his study that acquired similar results during his data collection. Apart from that, the minimum involvement of the top management in the survey was due to the fact that there was limited knowledge of BIM among them as well as time constraint in the involvement of this survey.

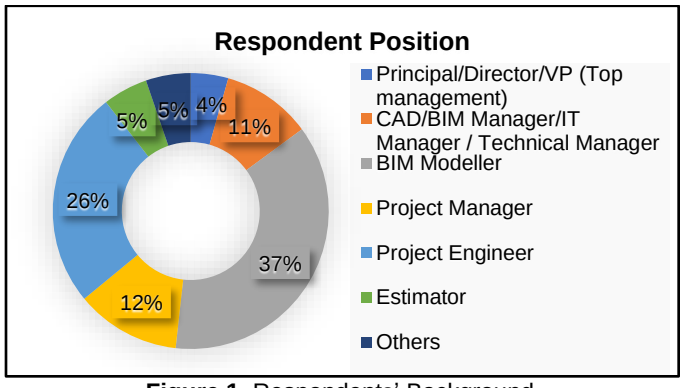

Figure 1. Respondents' Background

In term of the experience in the construction industry (as Figure 2), the respondents have various periods of experience in BIM-based projects in which the minimum experience is less than 5 years (31.6%), 6-10 years (26.3%), 11-20 years (33.3%) and above 20 years (8.8%). This clearly shows that the highest percentage of respondents in this discussion comes from respondents with more than 10 years of experience, indicating a high possession of knowledge in the construction industry among the respondents. Surprisingly, a substantial percentage of respondents in this study also comes from those with less than 5 years of experience in the construction industry. This is due to the fact that the adoption of BIM among BIM-based projects in Malaysia is still at infancy stage. Therefore, these groups (with less than 10 years of industrial experience) have great knowledge of BIM compared to the respondents with more than 20 years of industrial experience. Hence, as the nature of this study is to gauge BIM knowledge from experienced respondents, the respondents with more than 20 years' experience in the construction industry but with zero knowledge of BIM were excluded in this study. With various types of working experience in the construction industry, their participation proves to provide a rich and reliable value to the study.

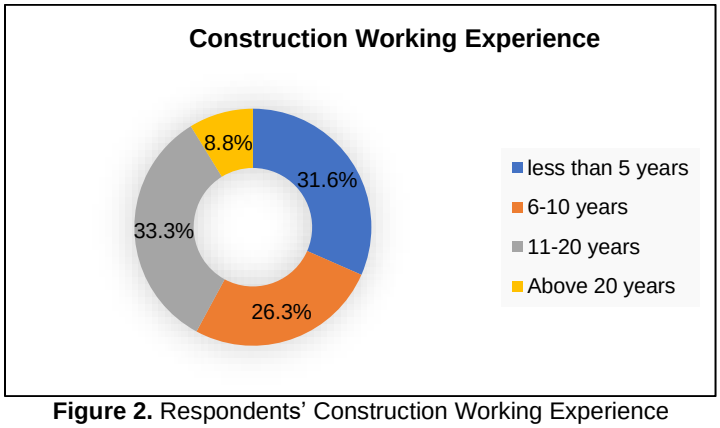

Figure 2. Respondents' Construction Working Experience

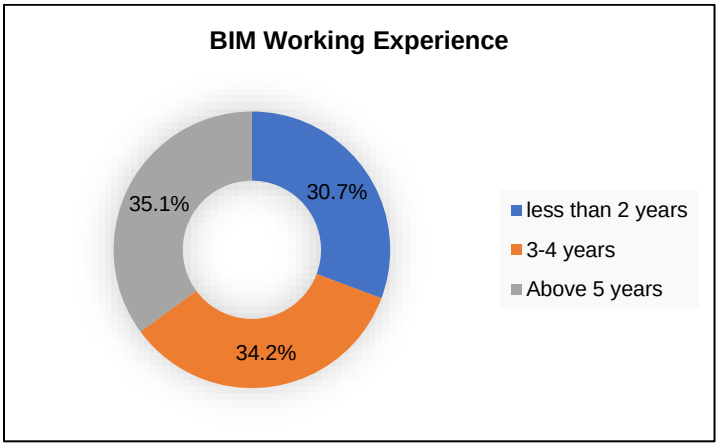

Figure 3. Respondent with BIM Working Experience

As mentioned earlier, respondents with BIM working experience are accepted in this study. Thus, as a result 35.1% of the respondents pertain more than 5 years of experience in BIM, 34.2% of respondents have been involved in 3-4 years and 30.7% of respondents have less than 2 years' experience in BIM. This shows that the respondents that have at least five (5) years of BIM experience are familiar with the issues that occur as well as an understanding on the BIM concept (Ku & Taiebat, 2011; Brahim, 2018). Consequently, it can be deduced that the selection of respondents is sufficiently appropriate and suitable as they are able to provide related issues on BIM as well as the current scenario in the construction industry.

Statistical Analysis

The results by means of means index and standard deviation values were analysed and obtained from using the IBM SPSS Statistic version 23.0. The descriptive analysis which consists of mean and standard deviation values are ranked from the highest mean index to the lowest mean index. In overall ranking as shown in Table 2 for use of BIM from BIM-based project contractors in the Malaysian Construction Industry '3D coordination' is ranked at the top use (mean=5.8070, SD=0.76282), followed by 'record model' (mean=4.9912, SD=1.00877), and 'construction system design' (mean=4.8070, SD=0.93010). Subsequently, fourth place until sixth place are listed as frequent uses of BIM such as '3D control and planning' (mean=4.6140, SD=1.15604), "site utilising planning' (mean=4.5789, SD=1.088110 and finally 'digital fabrication' (mean=4.3246, SD=1.14053). Each of these uses of BIM will explained accordingly based on ranking in this section.

Table 3. Uses of BIM in Construction Phase

Uses of BIM	Mean score	Standard deviation	Ranking
3D Coordination	5.8070	.76282	1
Record model	4.9912	1.00877	2
Construction system design	4.8070	.93010	3
3D control and planning	4.6140	1.15604	4
Site utilising planning	4.5789	1.08811	5
Digital fabrication	4.3246	1.14053	6

From the data shown in Table 3, 3D coordination is the highest ranking among other uses of BIM in the construction phase. This is supported by various researchers such as (Hanna et al., 2013; Kent, 2014; Guo et al., 2014; Kent, Miller & Farnsworth (2017) that revealed 3D coordination to be the highest use among commercial MEP contractors. Furthermore, several researchers (for example: Hussain & Choudhry, 2013; Jung & Lee, 2015; Won & Lee, 2016; Chong et al., 2016; Chou & Chen, 2017; Franz & Messner, 2019) also revealed that 3D coordination is the top use among BIM-based projects in North America, Europe, Oceania, Asia, Middle East and Africa and South America. In addition, this is also in line with Brahim (2018) who found that 3D coordination in the form of clash detection is the utmost used among construction players for BIM projects in Malaysia. Through this process, all the drawings are combined in the form of federated models by using BIM platforms such as Naviswork in order to perform clash detections. Later, the checking results on the model and the issues appropriated to the project phase are reported and recorded. These clash issues will be highlighted in coordination meetings chaired by the BIM-based project contractors and the responsible person in-charge for solving each clash. The deadline of updating their models was also decided during the process. Hence, the conflicts (either hard clash and soft clash) were able to be resolved before the construction started and reduced the number of request of information due to design changes and rework on the site (Rafael Sacks et al., 2018). Added to that, this 3D coordination is used to avoid conflicts in construction projects as well as to reduce cost and increase the quality of models.

The second in rank is the record model. This record model involves the depiction of the information related to architectural, structural and Mechanical Electrical and Plumbing (MEP) elements and is documented in the form of the model (The Computer Integrated Construction Research Program, 2010: The Computer Integrated Construction Research Program, 2019). It represents an accurate impression of how the buildings are built on site together with the information from all the disciplines that are embedded in this as-built 3D model. Furthermore, it also consists of non-graphical information such as the information for each object property that includes links to submittals, warranty information, operations and maintenance information (Hergunsel, 2011: Azhar et al., 2012). This single source of data base facilitates facility management in order to manage and find the information later and is applied to various scopes of operation and maintenance.

Subsequently, the third to sixth place of the significant uses of BIM are construction system design, 3D control and planning, site utilising planning and digital fabrication. The construction system design (virtual mock-up) is ranked in third place for the uses of BIM in the construction phase. This is due to the fact that the respondents are mostly G7 contractors and producing this mock-up system is normally done by sub-contractors. However, as presented in BIM-based projects, the respondents agreed the crucial of creating and constructing complex building systems such as formwork system, glass veneers, anchor systems (The Computer Integrated Construction Research Program, 2010; Chou & Chen, 2017; The Computer Integrated Construction Research Program, 2019) and mock-up system of building façades (Maing & Vargas, 2013). This virtual mock-up is essential as to visualise the complex building information model in a virtual perspective rather than merely a 2D plan. It facilitates the project team to assemble and execute the installation process which displays the detail of materials, fabrication and specification (Leicht & Kumar, 2010; Maing, 2012: Ortiz, 2020). Other than that, the virtual mock-ups allow in-depth detail studies of the building facades by which their interfaces are not burdened with high cost as compared to physical

mock-ups.

The subsequent important criteria is 3D control and planning. It is used as a basis of creating the construction site layout planning. As such, 3D control and planning can be used to assemble and manage the movement of the equipment and the accurate position or layouts such as layouts of walls using a total station and excavation depth by applying the Global Positioning System (GPS) (Computer Integrated Construction Research Program, 2010: Building Research Association New Zealand, 2014; Balakina, Simankina, & Lukinov., 2018; The Computer Integrated Construction Research Program, 2019). Later, as per the point taken from these Total Station and Global Positioning System (GPS), the construction layout will be demonstrated using the BIM Software tool. Whereas, the site utilising planning consists of documents which depict the location of temporary facilities within the construction site boundary (Deshpande & Whitman, 2014). This is in line with Gledson and Greenwood (2016) who established that 4D modelling involves much more than mapping a model to a sequence. Moreover, they further added that it involves the integration of project controls, costing, resourcing, design and fabrication, warehousing procurement, site logistics and other functions with outputs in many different formats. Furthermore, Balakina, Simankina, and Lukinov, (2018) revealed that the application of 4D enables the detection of design errors earlier, allowing the optimization of the construction such as: optimising the operation of cranes, the placement of building structures and materials at different stages of construction, optimizing the organization of work and to monitor the activities related to the preparation of the construction site for the compliance of labour protection and safety engineering.

The final significant use of BIM in the construction phase is digital fabrication. Despite the advantages of digital fabrication, based on this study, the digital fabrication has obtained less attention from contractors compared to 3D coordination in the forms of clash detection, construction analysis, planning, quantity take off and cost estimating that are normally used Eastman et al. (2011). This is due to the fact that most of the respondents are G7 contractors (main contractors) and digital fabrication is normally executed by sub-contractors or MEP contractors. It is also supported by Kent (2014) which declared that prefabrication is the third highest use among commercial MEP contractors where the BIM Model is able to be downloaded into equipment that is used to automate processes such as ducting. Whilst, Hergunsel (2011) revealed that walls, rooms and houses can be virtually designed and constructed with the Building Information Model and can be prefabricated with rough mechanical, electrical, plumbing (MEP) components. Thus, the final MEP connections can be made once the prefabricated components are assembled onsite.

CONCLUSION

This paper examines the perspectives of BIM-based project contractors in the Malaysian Construction Industry towards the adoption of BIM uses. Consequently, from the 340 distributed surveys, 114 responses from BIM-based project contractors were successfully collected. As per the methodological analysis, IBM SPSS Statistics has been used in the development of the quantitative results and analysis. Hence, from the findings it can be deduced that six (6) uses of BIM were from the construction phase such as 3D coordination, site utilising planning, construction system design, digital fabrication, 3D control and planning and the record model are significant from the BIM-based project contractor's perspective. Nevertheless, among these uses, 3D coordination and the record model are highly

significant as these uses contribute to great impact for BIM-based projects. As such, 3D coordination allows early detection of clashes in projects and thus reduces the potential of issuing request of information, changes order and rework of the project. Consequently, it enables BIM-based projects to reduce the cost and time and subsequently increase the project quality. While for the record model, information related to the building such as architectural, structural and MEP elements are recorded and documented in the form of an as-built model during the construction phase, thus enables the contractors to have more ease in submissions to the clients. Moreover, it also allows the clients to properly manage and utilise the usage during the maintenance and operation phase during the later stage. Hence, this study also provides vital practical implications on the development of BIM uses especially for BIM-based project contractors. It would benefit and provide insights to other BIM-based project contractors in adopting BIM uses for their projects.

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REFERENCES

Akwaah George. (2015). *Guideline For Adoption and Implementation of Building Information Modeling (BIM) By Contractors in Ghana*.

Alaloul, W. S., Liew, M. S., Zawawi, N. A. W. A., & Mohammed, B. S. (2018). Industry Revolution IR 4.0: Future Opportunities and Challenges in Construction Industry. *MATEC Web of Conferences*, *203*, 1–7. https://doi.org/10.1051/matecconf/201820302010

Azhar, S., Khalfan, M., & Maqsood, T. (2012). Building information modelling (BIM): now and beyond. *Construction Economics and Building*, *12*(4), 15–28.

Balakina, A., Simankina, T., & Lukinov, V. (2018). 4D modeling in high-rise construction. *E3S Web of Conferences*, *33*, 1–5. https://doi.org/10.1051/e3sconf/20183303044

Brahim, J. (2018). *Development of Building Information Modelling (BIM) Migration Path Model For Construction Professionals*. Universiti Tun Hussein Onn Malaysia.

Building Research Association New Zealand. (2014). *New Zealand BIM Handbook; A guide to enabling BIM on building projects*. *July*, 1–26.

Chong, H. Y., Lopez, R., Wang, J., Wang, X., & Zhao, Z. (2016). Comparative Analysis on the Adoption and Use of BIM in Road Infrastructure Projects. *Journal of Management in Engineering*, *32*(6), 1–13. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000460

Chou, H. Y., & Chen, P. Y. (2017). Benefit Evaluation of Implementing BIM in Construction Projects. *IOP Conference Series: Materials Science and Engineering*, *245*(6). https://doi.org/10.1088/1757-899X/245/6/062049

CIDB. (2014). *Building Information Modeling Roadmap for Malaysia's Construction Industry, Workshop Report (Series 2)* (Issue 2).

CIDB. (2016a). *BIM report 2016*.

CIDB. (2016b). Construction Industry Transformation Programme (CITP) 2016-2020. In *Construction Industry Development Board Malaysia*.

CIDB. (2019). The Construction Industry Transformation Program Mid-term Review for Enhancement Delivered By : Mid-Term Review of CITP KPIs. In *Construction Industry Development Board Malaysia (CIDB)* (Issue January 2019).

Deshpande, A., & Whitman, J. B. (2014). Evaluation of the use of BIM tools for construction site utilization planning. *50th ASC Annual International Conference Proceedings*, *Elbeltagi 2008*.

Eastman, C., Teichols, P., Sacks, R., & Liston, K. (2011). *BIM Handbook: A Guide to Building Information Modelling for Owners, Managers, Designers, Engineers, and Contractor*. John Wiley & Sons, Inc.

Fellows, R., & Liu, A. (2003). Research Methods for Construction. *John Wiley & Sons, Inc.*

Franz, B., & Messner, J. (2019). Evaluating the Impact of BIM on Project Performance. *Journal of Computing in Civil Engineering*, 33(3), 1–15.

Gledson, B. J., & Greenwood, D. J. (2016). Surveying the extent and use of 4D BIM in the UK. *Journal of Information Technology in Construction*, *21*(April), 57–71.

Gu, N., & London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction*, *19*(8), 988–999.

Guo, F., Turkan, Y., & Jahren, C. T. (2014). Case Studies of BIM Practices within Mechanical Contractors. *Construction Research Congress 2014*, 229–238.

Hadzaman, N. A. H., Takim, R., & Nawawi, A. H. (2015). *Building Information Modelling (BIM): the impact of project attributes towards clients' demand in BIM-based project*. WIT Transaction on the Built Environment, 59–69.

Hanna, A., Boodai, F., & El Asmar, M. (2013). State of Practice of Building Information Modeling in Mechanical and Electrical Construction Industries. *Journal of Construction Engineering and Management*, *139*(10), 1–8.

Hatmoko, J. U. D., Kistiani, F., & Khasani, R. R. (2019). Assessing Company Readiness Level Towards The Implementation of Building Information Modelling (BIM) In Indonesia. *Malaysian Construction Research Journal*, *29*(3), 95–108.

Hergunsel, M. F. (2011). Benefits of Building Information Modeling for Construction Managers. MSc thesis: Worcester Polytechnic Institute

Hussain, K., & Choudhry, R. (2013). Building Information Modeling (BIM) Uses Applications in Pakistan Construction Industry. *Proceedings of the 13th International Conference on Construction Applications of Virtual Reality*, *October*, 30–31. (proceeding)

Idrus, A., & Bahar, N. (2018). Level of Implementation of Building Information Modelling (BIM) Among Construction Contractors. *International Journal of Advances in Mechanical and Civil Engineering*, *5*(Febuary), 53–55.

Jung, W., & Lee, G. (2015). The Status of BIM Adoption on Six Continents. *International Journal of Civil, Structural, Construction and Architectural Engineering*, *9*(5), 406–410.

Kent, B. (2014). Current BIM Practices of Commercial MEP Contractors. MSc Thesis: Brigham Young University

Kent, B. J., Miller, K. R., & Farnsworth, C. B. (2017). BIM Practices of Commercial MEP Contractors. *53rd ASC Annual International Conference Proceedings*, 471–481.

Khosrowshahi, F and Arayici, Y. (2012). Roadmap for implementation of BIM in the UK construction industry. *Engineering, Construction and Architectural Management*, *19*(6), 610–635.

Ku, K., & Taiebat, M. (2011). BIM experiences and expectations: The constructors' perspective. *International Journal of Construction Education and Research*, *7*(3), 175–197.

Leicht, R. M., & Kumar, S. (2010). Gaining End User Involvement Through Virtual Reality Mock-Ups : a Medical Facility Case Study. *October*, *2*, 16–18.

Maing, M. (2012). Physical or Virtual ? : Effectiveness of virtual mockups of building envelope systems. *Building Envelope Science and Technology*, 1–17.

Maing, M., & Vargas, R. (2014). Digital Fabrication Processes of Mass Customized Building Facades in Global Practice. *Proceedings of the XVII Conference of the Iberoamerican Society of Digital Graphics: Knowledge-Based Design*, *1*, 415–419.

Monko, R. J., Berryman, C. W., & Friedland, C. J. (2017). Critical Factors for Interorganizational Collaboration and Systemic Change in BIM Adoption. *International Journal of Construction Engineering and Management*, *6*(4), 111–132.

Mutai, A. (2009). *Factors Influencing the Use of Building Information Modeling (BIM) Within Leading Construction Firms in The United States of America. Doctoral Dissertation.* (Issue December). Indiana State University, Terre Haute, Indiana.

Ortiz, R. (2020). *Application of BIM Technology On Virtual Mock-up And Application Of BIM Technology On Virtual Mock-up Implementation For General Contractor In Construction*. *March*.

Othman, I., Al-Ashmori, Y. Y., Rahmawati, Y., Mugahed Amran, Y. H., & Al-Bared, M. A. M. (2020). The level of Building Information Modelling (BIM) Implementation in Malaysia. *Ain Shams Engineering Journal*, 1(12), pp.455-463

Rafael Sacks; Charles Eastman; Chang Lee; Paul Teicholz. (2018). *BIM Handbook* (Third Edit). Wiley.

Rohena, R. (1999). *Building Information Management (BIM) Implementation in Naval Construction*. MSc Thesis: Louisiana State University.

Rojko, A. (2017). Industry 4.0 concept: Background and overview. *International Journal of Interactive Mobile Technologies*, *11*(5), 77–90.

Sarpin, N., Ling, C. Y., Kasim, N., Noh, H. M., Omar, R., & Yahya, M. Y. (2019). Key Strategies In Embark on International Construction Project: Malaysian Contractors Perspective. *Malaysian Construction Research Journal*, *8*(Special Issue), 94–106.

The Computer Integrated Construction Research Program. (2010). *Building Information Modeling Execution Planning Guide*.

The Computer Integrated Construction Research Program. (2019). *BIM Project Execution Planning Guide - Version 2.2*.

The National Building Information Modeling Standard (NBIMS) Committee. (2007). *National Building Information Modeling Standard*.

Won, J., & Lee, G. (2016). How to tell if a BIM project is successful: A goal-driven approach. *Automation in Construction*, *69*, 34–43.

FACTORS AND PARTIES INITIATING VARIATION ORDERS OF MOSQUES CONSTRUCTION IN PERAK, MALAYSIA: A CASE STUDY

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Abstract
Variation order is a formal document used for any form of amendment during construction on an agreed upon, well-defined scope or schedule of works. Variations are mostly inevitable despite leading to dispute among stakeholders, affecting labor's productivity and consume time and cost. Variation order were treated variedly according to the conditions of contract of the particular construction. This study focused on mosque project as per Public Work Department condition of contract which is Public Work Department Form of Contract PWD203a 2010 with quantity and Public Work Department Form of Contract PWD203 2010 with drawings and specifications. Both of the article of agreement partakes different approach on variation order calculation specifically on cost incurred. This paper aims to identify the variation order factors of mosque construction as in Perak and identify the contributors that caused variation orders of mosque constructions in Perak, Malaysia. From literature review, a total of fourteen (14) variation order factors were identified. The variation order factors were then analysed by matching the total of ten (10) mosques projects in Perak, Malaysia. It was found that, all mosques had variation orders resulted from change of scope and change of schedule. Other prominent factors that initiate variation order includes impediment to prompt decision-making process, changes in specifications, inadequate design and changes in design by consultant. It was also found that through frequency descriptive analysis, most variation orders were influenced by the client.

Keywords: *Amendment; construction; project; variations; variation order.*

INTRODUCTION

Construction industry is loaded with complexity and complication. Most authors agreed that practically all projects either big or small will always avert from its original plan and design. Memon (2014) asserted that all types of construction is never absence from variation highlighting how common the process is (Memon et al., 2014). Muhammad also emphasized that the complex nature of construction will always eventually lead to variations (Muhammad et al., 2015). Klee (2018) stressed that there is no perfectly prepared, drafted, designed and engineered large project that could deflect from variations (Klee, 2018). In fact, variation costs in United States alone were estimated around 13-26 billion dollars per year (Memon et al., 2014). One of the significant contributor to sick projects in Nigeria as claimed by Muhammad (2015), is variation (Muhammad et al., 2015). Evidently, Malaysia showed variations had taken tolls leading to sick and abandoned projects (Memon et al., 2014).

Variations are often perceived in a pessimistic light as it was presumably result in cost increment, but stakeholders should be able to solve the changes as the contract agreement thus further confirming the inevitable nature of variations (Klee, 2018). Hence, to achieve project's victory, it is essential that a well-drafted variation clauses were emphasized during inception (Klee, 2018). Variation order could either be beneficial or detrimental (Muhammad et al., 2015). According to Mohammad et al. (2010) a variation order is beneficial when the order

causes cost reduction, quality standard improvement, schedule reduction or degree of difficulty reduction whereas a variation is detrimental when it causes increment to the client's budget or decrease in project performance (Mohammad et al., 2010). Nevertheless, the effects of variations highlighted by Muhammad (2015) are delayed payment, delay in completion, additional overhead, cost overrun, rework, low productivity, additional payment to contractor, delayed logistics, disruption of progress of work, affects integrity of the firm, time overrun, incidence of building failure, source of corruption, affect project performance and abandonment of project (Muhammad et al., 2015).

Although variations are often viewed negatively, the function of variations in a contract cannot be denied as it empowers architects or the client's proxy to instruct changes should there any changes required to the project (Obagboye, Hellen, Ariffin, Williams, & Samuel, 2019). The absence of variation clause in a contract would hinder any changes to the project outside of the original contract scope thus variation clause seeks to bring flexibility to both parties (Obagboye et al., 2019).

In contrast to other types of building constructions, mosque construction is unique particularly in Malaysia due to the fusions of Arabic, Malaysian, Indonesian, and Chinese culture (Megat, Arbi, & Keumala, 2016). Not to mention the skill or workmanship required to construct arches, domes and other architecture features predominantly known to mosque constructions such as mihrab wall, Islamic patterns and calligraphy.

Therefore, to address issue of mosque projects variation orders, this research aims: -

1. To identify the variation order factors for the constructions of mosques in Perak, Malaysia.
2. To distinguish the contributors of variation orders for the constructions of mosques in Perak, Malaysia.

LITERATURE REVIEW

The term variation is widely interpreted across literatures but all carrying the same meaning more or less. Arain and Pheng (2005) defines variation as: -

"*Any deviation from an agreed well-defined scope and schedule. Stated differently, this is a change in any modification to the contractual guidance provided to the contractor by the owner or owner's representative. This includes changes to plans, specifications or any other contract documents*" (Arain & Pheng, 2005).

Whereas variation order as defined by Fisk (1997) and O'Brien (1998) is: -

"*The formal document that is used to modify the original contractual agreement and becomes part of project's documents*" (Fisk, 1997; O'Brien, 1998).

Conclusively, a variation order is issued upon variation to the contracted work which include adding or omitting work or changing the quality or character of material or the order of work. Numerous authors had identified different factors of variation orders. The factors were attributed to clients, consultants, contractors and others. A study by Wu et al. (2005)

reported that there were 1038 variation orders authorized for a highway construction project in Taiwan and it was revealed that one of the significant factors of variation order of the project is design changes resulted from civilian complaints and geological conditions (Wu, Hsieh, & Cheng, 2005). Other study by Arain & Pheng (2006) established 53 factors of variation orders in institutional buildings in Singapore whereby the significant factors were identified as errors and omission in design, changes in specification by both owner and consultant, design differences, changes and designs that did not comply with regulations (Arain & Pheng, 2006).

Other than that, a survey by Ismail et al. (2012) disclosed that the greatest cause of variation order is change of scope by owner followed by errors and omissions, differing site conditions and contractor's financial difficulty (Ismail, Pourrostam, Soleymanzadeh, & Ghouyounchizad, 2012). However, a study by Memon (2014) had concluded that the most severe factor that affect time and cost performance are changes in schedule (Memon et al., 2014). Mohammad (2019) established top five (5) key factors of variation order which are changes in the scope of the work by the client, exchange of construction materials by the client, specification changes by the client, changes in building design by the consultant and discrepancies between the contract documents and drawings. (N. Mohammad et al., 2017).It was accepted that although most researchers had identified the causes of variation orders, the significant factor identified by each author differs from one another depending on the nature of projects, sites, stakeholders and many other internal and external influences.

RESEARCH METHODOLOGY

This research adopted qualitative method of case study and document reviewing. Although often chosen as a latter research approach, document reviewing is an effective and legitimate research tool (Prior, 2003). The analyses carried out are by examining the final account of ten (10) mosques in Perak including variation order approval documents, monthly progress reports, design reports, project completion reports, exchange correspondence between clients, consultants, contractors, third-parties as well as various meetings recorded in the form of minutes of meeting which indicated the causes and effects of variations on projects. The raw data were then tabulated and analysed using simple frequency descriptive analysis so that the data were displayed in the most organized and easy-to-read format (Salkind, 2010).

FINDINGS AND ANALYSIS

Factors of Variation Order of Mosques Construction in Perak

Through document reviewing of ten (10) mosques in Perak, fourteen (14) factors of variation order related to the project are tabulated in Table 1.

Table 1. Frequency of Variation Order Factors

	Variation orders / Mosque	Layang Kiri	Klian Intan	Bandar Universiti	Al-Ikhwan Slim River	Ijok Perak	Menglembu	Lekir	Bukit Chupak	Halaman Meru	Padang Changkat
1	Changes of scope	√	√	√	√	√	√	√	√	√	√
2	Changes of schedule	√	√	√	√	√	√	√	√	√	√
3	Impediment to prompt decision making process			√	√	√	√			√	√
4	Changes in specifications	√	√	√	√	√	√		√	√	√
5	Inadequate design								√		
6	Changes in design by consultant			√	√		√	√	√	√	√
7	Errors and omissions in design			√							
8	Poor procurement process			√							
9	Conflicts within contract documents		√						√		
10	Value engineering			√	√						
11	Lack of coordination	√							√		√
12	Design complexity			√				√			
13	Inadequate working drawing details			√					√		
14	Poor knowledge of available materials and equipment							√			

Although there are more than fifteen (15) variation order factors recorded in the literature review, some variation order factors are not significant to the mosques' construction as per contract. Mosques construction fall under the jurisdiction of government thus the contract basis is the Public Work Department Form of Contract PWD203a 2010 with quantity and Public Work Department Form of Contract PWD203 2010 with drawings and specifications. According to the table, all mosque undergone variation orders resulted from change of scope and change of schedule. Apart from that, other frequent factors identified to have contributed variation order includes impediment to prompt decision-making process, changes in specifications, inadequate design and changes in design by consultant. Elaborated further is the variation order factors along with the relations to mosques construction.

According to Al-Rubaiei (2018), changes of scope is the biggest contributor to variations (Al-Rubaiei et al., 2018). Changes of scope refer to addition or omission of original scope of works as per contract which would either increase or decrease the contract amount. These situations often occurred in mosques construction due to request from the end user, such as additional space for dining or cooking, additional fixtures such as chandelier, furniture, CCTV and air-conditioning system. Al-Rubaiei (2018) added that the project progress is expected to become more difficult if the project scope were not clearly define during commencement (Al-Rubaiei et al., 2018).

Changes of schedule as stated by Memon (2014) may cause major reallocation resources whereby contractor would have to keep resources on hold or increase resources but either way both resulted in cost incurring (Memon et al., 2014). In some cases, the handling of several works on site as opposed to plan would affect contractor's costs.Prompt decision making is an important factor for a successful project. Delay in decision making during mosques construction often occurred during the stage of material approval as the selection process often took longer than expected. Keane (2010) addressed that failure to decide efficiently would cost time and money (Keane et al., 2010).

Change in specification refers to the change of the quality of product which happen during construction phase and normally due to Authority's requirement, site condition, or non-approved SIRIM products. In some circumstances mosques construction's specifications were upgraded when there are extra budgets that come from donation and these include additional air-conditioner, additional interior or exterior works or increasing the thickness of carpet. There are instances where Local Authority interferes with the ongoing mosques construction that causes variation and changes in design such as the numbers of carpark, sewerage system and due to site condition.

Inadequate design as claimed by Memon (2014) is the most frequent cause of variations (Memon et al., 2014). Due to time constraint during pre-contract stage as well as insufficient detail drawings provided to the quantity surveyor, some items in the bill of quantities are not fully described as per final drawing by the consultants. This situation create gap to the real and expected cost which eventually resulted in variations. Arain & Pheng (2005) had identified changes in design by consultant as one of the significant roots to variation order (Arain & Pheng, 2005). Changes in design occurred during construction phase to accommodate unforeseeable conditions. Design errors presumably caused additional cost meanwhile omission could reduce the cost of project. Arain & Pheng (2006) which studied 53 factors that caused variation orders in institutional buildings in Singapore had reported that one of the significant causes of variation is errors and omissions in design (Arain & Pheng, 2006).

According to Ndihokubwayo (2008) one type of procurement method may result in more variation orders than another (Ndihokubwayo, 2008). Some mosques construction procurement adopt design and build contract which provide very general description of the project. This left consultants with the responsibility to design and build the mosque not knowing details needed by the client resulting in series of changes throughout the project commencement. Therefore, poor procurement processes led to many variations in projects. One of the key factors to variation order as insisted by Muhammad et al. (2015) is conflicts among contract documents (Muhammad et al., 2015). It is ideal for an architect to specify the

materials in drawing at design stage to ensure the price is synchronized throughout the construction.

Value engineering is a method to optimize cost by team brainstorming consisting project stakeholders. In mosques construction, consultants would advise on changing items or materials to minimize cost without affecting the building performance. Mohammad & Hamzah (2019) insisted that an ideal value engineering should be conducted during design stage for optimum impact (Mohammad & Hamzah, 2019). One of the significant causes of variation order to construction projects in Gaza Strip is lack of coordination among stakeholders (Mahamid, 2017). In mosques construction, project delay could be caused by lack of planning and communication among contractor and sub-contractor.

Mosques construction specifically in Malaysia is complex and cross-dimensional resulted from the overlapping designs background of Arabic, Malaysian, Indonesian, and Chinese (Megat, Arbi, & Keumala, 2016). Undertaking mosques construction require high skill in workmanship to complete fine task such as arch, Islamic patterns, decorative timber facial board, mihrab wall and etc. Often mosques construction design approach that utilise decorative glass reinforce concrete (GRC) panel faced with increasing construction cost and variation order due to additional item as per manufacturer's requirement for installation. Some mosque that utilise Turkish-style dome or double layer dome also faced variation order due to execution difficulty.

For a project to be successfully conveyed, the drawing should be clear and concise otherwise it will result in misinterpretation and eventually variations (Keane et al., 2010). Some of the mosques construction were given additional detail drawing which resulted in the increase of project costs. Therefore, a complete detailed drawing should be provided beforehand to the QS so that a precise bill of quantities can be provided. Keane et al. (2010) elaborated that if a consultant does not possess adequate knowledge on available materials and equipment, the project would likely face variation in later stages of construction due to changes in the mentioned segment. Therefore, it is important for consultant to have relevant knowledge in materials and equipment to ensure the contract is priced appropriately.

Parties Contributed to Variation Order of Mosque Construction in Perak

The factors for frequency of variation order are tabulated below. Based on the table, it can be observed that most variation order factors came from client and consultants. This is because the condition of contract for PWD Form 203A clearly stated that for a variation order taking place, it must be authorised by a Superintending Officer (SO) acting as client's agent. On the other hand, contractor's contribution in variation order are derived from changes of schedule.

Table 2. Frequency of Variation Order Factors

No	Factors of Variation Order	Client	Consultant			Contractor	Others
			Architect	Mechanical & Electrical	Quantity Surveyor		
1	Changes of scope	5					
2	Changes of schedule	5				5	
3	Impediment to prompt decision-making process						
4	Changes in specifications	5					2
5	Inadequate design						
6	Changes in design by consultant						
7	Errors and omissions in design	3	5		1		
8	Poor procurement process	1					
9	Conflicts among contract documents				2		
10	Value engineering	2		2			
11	Lack of coordination	2			4		4
12	Design complexity		2		3		5
13	Inadequate working drawing details	2					
14	Poor knowledge of available materials and equipment		1				2
	Total of variation order	**25**	**8**	**2**	**10**	**5**	**13**

CONCLUSION AND RECOMMENDATION

Change of scope and change of schedule were the most inevitable factors that cause variation order in all ten (10) mosques case studies in Perak, Malaysia. Meanwhile, most variation order of mosques construction in Perak came from clients and consultants. Most literatures only focused on the factors, causes and effects of variation order while dismissing the solution-oriented outcomes which are more important given the current urgency and demanding nature of construction industry. Therefore, it is highly recommended that an in-depth research be carried out in the future to formulate a comprehensive framework that could help reduce variation order and increase project performance from all aspects.

REFERENCES

Al-Rubaiei, Q. H. S., Nifa, F. A. A., & Musa, S. (2018). Project Scope Management Effect on Variation Orders in Government Funded Projects: A Proposed Study on the Sultanate of Oman. *Malaysian Construction Research Journal*, *3*(Special Issue 1), 52–62.

Arain, F. M., & Pheng, L. S. (2005). The potential effects of variation orders on institutional building projects. *Facilities*, *23*(11–12), 496–510. https://doi.org/10.1108/02632770510618462

Arain, F. M., & Pheng, L. S. (2006). Developers' views of potential causes of variation orders for institutional buildings in singapore. *Architectural Science Review*, *49*(1), 59–74. https://doi.org/10.3763/asre.2006.4908

Ismail, A., Pourrostam, T., Soleymanzadeh, A., & Ghouyounchizad, M. (2012). Factors causing variation orders and their effects in roadway construction projects. *Research Journal of Applied Sciences, Engineering and Technology*, *4*(23), 4969–4972.

Keane, P., Sertyesilisik, B., & Ross, A. D. (2010). Variations and Change Orders on Construction Projects. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *2*(2), 89–96. https://doi.org/10.1061/(asce)la.1943-4170.0000016

Klee, L. (2018). *International Construction Contract Law* (2nd ed.). Hoboken, NJ 07030, USA: John Wiley Sons Ltd. https://doi.org/10.1002/9781118717868

Mahamid, I. (2017). Effect of change orders on rework in highway projects in Palestine. *Journal of Financial Management of Property and Construction*, *22*(1), 62–76. https://doi.org/10.1108/JFMPC-03-2016-0015

Megat, S. A., Arbi, E., & Keumala, N. (2016). Historiography of mosque architecture in Malaysia: Analysis of texts by 5 authors. *Journal of Design and Built Environment*, *16*(2), 44–54. https://doi.org/10.22452/jdbe.vol16no2.1

Memon, Aftab Hamed, Rahman, I. A., & Jamil, M. H. A. (2014). Severity of Variation Order Factors in affecting Construction Project Performance. *Journal of Basic and Applied Scietific Research*, *4*(6), 19–27.

Memon, Aftab Hameed, Rahman, I. A., & Hasan, M. F. A. (2014). Significant causes and effects of variation orders in construction projects. *Research Journal of Applied Sciences, Engineering and Technology*, *7*(21), 4494–4502. https://doi.org/10.19026/rjaset.7.826

Mohammad, N., Ani, A. I. C., Rakmat, A. A. O. K., & Yusof, M. A. (2010). Investigation on the Causes of Variation Orders in the Construction of Building Project – a Study in the State of Selangor, Malaysia. *Journal of Building Performance*, *1*(1), 73–82.

Mohammad, Noraziah, Che-Ani, A. I., & Rakmat, R. A. O. K. (2017). Causes and effects of variation orders in the construction of terrace housing projects: A case study in the State of Selangor, Malaysia. *International Journal of Supply Chain Management*, *6*(1), 226–232.

Mohammad, Noraziah, & Hamzah, Z. (2019). A review of causes of variation order in the construction of terrace housing projects in Malaysia. *MATEC Web of Conferences*, *277*, 03013. https://doi.org/10.1051/matecconf/201927703013

Muhammad, N. Z., Keyvanfar, A., Abd Majid, M. Z., Shafagat, A., Magana, A. M., & Dankaka, N. S. (2015). Causes of Variation Order in Building and Civil Engineering Project in Nigeria. *Jurnal Teknologi*, *77:16*, 91–97.

Muhammad, N. Z., Keyvanfar, A., Majid, M. Z. A., Shafaghat, A., Magana, A. M., & Dankaka, N. S. (2015). Causes of variation order in building and civil engineering projectsin Nigeria. *Jurnal Teknologi*, *77*(16), 91–97. https://doi.org/10.11113/jt.v77.6404

Ndihokubwayo, R. (2008). *An Analysis Of The Impact Of Variation Orders On Project Performance*. Master Thesis, Cape Peninsula University of Technology.

Obagboye, Hellen, O., Ariffin, H. L. T., Williams, & Samuel, O. (2019). Implications of Contractual Variation Orders on Building Construction Projects. *International Journal of Advanced Research in Science, Engineering and Technology*, *6*(9), 10764–10773.

Prior, L. (2003). *Using Documents in Social Research*. Sage Publications Ltd. London.

Salkind, N. J. (2010). Encyclopedia of Research Design (Volume 1). Sage Publications Ltd. London.

Wu, C. H., Hsieh, T. Y., & Cheng, W. L. (2005). Statistical analysis of causes for design change in highway construction on Taiwan. *International Journal of Project Management*, *23*(7), 554–563. https://doi.org/10.1016/j.ijproman.2004.07.010

KEY INITIATIVES AND PERSPECTIVES OF CONSTRUCTION WASTE MANAGEMENT IN MALAYSIA

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Abstract
The construction industry is known as one of the most important industries that produces wealth and contributes to the country's social and economic growth. However, this industry generates waste from the construction activities. Numerous substantial initiatives become an important area of concern in the implementation of good construction waste management in the Malaysian construction industry. The aim of this paper is to examine the current published literature on construction waste management in Malaysia as well as the initiatives that have been implemented in the Malaysian construction industry. A systematic review was conducted on the initiatives that have been implemented on construction waste management in Malaysia. Guided by the PRISMA Statement (Preferred Reporting Items for Systematic reviews and Meta-Analyses) review method, a systematic review of the Scopus and Web of Science databases have identified 18 related studies. Further review of these articles resulted in four main themes namely technology, strategies, enforcement and procurement. A total of 47 studies focused on the strategies initiative which reported the highest number of studies. Initiative strategies which consist of of awareness, training, award and 3Rs practices have significant impact on the economic, social, and environmental aspects of Malaysian construction project. Next, enforcement initiative with 16 studies, followed by procurement initiative with 14 studies and the least is technology initiative with 11 studies. Therefore, these initiative leads to give positive impacts to the construction waste management practice and the environment.

Keywords: *Systematic review; construction waste; construction industry; initiatives; Malaysia.*

INTRODUCTION

The increasing urban population has become a substance for economic growth, making an important impact on the construction industry (Esa et al., 2017a). The significance of sustainable development has been a growing acceptance among practitioners and researchers as a new value. Therefore, construction industry has started to recognise its detrimental impacts on the environment (Lu & Yuan, 2011). The nature of construction is well known as not being environmentally friendly activities. In-depth studies by researchers discovered the negative consequences of construction activities, which primarily involve land destruction, resource depletion, waste generation, and various types of pollution. Solid waste processed from construction activities are severe concerns in many countries in term of economic perspective. The expanding growth of construction activities has given a rise to construction waste management (CWM) around the world.

Construction and demolition (C&D) waste that is used interchangeably with the term construction waste, refers to the solid waste that arises from construction activities, such as new building, site formation, renovation, or demolition that has no residual value. (Begum et al., 2007; Roche & Hegarty, 2006). The construction and demolition (C&D) waste normally forms a signification portion of total solid waste. Approximately, 35% of the solid waste generated in the world comes from construction and it is usually disposed of in landfills, uncontrolled or inadequately maintained locations (Maués et al., 2020). Therefore, the huge

percentage of construction waste from the total municipal solid waste leads to environmental degradation (Abidin et al., 2020; Bohari et al., 2020; Islam et al., 2019; Rahim et al., 2017).

Construction waste can be categorised into two groups which are physical waste and non-physical waste. Physical waste from construction site can be known in the form of material waste such as concrete, timber, steel, and others. Disadvantages of physical wastes are their impacts to project cost and adverse impacts to the environment. Non-physical wastes are the time and cost overrun for the construction project. This problem can become critical when the project must be stopped and thus leads to project abandonment. There are many factors that lead to the waste at construction sites. Several factors that were identified are inadequate monitoring and controlling, lack of coordination between parties, slow information flow between parties, shortage of technical personnel (skilled labour), changes in material specification, effect of weather, poor site management and supervision, lack of experience, inadequate planning and scheduling, mistakes and errors in design, mistakes during construction, incompetent subcontractors, rework, frequent design changes, and low labour productivity (Sasitharan Nagapan et al., 2012).

Rapid growth of the construction industry in Malaysia has resulted in a large amount of waste being generated as the number of infrastructure projects, commercial and residential buildings increased (Begum et al., 2010). In addition, an ineffective waste management practiced at construction site increases the generation of construction waste (Mahayuddin & Pereira, 2014). Therefore, an appropriate construction waste management practice on-site is needed. The construction waste needs appropriate mechanism and management so that unnecessary dumping activities and impacts on the environment can be avoided (Hung & Kamaludin, 2017). Without proper management, construction waste will cause severe damage to the natural environment and quality of life. The implementation of zero waste is known as the best solution to manage construction waste (Liyanage et al., 2019).

Construction waste is often highly monitored by authorities due to its detrimental effects on the natural environment as a public good. A sound support is required from all Malaysian stakeholders in order to effectively manage construction waste in Malaysia (Rahim et al., 2017). Hence it is vital for the Malaysian government to address this issue by providing comprehensive legal enforcement regarding the construction waste minimisation. Over the last few decades, construction waste management (CWM) initiatives have been implemented by the Government of Malaysia. The implementation includes policies, regulations, codes, and guidelines. The success of these initiatives needs to be analysed to provide insights for future improvements. Therefore, this paper aims to examine the current literature on relevant initiative implemented for construction waste management in Malaysian construction industry.

METHODOLOGY

The method that was used to retrieve articles related to construction waste management and initiatives in Malaysia is described in this section. The method that was used is Preferred Reporting Items for Systematic reviews and Meta-Analyses or known as PRISMA. The eligibility and exclusion criteria were applied to the resources before the review process. This review process consists of three stages namely identification, screening and eligibility. Then data abstraction was conducted before analysis as the final step.

The present study was guided by the PRISMA Statement (Preferred Reporting Items for Systematic reviews and Meta-Analyses). The PRISMA Statement allows for rigorous search of terms related to construction waste management and initiatives in Malaysia. PRISMA Statement also aims to promote researchers to ensure the right information with the correct level of detail is applied. This method offers three unique advantages which are 1) defining clear research questions that permits a systematic research, 2) identifies inclusion and exclusion criteria and 3) attempts to examine large database of scientific literature in a defined time.

Resources

The review relied on two main journal databases – Scopus and Web of Science (WoS). WoS is a robust database consisting more than 33,000 journals with coverage of over 256 disciplines including subjects related to environmental science, social science, and management. WoS includes over 100 years of comprehensive back file and citation data, established by Clarivate Analytics, and ranks them by three separate measures: citations, papers, and citations per-paper. Scopus is the second database that was used in the review. Scopus is one of the largest abstracts and citation databases of peer-reviewed literature with more than 22,800 journals from 5000 publishers worldwide. Scopus consists of diverse subject areas such as environmental sciences, social science and engineering and energy.

Eligibility and Exclusion Criteria

Several eligibility and exclusion criterion were determined. First, with regards to literature type, only journal articles with empirical data were selected which means review articles, book series, books, chapters in book and conference proceedings were all excluded. Second, to avoid any confusion and difficulty in translating, the searching efforts excluded the non-English publication and focused only on articles published in English. Thirdly, with regards to timeline, a period of 13 years was selected (between 2007 and 2020) as the Solid Waste and Public Cleansing Management Act 2007 (Act 672) was gazetted on 30th August 2007. This act was enacted to ensure uniformity of law relating to the management and regulation of solid waste and public cleansing throughout Peninsular Malaysia and the Federal Territories of Kuala Lumpur, Putrajaya, and Labuan (Laws of Malaysia, 2007). This period of 13 years also was adequate to review the evolution of research and related publications. Lastly, in line with its objective which focuses on Malaysia, only articles focusing on Malaysia were selected (see Table 1).

Table 1. The Inclusion and Exclusion Criteria

Criterion	Eligibility	Exclusion
Literature type	Journal (research articles)	Book series, book chapter in book
Language	English	Non-English
Timeline	Between 2007 and 2020	<2007
Indexes	Social Science Citation Index	Science Citation Indexed Expanded
Country	Malaysia	Other Country

Systematic Review Process

Four stages were involved in the systematic review process. The review process was performed in August 2020. The first phase was identification. Identification is a process to search any synonyms, related terms, and variations for main keywords for the study. Reviewers had to identify keywords used for the search process. Relying on previous studies and thesaurus, keywords similar and related to construction waste, and initiative were used (Table 2). Two main databases namely Scopus and Web of Science were used in this phase. These two databases have the ability to be a leading database in a systematic literature review due to several advantages it possesses such as advance searching functions, comprehensive (indexing more than 5000 publishers), it controls the articles' quality and has multidisciplinary focus, including construction waste management related studies. At this stage, after careful screening, three duplicated articles were removed.

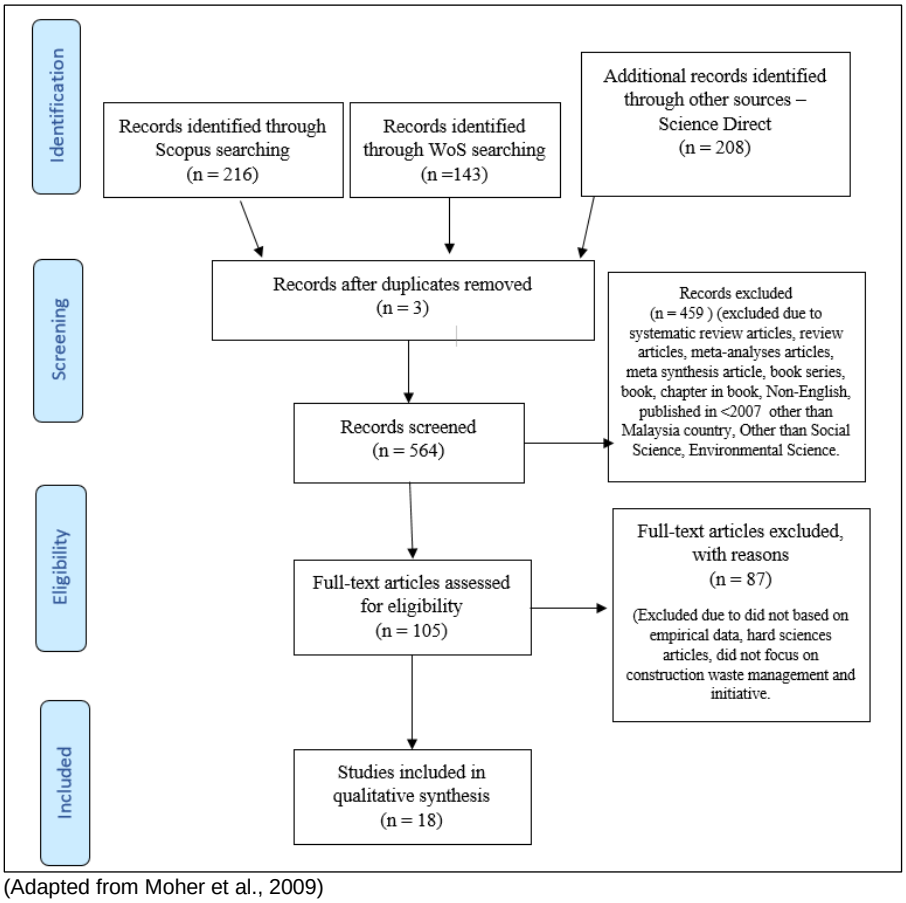
The second stage was screening. This study screened all the selected articles. At this stage, out of 564 articles eligible to be reviewed, a total of 459 articles were removed. The third stage was eligibility, where the full articles were accessed. This was the process where the retrieved articles were manually monitored to ensure all the remaining articles (after the screening process) were in line with the criteria. After careful examination, a total of 88 articles were excluded as some articles did not focus on construction waste, were not empirical articles, did not focus on initiatives practices or did not focus on Malaysia. The last stage of review resulted in a total of 18 articles that were used for the qualitative analysis (see Figure 1).

Table 2. The Search String Used for the Systematic Review Process

Databases	Keywords used
Scopus	TITLE-ABS-KEY ((“construction waste” AND (initiative* OR strategy*))
Web of Science	TS = KEY ("construction waste” AND (initiative* OR strategy*))

Data Abstraction and Analysis

This study relied on integrative review. The remaining articles were assessed and analysed. The data were extracted by reading through the abstracts first followed by reading the full articles (in-depth) to identify appropriate themes and sub-themes. Qualitative analysis was performed using content analysis to identify themes related to initiative of construction waste management. In the process, patterns were identified that emerged among the abstracted data of all reviewed articles. Any similar or related abstracted data were pooled in a theme and eventually, a total of four theme were created. Next the four data themes were examined and other 14 sub themes were found. Then, these sub-themes were organised around the themes established by typology.



(Adapted from Moher et al., 2009)

Figure 1. The Flow Diagram of the Study

RESULTS AND DISCUSSION

Based on the analysis, the review resulted in four main themes and 14 sub-themes related to initiative implemented. The four main themes namely technology (three sub-themes), strategies (four sub-themes), enforcement (three sub-themes) and procurement (four sub-themes) (Table 3). In term of study design, there were 3 study designs that were discovered which are quantitative design, qualitative design and mix method design which consist of both qualitative and quantitative. The highest number was qualitative design accounted of 10 numbers. Mix method design and quantitative design accounted for 4 numbers of study, respectively. The results provided an extensive analysis of the current initiative implemented in Malaysia. A rigorous review sourced from two data based have resulted in 18 articles related to construction waste management and initiatives in Malaysia.

Technology

A total of 11 studies focused on technology as one of the initiatives to have a good waste management practice. The most common technology being practised is Industrialised Building System (IBS) (6 studies) while 3 studies found that Building Information Modelling (BIM) and Geographic Information System (GIS) were found to have 2 studies. Technology

is one of the advanced approaches that can contribute to high and efficient construction waste management (Wai et al., 2020). The use of IBS components for building constructions is an effective waste minimisation solution for the general project and commercial project in the construction industry. The most important benefits of this system are minimization of the overall cost, time, manpower, produces better quality buildings and improve the environmental performance for construction project (Ashikin Suhaini et al., 2019). The introduction of Industrialised Building System (IBS), which is an enhanced construction technique in developed countries, has helped the growth of recycling rate (Esa et al., 2017b). IBS also was the best ranked building system or technology which can be utilised. IBS was considered the best in terms of its effectiveness in improving sustainable building systems in Malaysia (Taherkhani, 2014).

Meanwhile, BIM was helping in reducing construction waste generation by enhancing the communication reaching extent to all parties involved, establish a constant collaboration among them and reduce probably errors and thus will increase efficiency in energy, resources, materials savings(Wai et al., 2020). Apart from that, BIM also has helped in green related practices in terms of the product and process to reduce construction waste generated at site (Bohari et al., 2017). GIS is one of the mapping tools that helps with the acquaintance of amount and composition of construction waste generated and the flow of where these waste will be directed to in a given geographical area. (Wai et al., 2020; Manoharan et al., 2020). GIS technology has been deployed in countries which have limited confined space for their building development project. The control of material arriving on sites also reflects the capability in reducing waste generation which waste generation were due to improper handling or damages by mobilisation transports (Wai et al., 2020). Therefore, a more effective and acceptable waste management practice is through innovation of technology.

Table 3. The Findings

Authors	Study Design	Technology			Strategies				Enforcement			Procurement			
		BIM	GIS	IBS	AWS	TRN	AWD	3Rs	RGN	PCY	GDL	END	GNP	GBI	EPD
(Wai et al., 2020)	QL	√	√		√	√									
(Manoharan et al., 2020)	QL		√		√	√	√	√	√	√					
(Ashikin Suhaini et al., 2019)	QL			√	√			√							
(Rahim et al., 2017)	QL				√	√		√							
(Saadi et al., 2016)	QL				√	√		√				√			
(Sa'adi et al., 2016)	QL				√			√		√	√	√			
(Esa et al., 2017b)	QN	√		√	√		√	√				√	√	√	√
(Bohari et al., 2017)	QL					√		√				√	√	√	
(Bohari et al., 2020)	QN	√		√	√	√	√	√		√	√		√	√	
(Ikau et al., 2016)	QN				√	√	√	√		√					
(Othuman Mydin et al., 2014)	MM			√	√			√						√	
(Begum et al., 2007b)	QL			√	√	√	√	√	√	√	√				
(Nagapan et al., 2013)	QL				√			√		√					
(Hung & Kamaludin, 2017)	MM			√	√			√		√	√				
(Umar et al., 2016)	MM							√						√	
(Abidin et al., 2020)	QL				√			√							
(Ng et al., 2018)	MM				√	√		√	√		√			√	
(Kam et al., 2019)	QN				√			√	√						

Technology	Strategies	Enforcement	Procurement
BIM- Building Information Management	AWS- Awareness	RGN- Regulation	EDN- Eco Design
GIS- Geographic Information System	TRN- Training	PCY- Policy	GNP- Green Procurement
IBS- Industrialised Building System	AWD- Award	GDL- Guideline	GBI- Green Building Index
	3Rs- Reduce, Reuse, Recycle		EDP- Eco Industrial Park Development

QL= Qualitative; QN= Quantitative; MM= Mix Method

Strategies

A total of 47 studies focused on the strategies initiative. The most common strategies practice are 3Rs which is reduce, reuse, and recycle practice. Majority of the study reported that 3Rs is the best initiative to have the best waste management practice. Awareness reported 16 studies which is second highest studies in the strategies practise. Meanwhile training reported 9 studies and lastly initiative through award was found the least total studies accounted for 5 studies in the strategies practise. 3Rs principle is known as the hierarchy of waste management which is arranged in the form of pyramid of their adverse impacts to the environment from low to high. Figure 2 shows waste management hierarchy with an arrangement of most preferred to least preferred in the form of a pyramid. Waste management hierarchy is one of the approaches to manage construction waste in an efficient way and assist as a structured instrument (Hwang & Yeo, 2011). The practice is in line with the guideline of construction waste management in Malaysia produced by CIDB. This practice or initiative tend to be the most favoured exercise among construction players (Esa et al., 2017a; Esa et al., 2017b; Saadi et al., 2016; Manoharan et al., 2020).

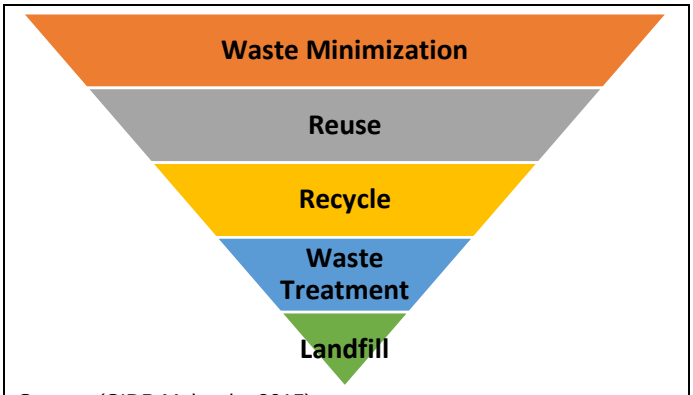


Figure 2. Waste Management Hierarchy

In practice, the level of awareness of construction waste is relatively low as seen from little measures taken against the issue. Therefore, it is vital to increase the level of awareness among stakeholders involved in construction industry. Hence, the attitude of each individual engaged with the project directly influences on waste levels. (Othuman Mydin et al., 2014; (Ng et al., 2018; Abidin et al., 2020; Nagapan et al., 2013; Esa et al., 2017b; Saadi et al., 2016; Sa'adi et al., 2016). Meanwhile, training practice need to be implement as one of the induction way to prevent waste on-site and along with that award should be given for those who highlighted success in the program.(Manoharan et al., 2020; Esa et al., 2017b; Bohari et al., 2020; Ikau et al., 2016; Begum et al., 2007b).

Enforcement

A total of 16 studies reported enforcement as one of the initiatives taken in managing construction waste. Under this theme, a total of 3 sub-themes emerged namely regulation, policy and guideline. Enforcement is the best approach to develop construction practitioner's mind-set, attitude, and behaviour. Enforcement needs to be carried out in phases and engagement on outline, briefing, media, newspaper and ministry statement should be part of

it (Ng et al., 2018). Regulation reported 4 studies found. Based on the increasing construction waste generation issue each year, Malaysian Government has announced the Solid Waste and Public Cleansing Management Act (Act 672) on 30 August 2007. This Act or regulation focused on control, reduce, recycle, recover, and disposal of solid wastes in the right manner without affecting the environment and local communities. Though this act mentioned construction solid waste as part of controlled solid waste management, the scope of proper construction waste management as a whole is not enough and comprehensive.Therefore, there is an urgent need to come out with a proper framework in order to have best waste management practice (Manoharan et al., 2020; Begum et al., 2007b; Ng et al., 2018).

Meanwhile, policy and guideline reported 7 and 5 studies, respectively. Low enforcement and less implementation initiative through policies and guideline was discovered among researchers. Thus, this factor needs to be taken into consideration in order to have the best waste management practice (Sa'adi et al., 2016; Bohari et al., 2020; Begum et al., 2007b; Hung & Kamaludin, 2017)

Procurement

A total of four sub-themes emerged under procurement theme namely eco design, green procurement, green building index and eco industrial park development. Eco design and green procurement reported 4 and 3 studies, respectively. Green procurement was introduced to accelerate practitioners to procure green buildings. Adopting green procurement and eco design means an organization needs to commit to minimising the environmental impacts and consequences of its construction activities by the deliberate selection and assessment of products and services at all developmental stages. For the construction industry, project performance is typically measured in terms of quality, cost, and time. Thus, this initiative leads to produce positive impact to the construction waste management. (Esa et al., 2017b; Bohari et al., 2017; Bohari et al., 2020).

Meanwhile, green building index reported 6 studies under this procurement themes. Green Building Index (GBI) rating tools have been commonly used by clients and design teams to plan environmentally friendly project delivery. GBI is in voluntary use for appraising the environmental design and performance of Malaysian buildings (Bohari et al., 2017). The Green Building Index (GBI) is Malaysia's industry recognised green rating tool for buildings to promote sustainability in the built environment and raise awareness among stakeholders about environmental issues and our responsibility to the future generations. The GBI rating tool provides an opportunity for developers and building owners to design and construct green, sustainable buildings that can provide energy savings, water savings, a healthier indoor environment, better connectivity to public transport and the adoption of recycling and greenery for their projects and reduce our impact on the environment hence increase the progressive effect of waste management. Eco industrial park only reported 1 study under this theme.

CONCLUSION

This systematic review has highlighted the waste management initiatives within Malaysia context. The study offers several significant contributions for practical purposes and the body of knowledge. Based on the systematic reviews performed, four initiative themes have been

identified namely technology, strategies, enforcement and procurement. These initiatives were further extended to 14 sub-themes. A total of 47 studies focused on the strategies initiative which reported the highest number of studies. Follow with enforcement initiative with 16 studies. Next is procurement initiative reported 14 studies and the least was technology initiative with 11 studies.

Strategies initiatives revealed to be the highest to be practiced within the construction waste management perspective. Through these strategies which include of awareness, training, award and 3Rs practices it will give a major impact to the economic, social and environment of a construction project within Malaysian context. On the other hand technology initiative was discovered to be the least practiced. Eventhough technology initiative was the least practiced, yet it is still important because technology initiative helps in minimizing waste before the real waste generated which needs to be taken into consideration before any construction process starts.

PRISMA method assists to practice complimentary searching methods such as citation tracking, reference searching and snowballing. The review suggests several recommendations for future studies. First, more studies are needed to offer in-depth analysis and detailed explanations regarding waste management practice and initiative. Second, to have specific and a standard systematic review method for guide research synthesis in context waste management initiative.

REFERENCES

Abidin, N. A. Z., Ghani, A. H. A., & Mohammad, H. (2020). Identifying the Environmental Strategies in Construction Site for Malaysian Contractors in Johor. *IOP Conference Series: Earth and Environmental Science*, *498*(1):1-7 https://doi.org/10.1088/1755-1315/498/1/012108

Ashikin Suhaini, N., Haslinda Abas, N., Nagapan, S., & Nadarason, K. (2019). Identification of Construction Waste Generated at Precast Concrete Plants: Case study. *IOP Conference Series: Materials Science and Engineering*, *601*(1). https://doi.org/10.1088/1757-899X/601/1/012036

Begum, R. A., Satari, S. K., & Pereira, J. J. (2010). Waste generation and recycling: Comparison of conventional and industrialized building systems. *American Journal of Environmental Sciences*, *6*(4):383–388. https://doi.org/10.3844/ajessp.2010.383.388

Begum, R. A., Siwar, C., Pereira, J. J., & Jaafar, A. H. (2007a). Factors and values of willingness to pay for improved construction waste management - A perspective of Malaysian contractors. *Waste Management*, *27*(12):1902–1909. https://doi.org/10.1016/j.wasman.2006.08.013

Begum, R. A., Siwar, C., Pereira, J. J., & Jaafar, A. H. (2007b). Implementation of waste management and minimisation in the construction industry of Malaysia. *Resources, Conservation and Recycling*, *51*(1):190–202.

Bohari, A. A. M., Skitmore, M., Xia, B., & Teo, M. (2017). Green oriented procurement for building projects: Preliminary findings from Malaysia. *Journal of Cleaner Production*, *148*:690–700. https://doi.org/10.1016/j.jclepro.2017.01.141

Bohari, A. A. M., Skitmore, M., Xia, B., Teo, M., & Khalil, N. (2020). Key stakeholder values in encouraging green orientation of construction procurement. *Journal of Cleaner Production*, *270*, 122246

CIDB Malaysia. (2015). Guidelines on Construction Waste. *Guidelines on Construction Waste Management*. Malaysia: CIDB

Esa, M. R., Halog, A., & Rigamonti, L. (2017a). Developing strategies for managing construction and demolition wastes in Malaysia based on the concept of circular economy. *Journal of Material Cycles and Waste Management*, *19*(3):1144–1154. https://doi.org/10.1007/s10163-016-0516-x

Esa, M. R., Halog, A., & Rigamonti, L. (2017b). Strategies for minimizing construction and demolition wastes in Malaysia. *Resources, Conservation and Recycling*, *120*:219–229. https://doi.org/10.1016/j.resconrec.2016.12.014

Hung, F. C., & Kamaludin, N. S. (2017). Professionals' views on material wastage level and causes of construction waste generation in Malaysia. *Malaysian Construction Research Journal*, *21*(1):33–54.

Hwang, B. G., & Yeo, Z. B. (2011). Perception on benefits of construction waste management in the Singapore construction industry. *Engineering, Construction and Architectural Management*, *18*(4):394–406. https://doi.org/10.1108/09699981111145835

Ikau, R., Joseph, C., & Tawie, R. (2016). Factors Influencing Waste Generation in the Construction Industry in Malaysia. *Procedia - Social and Behavioral Sciences*, *234*:11–18. https://doi.org/10.1016/j.sbspro.2016.10.213

Islam, R., Nazifa, T. H., Yuniarto, A., Shanawaz Uddin, A. S. M., Salmiati, S., & Shahid, S. (2019). An empirical study of construction and demolition waste generation and implication of recycling. *Waste Management*, *95*:10–21. https://doi.org/10.1016/j.wasman.2019.05.049

Kam, K. J., Lim, T. S., Tan, K. K. W, Soon, L. T., Leong, B. T. (2019). Sustainable Construction Waste Management Practice in Malaysia Construction Industry; The Kuala Lumpur Federal Territory Context. *Malaysian Construction Research Journal*, *2*(7 Special issue):104–123.

Laws of Malaysia (2007). "Solid Waste and Public Cleansing Management Act 2007". (Act 672).

Liyanage, K. L. A. K. T., Waidyasekara, K. G. A. S., & Mallawaarachchi, H. (2019). Enablers and barriers to adopt zero waste concept in the construction industry. *Malaysian Construction Research Journal*, *8*(3 Special issue):41–49.

Lu, W., & Yuan, H. (2011). A framework for understanding waste management studies in construction. *Waste Management*, *31*(6):1252–1260.

Mahayuddin, S. A., & Pereira, J. J. (2014). Generation and management of waste in residential construction. *Malaysian Construction Research Journal*, *14*(1):17–29.

Manoharan, E., Othman, N., Mohammad, R., Chelliapan, S., & Tobi, S. U. M. (2020). Integrated approach as sustainable environmental technique for managing construction waste: A review. *Journal of Environmental Treatment Techniques*, *8*(2):560–566.

Maués, L. M. F., Nascimento, B. do M. O. do, Lu, W., & Xue, F. (2020). Estimating construction waste generation in residential buildings: A fuzzy set theory approach in the Brazilian Amazon. *Journal of Cleaner Production*, *265:121179*

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *BMJ (Online)*, *339*(7716):332–336. https://doi.org/10.1136/bmj.b2535

Nagapan, S., Abdul, I., Asmi, A., & Fadhilah, N. (2013). Study of Site's Construction Waste in Batu Pahat, Johor. *Procedia Engineering*, *53*:99–103. https://doi.org/10.1016/j.proeng.2013.02.015

Ng, L. S., Tan, L. W., & Seow, T. W. (2018). Constraints to 3R construction waste reduction among contractors in Penang. *IOP Conference Series: Earth and Environmental Science*, *140*(1). https://doi.org/10.1088/1755-1315/140/1/012103

Othuman Mydin, M. A., Khor, J. C., & Sani, N. M. (2014). Approaches to construction waste management in Malaysia. *MATEC Web of Conferences*, *17*:3–9. https://doi.org/10.1051/matecconf/20141701014

Rahim, M. H. I. A., Kasim, N., Moham, I., Zainal, R., Sarpin, N., & Saikah, M. (2017). Construction waste generation in Malaysia construction industry: Illegal dumping activities. *IOP Conference Series: Materials Science and Engineering*, *271*(1). https://doi.org/10.1088/1757-899X/271/1/012040

Roche, D., & Hegarty, S. (2006). *Best Practice Guidelines on the Preparation of Waste Management Plans for Construction and Demolition Projects*. *June*, 1–38.

Sa'adi, N., Ismail, Z., Makmor, M., & Zawawi, E. M. A. (2016). Implementation of Malaysian goverment initiatives in managing construction waste. *Jurnal Teknologi*, *78*(5–2):55–60. https://doi.org/10.11113/jt.v78.8490

Saadi, N., Ismail, Z., & Alias, Z. (2016). A review of construction waste management and initiatives in malaysia. *Journal of Sustainability Science and Management*, *11*(2):101–114.

Sasitharan Nagapan, Ismail Abdul Rahman, & Ade Asmi. (2012). "Construction Waste Management: Malaysian Perspective." *The International Conference on Civil and Environmental Engineering Sustainability IConCEES 2012*, *2*. http://eprints.uthm.edu.my/2530/1/Construction_Waste_Management_Malaysian_Perspective.pdf

Taherkhani, R. (2014). A Strategy towards Sustainable Industrial Building Systems (IBS): The Case of Malaysia. *Journal of Multidisciplinary Engineering Science and Technology (JMEST)*, *1*(4):86–90.

Umar, U. A., Shafiq, N., Malakahmad, A., Nuruddin, M. F., Khamidi, M. F., & Salihi, I. U. (2016). Impact of construction waste minimization at construction site: Case study. *Jurnal Teknologi*, *78*(5–3):33–40. https://doi.org/10.11113/jt.v78.8508

Wai, T. K., Ismail, R., Jing, K. T., Riazi, S. R. M., & Nawi, M. N. M. (2020). Innovation technology towards construction & demolition (C&D) waste management. *International Journal of Advanced Science and Technology*, *29*(6 Special Issue):1971–1985.

FACTORS IMPROVING THE IMPLEMENTATION OF KEY PERFORMANCE INDICATORS (KPIs) IN ASSESSING OPERATIONAL PERFORMANCE OF PPP PROJECTS: CASES IN MALAYSIA

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Abstract
Public-Private Partnership (PPP) is a performance-based procurement method in which the concessionaire is responsible for providing efficient facilities and services to the government. The performance on the quality of facilities and services provided by the concenssionaires will then be assessed according to the stipulated key performance indicators (KPIs). This KPIs is used for determining the level of performance against the agreed level of standards as expected by the government. However, most of the PPP projects are currently facing difficulties in meeting the government's standards. It is due to several issues such as lack of methods for measuring the KPIs, the lack of understanding of the KPIs implementation, project performance not reflecting the actual performance (physical) on-site, and inconsistent of works performance. These shortcomings have led to the difficulty in determining the performance level of the PPP projects. Thus, this paper aims to determine factors that facilitate in improving the implementation of KPIs for assessing the operational performance of PPP projects. The qualitative research methods using case studies via semi-structured interviews were conducted within PPP stakeholders. The data were obtained from 32 semi-structured interviews conducted across six (6) case studies university campuses. The results revealed that seven (7) factors were determined to improve KPIs implementation for PPP projects. Strengthen the Implementation of KPIs are among the most important factor contributing in improving the implementation of KPIs. The determination of these factors can serve as an improved measure in assessing the PPP project performance at the operational level throughout the concession period.

Keywords: *Factors improving; key performance indicators; operational performance; Public Private Partnership.*

INTRODUCTION

PPP is a unique procurement approach nominated and used by governments worldwide. It is unique in the sense of projects and the smart partnerships adopted in the contract, even though they involve a lengthy period of contracting throughout the entire life cycle of the projects. Public-Private Partnership (PPP) refers to the contractual arrangement between the public and private sectors to enhance their participation in economic development. The PPP project originating in the United Kingdom (UK) has been extensively practised globally including Australia, Hong Kong, China and Malaysia. The PPP procurement method transforms the conventional contract of delivery (design and construction) of providing public service projects to privately financed (finance, design, construct, manage and operate) public facilities. Importantly, PPP contracts require the private concessionaire to take full responsibility for the performance of a public project over the long-term period of concession.

According to Boussabaine (2007), the PPP project is implemented to create a structure. It aims to achieve VFM through private sector innovation and management skills that deliver significant performance improvements. According to Yuan et al. (2009), PPP projects have always emphasised value for money (VFM) based on a concordant partnership. Atkin and Brooks (2009) stated that VFM is concerned about the quality of service and the effectiveness of how it is delivered. Thus, to achieve VFM, it is vital to monitor the performance of the projects throughout the PPP life cycle (Liu et al., 2015). Besides, Yuan et al. (2009) stated that performance might be affected by several factors during the PPP project life cycle. For instance; poor procurement incentive, flawed measurement system and poor risk management may result in inefficiency and ineffective project performance.

In PPP contracts, the public sector has adopted performance measurement tools to measure and monitor the performance and quality of services delivered by the concessionaires. The adoption ensures that the level of agreed standards as specified in the output specifications are achieved. Further, the concessionaires are paid to deliver the services according to the required quality and performance level (Yuan et al., 2009). It is in line with the PPP concept that refers to a performance-based payment mechanism, where payments will be deducted from the unitary charges if the services do not meet the performance standards as outlined in the output specification (Oyedele, 2013; Ernst & Young, 2008). In addition, Lam and Javed (2015) added that failure to achieve performance standards would also lead to continual payment deductions and rectification works within a specified period. This is parallel with the PPP Malaysian guideline that imposes penalties using price deductions due to under-performance and non-compliance if the key performance indicators (KPIs) are not met (UKAS, 2009).

Ogunsanmi (2013) and Yuan et al. (2009) stated that KPIs are the most reliable tool to measure project performance, particularly in the PPP procurement approach. Principally, KPIs for PPPs have been developed to ensure that all concessionaires perform their responsibilities in complying with the government's standards (Ninth Malaysian Plan, 2006). These standards will lead to either rewards or imposing penalties on the concessionaires. Moreover, it is crucial to re-establish the importance of KPIs in the PPP procurement approach to sustain the project's performance for a longer period of time. Although numerous studies have concentrated on performance measurement and monitoring with the aim to achieve VFM, limited attention has been directed towards its implementation that can strongly influence and improve the performance of PPP projects. As suggested by Yuan et al. (2009), it is necessary to include performance objectives and KPIs in PPP projects. Therefore, previous research has revealed that there are limited studies that have investigated KPIs in the context of PPP projects. Therefore, it is observed that limited research has been undertaken to examine the importance of KPIs implementation, especially during the operational and maintenance (O&M) phase of PPP projects. Thus, the contention of this research is to determine factors that facilitate in improving the implementation of KPIs for assessing the operational performance of PPP projects.

ISSUES OF PPP IMPLEMENTATION IN MALAYSIA

The PPP procurement approach has been adopted extensively in construction projects globally to achieve VFM. As mentioned by Almarri & Boussabaine (2017), the main driver behind the paradigm of PPP procurement is achieving VFM by providing all the necessary

service provisions at an optimal cost and to the output specified standards. Furthermore, VFM in the PPP context is often used to express satisfaction on the cost of good quality service by achieving good performance (Ismail, 2009). Although the importance of achieving good performance is often emphasised in implementing this procurement approach, there are still numerous PPP projects that demonstrate poor performance levels especially in social infrastructure projects (Liu et al., 2016). Besides this, Hashim et al. (2017) reported that most PPP projects face difficulties in meeting client expectations known as government. Accordingly, these issues have raised questions concerning the rationale of adopting the PPP approach in Malaysia, where VFM is a part of the goal to achieve success (UKAS, 2009).

Currently, the implementation of PPP's, especially for PFI schemes in Malaysia, has entered into the fifth year of the O&M phase and many researchers had argued on the issues and challenges that will be faced by the stakeholders in this phase (Lop et al., 2020; Hashim et al., 2017; Khaderi & Aziz, 2010). Among these include insufficient PPP implementation guidelines, difficulties in managing KPIs, maintenance approach, service delivery failure, asset risk, and life cycle issues, and challenges in PFI management (Hashim et al., 2017). He further added that these issues would indirectly contribute to project implementation failure. This is also supported by Hashim et al. (2018) in a study stating that defects occurring in PPP projects had significantly affected project performance and disrupted project operations during the O&M phase. Lop et al. (2020) revealed that four major issues were discovered in the implementation of PFI project, namely lack of skills and knowledge on PFI, lack of procedures and its implementation, challenges in PFI management, and conflicts on documentation. All the issues highlighted will significantly affect the operational performance of PFI projects and simultaneously lead to project failure.

In Malaysia, one of the problems faced by PPP stakeholders is managing KPIs effectively (Lop et al., 2018; Hashim et al., 2017). In the PPP approach, KPIs is used to ensure that project performance is achieved at a certain level in line with agreed quality standards. Thus, KPIs are a useful mechanism in assessing the performance of a PPP project operation. The agreed level of performance helps determine the payments or deductions from the public sector to the private sector. Therefore, if the quality of service does not meet the minimum standards and requirements as stipulated in the output specification, a payment deduction or other penalties can be triggered in the form of a performance failure payment deduction (Yescombe, 2007). Javed et al. (2013) revealed that there were numerous complex KPIs specified in the PPP contract, resulting in the difficulties in monitoring, measuring, and implementation by end users. This finding is further supported by an interview conducted by Javed et al. (2013) on the challenges faced by Australian PPP projects. Therefore, actions need to be taken to ensure that all the problems can be overcome without affecting the operational performance and VFM of the projects. Thus, the development of appropriate KPIs is essential in determining and ensuring the level of quality services to be delivered to monitor and measure effectively and efficiently.

KEY PERFORMANCE INDICATORS (KPIs) FOR PPP PROJECT IMPLEMENTATION

The key features of PPP involve the allocation of risk, VFM, output specification, whole service approach, payment-based mechanism and KPIs (UKAS, 2009). The Ninth Malaysia Plan (9MP) spelt out certain issues regarding the implementation of PFIs, especially with

regards to KPIs. More importantly, the development of KPIs for PPPs allows greater public participation in the formation of those KPIs. Moreover, it is anticipated that KPIs will assist in making PPPs more significant to public needs and requirements instead of benefiting mainly the profit-driven private concessionaires (Ismail, 2009).

In the context of PPPs and infrastructure delivery, KPIs are defined by Ismail (2009) as organised and characterised KPIs through careful and systematics discussion, weighing and examination. KPIs have also been referred to as key success indicators (KSIs) which help organisations define and measure their progress towards achieving their planned organisational goals and objectives (Reh, 2018a). Therefore, KPIs are a systematic compilation of data employed to measure performance with respect to specific success factors. Accordingly, for this research context, KPIs are defined as a compilation of data measures used to measure the operational performance which includes dimensions and sub-dimensions as a full set of KPIs.

The importance of KPIs in PPPs is the ability to assess the work performance against the standards as agreed by the public and private sectors. There are several factors concerning the importance of implementing KPIs in PPP projects. The importance of using KPIs as a measurement tool is in the ability of the KPIs to benchmark the performance of a project against other comparable industries or projects where the lessons learned from others can be used to make targeted improvements (Ismail, 2009). Whereas, according to Reh (2018b); Ismail and Yusuf (2009); and Smith (2001), benchmarking can be described as the process of comparing an organisation's operations or processes against other organisations within the same industry or other related organisations. The concept involves measuring the actual performance of certain aspects related to activities and comparing these against others, referred to as best practice examples in a specific sector (Haponava & Al-Jibouri, 2012). Consequently, benchmarking has become an important component in many organisations and industries (i.e. construction) for continuous improvement and quality initiatives. Moreover, benchmarking encourages industry practitioners to collaborate in sharing best practices and ideas while avoiding the burden of having too many KPIs (Ismail & Yusuf, 2009).

Nevertheless, KPIs are also important in highlighting organisational and project-related weaknesses by performing a project assessment using KPIs. For instance, an organisation without an effective strategy, supported by KPI's to measure project performance, may experience significant defects or poor service delivery (Lop et al., 2017). Inevitably, if these weaknesses or failures are not addressed, poor performance and low satisfaction level may result. Thus, KPIs are crucial to assist organisations and projects continuously improve for the organisation and projects to be successful.

As a useful tool to improve performance, KPIs can help monitor and evaluate performance, particularly in PPP projects. According to Liu et al. (2014), monitoring and evaluating the performance of PPP projects are the core activities of contract and project management, which are considered important in most countries as part of their PPP policy regime. Therefore, KPIs are not only used in scoring the performance level but are also for monitoring the activities and outcomes in PPP projects (Yuan et al., 2009). This is also supported by Mladenovic et al. (2013); Cox et al. (2003) and Kagioglou et al. (2001) stating that KPIs are recognised as one of the popular tools used to measure the performance of PPP projects. Likewise, PPP project performance needs to be measured continuously to ensure

that the concessionaire complies and meets established standards. Principally, performance will be measured when the project enters the O&M phase of the PPP project. According to Akbiyikli (2013), during the O&M phase, service delivery is frequently measured to determine its compliance with the output specification(s) and payment deductions for performance failure according to the payment mechanism.

RESEARCH METHODOLOGY

A qualitative method via the exploratory approach of six (6) case studies was conducted using semi-structured interviews. This corresponds with the semi-structured face-to-face interviews with professionals and experts that were involved in PFI projects at the operational and maintenance (O&M) phase. The selection of case studies was based on the list of projects established by the Public-Private Partnership Unit (UKAS) of the Prime Minister's Department of Malaysia. However, this research only focused on the educational sector. Six (6) university campuses under Phase 1 were chosen as the research case studies. It is due to the earliest PPP projects that have been implemented in Malaysia (PFI phase 1). Purposive sampling was adopted for the data collection. Thirty-two (32) participants among PPP stakeholders (i.e. public sector and private sector) involved in the case study projects were selected and participated.

The data obtained from these interviews were analysed using the thematic technique (Atlas.ti 8). The analysis of qualitative data has been conducted according several stages, namely; transcription, organise, familiarisation, coding, identify themes, and report writing. These steps involved in analysing the data from the within-case studies and cross-sectional analysis. The analysis of within-case study was initially performed and followed by cross-case analysis (i.e. comparative analysis) to produce broad themes that emerge from the data and highlight similarities and differences that arise from the case study.

RESULT AND DISCUSSIONS

Table 1 presents the findings from the six (6) case studies on the factors that contribute to improve the current implementation of KPIs for PFI Projects. Seven (7) factors were recommended by the participants that include; *(1) strengthen the implementation of KPIs; (2) establish construct indicators; (3) establish a method of measurement; (4) increase the knowledge on KPIs; (5) close monitoring on the KPI's element; (6) provide sufficient competent staff and (7) avoid contractual conflict.* The findings show that strengthening the implementation of KPIs was seen as the topmost factor contributing to improving the implementation of KPIs in PFI projects in Malaysia. Based on the findings, most participants across all cases had similar views, emphasising the issue of strengthening and enforcing the monitoring of KPIs regarding their implementation for improving project performance. The results also indicate that this is an important strategy that needs to be stressed for improving the implementation of KPIs for PPP projects in Malaysia.

Table 1. Findings of the Comparative Analysis on Factors Improving KPIs Implementation in PFI Projects Across All Cases

Broad Themes	Campus A	Campus B	Campus C	Campus D	Campus E	Campus F
Strengthen the Implementation of KPIs	Improve implementation To strengthen KPIs implementation Improve the implementation of KPIs To strengthen the method of implementation.	To strengthen KPIs implementation. To strengthen the method of implementation.	Enforcement on monitoring KPI implementation by end users. To strengthen KPI implementation To strengthen the method of implementing KPIs. Firm decision by top management is very important when involving issues on KPIs.	Enforcement on the implementation of a reward and penalty system. Full enforcement of KPI's implementation by end users. UiTM needs to standardise the KPIs documentation for better implementation To strengthen the method of implementation. Prepare guidelines to assist the concessionaire and UiTM in managing the PFI project. Upgrade and improve the CMMS by providing sufficient input to the system to match with the operational campus. To strengthen the KPI implementation.	Enforcement on KPI's implementation by end users. Fast decisions from top management are essential. Revision on KPI measures must be made every 5 years. To strengthen the KPIs implementation To strengthen the method of implementation.	To strengthen the KPIs implementation To strengthen the method of implementing KPIs. Comprehensive enforcement of the implementation of KPIs by end users. Invite faculty level stakeholders during the design stage as input from them are very crucial.

Table 1. Findings of the Comparative Analysis on Factors Improving KPIs Implementation in PFI Projects Across All Cases (cont'd)

Broad Themes	Campus A	Campus B	Campus C	Campus D	Campus E	Campus F
Establish Construct Indicators	Development of KPIs should be detailed. KPIs need to be prioritised so that the concessionaire can perform tasks according to the priority and giving emphasis to work performed.	Detailing and justification on each indicator must be clearly constructed. Assign weighting for each indicator. Should consider the sustainable element in the KPIs. Development of KPIs should be detailed. Prioritised KPIs in order to perform tasks according to priority of the work.	Development of KPIs should be detailed. KPIs need to be prioritised so that the concessionaire can perform tasks according to the priority and give emphasis to work.	To ensure the weighting of each element of the KPI is according to the priorities. Develop weightage for the indicators to make them more realistic. Development of KPIs should be detailed. Prioritised KPIs in order to perform tasks according to priority of the work.	Create weightage based on the important indicators Development of KPIs should be detailed. Prioritised KPIs in order to perform tasks according to priority of the work.	PPM should be measured as separate individual KPI. Development of KPIs should be detailed. Prioritised KPIs in order to perform tasks according to priority of the work.
Establish a Method of Measurement	Standardised KPI measures Fine tune the existing contract Improvement of the assessment method. To refine and standardised the method of assessment for each KPI.	Improvement of the assessment method. Finalise and establish a method of assessment for each KPI.	Establish a system to assist in calculating performance. Improve the assessment method.	Establish a method of measuring performance. Using true variables for measuring the performance. Improving the method of measuring performance in order to know the actual performance.	Establish a method of assessing the concessionaire's performance. Improving the method of measuring performance in order to know the actual performance. Clarify more on performance measurement.	Improve on the method of assessing PPM works. Improving the method of measuring performance. Improve and standardise the method of KPI assessment.

Table 1. Findings of the Comparative Analysis on Factors Improving KPIs Implementation in PFI Projects Across All Cases (cont'd)

Broad Themes	Campus A	Campus B	Campus C	Campus D	Campus E	Campus F
Increase the Knowledge on KPIs	Knowledge transfer	Provide training and seminars on KPI implementation. Increase Knowledge in PFI projects. Improve the understanding of KPIs among all stakeholders. Organise workshops on KPI measures.	Organise seminars and talks on KPIs to the management level as they are the decision maker. Organise seminars or workshops among stakeholders	The client needs to share knowledge between PFI campuses. Provide training related to the PFI concept.	Provide training related to the PFI concept.	Provide training to the people involved in the PFI project. Provide training related to the PFI concept.
Close Monitoring on KPI's Element	Client needs to critically supervise the KPI element. The client needs to monitor the KPI element.	Monitoring by end users.	Find a suitable method for monitoring and evaluating PPM works.	KPI on 'self-finding' by concessionaire (UiTM does not have enough manpower for monitoring work).		
Provide Sufficient Competent Staff	Provide sufficient and competent staff in monitoring works. Provide sufficient staff in monitoring works according to the location's size.					
Avoid contractual conflict		Should not involve any extension of time (EOT) as they can delay the work. Improvement on KPI documentation to avoid any conflict in the contract terms.				

During discussions, a Senior Engineer (End Users) from Campus D, asserted that: *"In order to improve good quality of service delivery, we need to increase the enforcement towards KPI implementation, for instance; by performing regular monitoring. This is to ensure that all established KPIs are well implemented according to the agreed level of standard."* **(D3-UD, Campus D).**

The above statements show that the enforcement from the government on the implementation of KPIs should be consistent and taken seriously to ensure both parties attain the benefits of this partnership arrangement. In addition, the government should standardise the KPI's documentation, so that, all campuses can use it for better implementation of KPIs. A Facility Manager of the Facilities Management Contractor added that *"...the government needs to make a fast and firm decision when it involves performance and KPI issues, meaning that, there should be a standard that can be referred to in resolving these issues especially when it comes to performance measurement issues."* (**C4-FM, Campus C**).

A study by Ng and Wong (2007) added that performance monitoring provides a powerful incentive for FM contractors to deliver the standard of services needed by the public-sector as stipulated in the output specification during the O&M phase. Therefore, it can be deduced that, although performance monitoring provides advantages to the public sector in managing and measuring project performance, the enforcement of performance monitoring using KPIs is essential. This method of enforcement can benefit the private sector in improving service delivery and facilities to the required level of standard.

The second factor that was suggested by the participants was *establishing construct indicators*. The results demonstrated the majority of participants agreed that the construct indicators should be sufficiently detailed and clearly described. In the PPP approach, project performance should be measured according to the set and agreed standards and KPIs specified in the Concession Agreement (CA). Thus, the development of KPIs is important to ensure the private sector (FM contractor) is clear about the priority and scope of work and impact on the project's operations. Moreover, it will indirectly affect the performance level of the project. This is aligned with the opinion received from the Director of the Public Private Partnership Unit of the Prime Minister's Department of Malaysia (UKAS) stating that: *"KPIs also need to be prioritised so that concessionaires can perform the tasks according to the priority and give emphasis for that work."* ***(GA2, all cases).*** This statement was further supported by the Senior Engineer (End Users) of Campus E, who added that *"... developed weighting for KPIs, so that we can measure their performance accurately. There is a KPI with bigger weight, and there is a KPI that has a small weight. It all depends on the priority and impact of each KPI towards project performance."* ***(E1-EU, Campus E).***

From the findings, it is clear that both the private and public sectors agree that assigning weightage for each KPI is crucial. This is to facilitate project implementation, especially involving the process of measuring performance and making payments. According to Yescombe (2007) and HM Treasury (2007), the performance measurement system (PMS) is closely related to KPIs, and it usually involves weighing systems. In this situation, each KPI is given weightage based on the critical level and impact on the project's operations. Likewise, Oyedele (2013) mentioned that explicit and realistic performance standards, criteria, and weighting systems are among the factors identified to avoid performance failure payment deductions in PFI projects. Therefore, it can be surmised that both public and private sectors

can gain the benefits and the private sector can, in turn, maximise their profits or returns on the investment by improving their performance and simultaneously avoiding payment deductions in PFI projects. On the other hand, the public sector (clients and end-users) can achieve VFM by enjoying the facilities that meet their needs and requirements.

Another significant factor in improving the implementation of KPIs in PFI projects was highlighted regarding *establishing a method of measurement*. The participants viewed this as a significant factor in improving the implementation of KPIs in PFI projects. According to Oyedele (2013), there is a mechanism by which the public sector measures and monitors performance of the quality of services delivered by the concessionaire against agreed standards set out in the output specification. There are three (3) approaches to measure performance under the PFI contract, (i.e. the scoring system, fixed deductions, and performance penalty points). This was expressed by the Senior Engineer for Campus A that:*"...the mechanism on how to get the actual percentage of a project's performance is still vague, and I would suggest that the method of how to measure this performance needs to be refined and established to be practised by all PPP projects. That's important; thus, the actual project's performance and achievement by the concessionaire can be easily determined."* **(A1-EU, Campus A).**

The above statement emphasises that it is crucial to establish a performance measurement mechanism in determining the accurate project performance level to improve PPP project implementation. Principally, in the PPP approach, the success of the projects depends on the performance level achieved which is determined by measuring the performance against the quality of service delivered by the concessionaire against the agreed standards (Oyedele, 2013). Thus, the determination of the actual percentage of project performance is vital since it determines the amount of payment to the concessionaire. Moreover, it is aligned with the key features of PPPs where payment for services is based on pre-determined standards and performance measures (UKAS, 2009).

The fourth factor raised by participants to improve the implementation KPIs in PPP projects was to *increase the knowledge of KPIs*. According to Mustapa and Carrillo (2008), knowledge in managing services and facilities is crucial particularly in terms of the processes, the approaches in dealing with problems and the management of day-to-day operations in achieving better project performance. Therefore, in managing PFI projects, adequate knowledge of KPIs is needed among those involved in the project to ensure the project is implemented accordingly. Carrillo et al. (2006) suggest that one way of improving PPP performance is through the transfer of knowledge gained from previous projects, applied to future projects and PPP project teams. As mentioned by a Building Surveyor (Internal Auditor) from Campus B:*"Training and seminars on KPI implementation... we have to conduct as many as possible to all facility staff (end users) and FM contractor staff to enhance the knowledge and understanding on the KPI...so that the project can be well implemented. Through the execution of this training and seminar, it can be a platform to transfer knowledge or knowledge sharing."* **(B3-EU, Campus B).**

Therefore, based on the findings, there are various means to improve the level of knowledge regarding the implementation of KPIs to the stakeholders such as conducting training, seminars and interactive workshops. It is also viewed as the best platform for transferring and sharing knowledge regarding KPI implementation among PPP project teams.

Other factors suggested by the participants to improve the implementation of KPIs were *close monitoring on KPI's element*, *provide sufficient competent staff* and *to avoid contractual conflict*. These factors are considered significant, even though the discussion around these factors was limited across all six cases. Table 2 presents the cross-case analysis of the factors for improving the implementation of KPIs in PFI projects.

Table 2. Cross-Case Analysis of the Factors for Improving the Implementation of KPIs in PFI Projects Across Case Studies

No.	Broad Themes	Sub-Themes	Campuses					
			A	B	C	D	E	F
1.	Strengthen the Implementation of KPIs	Improve the implementation method.	√	√	√	√	√	√
		Enforcement on KPIs implementation.	√	√	√	√	√	√
		Firm decision by top management.			√		√	
2.	Establish Construct Indicators	Construct indicators should be detailed.	√	√	√	√	√	√
		Prioritise the indicators by assigning a weightage.	√	√	√	√	√	√
3.	Establish a Method of Measurement	Standardise and improve the assessment method.	√	√	√	√	√	√
4.	Increase the Knowledge of KPIs	Organise training.		√	√	√	√	√
		Knowledge transfer.	√			√		√
5.	Close Monitoring on the KPI's Element	Supervise and monitor KPIs element.	√	√	√	√		
6.	Provide Sufficient Competent Staff	Provide sufficient staff for carrying out the monitoring works.	√					
7.	Avoid Contractual Conflict	Avoid the involvement of political issues.		√				
		Improve KPI documentation to avoid conflict with the terms of the contract.		√				

The cross-case analysis demonstrated that strengthening the implementation of KPIs, construct indicators, establish a method of measurement and increase knowledge on KPIs were among the four (4) most important factors to improve the implementation of KPIs in PFI projects. This was proven as highlighted by the majority of participants from all six cases as important actions to improve the implementation of KPIs. Based on these findings, the participants suggested three approaches to strengthen the implementation of KPIs, namely by *improving the implementation method, enforcement with respect to the implementation of KPIs* and *cooperation from top management in making a firm decision* when dealing with performance measurement and monitoring issues.

The participants also recommended that the construct indicators should be sufficiently detailed and prioritised by assigning the weightage to make the KPIs more effective. According to Oyedele (2013), KPIs should be constructed objectively and subjectively employing suitable methods to measure performance either using a scoring system or via a penalty system. For this research, most participants suggested that weighted indicators should be incorporated into the scoring system. A measurement method was also suggested to be established by standardising and improving the present assessment method. The benefits of increasing the knowledge on KPIs through training programmes and knowledge transfer were also mentioned in improving the implementation of KPIs.

The remaining three factors, *close monitoring on the KPI's element, provide sufficient competent staff* and *avoid contractual conflict*, were also acknowledged as effective ways in improving the effectiveness of KPI implementation in PFI projects. Only a few participants raised these factors, with minimal discussion. Nevertheless, these factors are also important towards enhancing the implementation of KPIs for PFI projects.

CONCLUSION

In Malaysia, the implementation of KPIs as a performance measurement tool at the O&M level is still quite novel given there are many issues faced in the implementation of KPIs, making them ineffective. These issues may invariably affect the effectiveness and usefulness of KPIs as a measuring tool in assessing the performance of PPP projects, so it is critical to address these issues. The results from the interviews identified that strengthening the implementation of KPIs, establish construct indicators, establish a method of measurement, increase the knowledge on KPIs, close monitoring on the KPI's element, provide sufficient competent staff and avoid contractual conflict was among the crucial factors to be considered. The implementation of KPIs was viewed as the most important factor in improving the implementation of KPIs in PPP projects. It can be attained by improving implementation method, enforcement and commitment from the top management in making the decision. Thus, it can be concluded that by identifying the factors for improving KPIs implementation, it can facilitate PPP stakeholders in managing and assessing the operational performance of the PPP projects.

REFERENCES

Akbiyikli, R. (2013). Performance assessment of a private finance initiative road project. Transport, 28(1), 11-24.

Almarri, K., & Boussabaine, H. (2017). Interdependency of value for money and ex-post performance indicators of Public Private Partnership projects. *Journal of Engineering, Project, and Production Management, 7*(2), 90–98.

Atkin, B., & Brooks, A. (2009). Total facility management (3rd ed.). Oxford, U.K: Wiley-Blackwell.

Boussabaine, A. (2007). *Cost planning of PFI and PPP building projects.* New York: Taylor & Francis.

Carrillo, P. M., Robinson, H. S., Anumba, C. J., & Nasreddine, M. (2006). A Knowledge Transfer Framework : the PFI context A Knowledge Transfer Framework : the PFI context. *Construction Management and Economics, (December 2014),* 37–41.

Cox, R. F., Issa, R. R. A., & Ahrens, D. (2003). Management's perception of key performance indicators for construction. *Journal of Construction Engineering and Management, 129*(2), 142-151.

Ernst & Young. (2008). *The Journey Continues: PPPs in Social Infrastructure*, September 2008. Retrieved July 3, 2017, from Autralian Government, Infrastructure Australia.

Haponava, T., & Al-Jibouri, S. (2012). Proposed system for measuring project performance using process-based key performance indicators. *Journal of Management in Engineering, 28*(2), 140-149.

Hashim, H., Che-Ani, A., & Ismail, K. (2017). Public Private Partnership (PPP) Project Performance in Malaysia : Identification of Issues and Challenges. *International Journal Supply Chain Management, 6*(2), 265–275.

Hashim, H., Che-Ani, A. I., Ismail, K., Isa, H. M., & Wahi, W. (2018). Procedures and Implementation of Defect Management in Malaysian Public Private Partnership (PPP) University Projects. *Malaysian Construction Research Journal (MCRJ), 3*(1), 232–244.

HM Treasury. (2007). Standardization of PFI contracts, version 4. London: HM Stationery Office.

Javed, A. A., Lam, P. T. I., & Zou, P. X. W. (2013). Output-based specifications for PPP projects: lessons for facilities management from Australia. *Journal of Facilities Management,11*(1), 5-30.

Ismail, S. (2009). *Key performance Indicator for Private Finance Initiative in Malaysia.* Universiti Teknologi Malaysia. PhD Thesis.

Ismail, S., & Yusuf, A. M. (2009). Benchmarking the performance of Malaysia's construction industry. *Management Research and Practice, 1*(1), 1-13.

Kagioglou, M., Cooper, R., & Aouad, G. (2001). Performance management in construction: A conceptual framework. *Construction Management & Economics, 19*(1), 85-95.

Khaderi, S. S., & Aziz, A. R. A. (2010). Adoption of Private Finance Initiative (PFI) in Malaysian Public Works Projects: Are We Ready ? *CIB TG72 World Building Congress*, 105–120.

Lam, P. T. I., & Javed, A. A. (2015). A comparative study on the use of output specifications for Australian and UK PPP/PFI projects. *Journal of Performance of Constructed Facilities, 29*,1-15.

Liu, J., Love, P. E. D., Sing, M. C. P., Smith, J., & Matthews, J. (2016). PPP Social Infrastructure Procurement: Examining the Feasibility of a Lifecycle Performance Measurement Framework. *Journal of Infrastructure Systems, (04016041)*, 1-12.

Liu, J., Love, P. E. D., Palaneeswaran, E., Regan, M., & Smith, J. (2015). Review of performance measurement: Implications for public–private partnerships. *Built Environment Project and Asset Management, 5*(1), 35-51.

Liu, J., Love, P. P. E. D., Smith, J., Regan, M., & Davis, P. R. (2014). Life cycle critical success factors for Public-Private Partnership infrastructure projects. *Journal of Management Engineering*, 1-7.

Lop, N. S., Ismail, K., & Isa, H. M. (2020). Exploring Private Finance Initiative Implementation Issues in Malaysia Construction Projects: A Way Forward. *Environment Behaviour Proceedings Journal, 5*(S13), 41-46.

Lop, N. S., Ismail, K., & Isa, H. M. (2018). The Execution of Key Performance Indicators in the Operational Phase of PFI Projects in Malaysia. *Asian Journal of Quality of Life, 3*(12), 157-167

Lop, N. S., Ismail, K., & Isa, H. M. (2017). The implementation of key performance indicators in the Malaysian private finance initiative projects. *Environment-Behaviour Proceedings Journal, 2*(5), 95-104.

Mladenovic, G., Vajdic, N., Wundsch, B., & Temeljotov-Salaj, A. (2013). Use of key performance indicators for PPP transport projects to meet stakeholders' performance objectives. *Built Environment Project and Asset Management, 3*(2), 228-249.

Mustapa, M., & Carrillo, P. M. (2008). The potential of knowledge management processes for facilitating PFI projects. In: Finch, E. and Then, D. (eds.), *Healthy and Creative Facilities, Proceedings, Facilities Management and Maintenance, CIB W070, 16th - 18th June*, 2008, Herriot Watt University, Edinburgh, UK (pp. 1–7).

Ng, S. T., & Wong, Y. M. W. (2007). Payment and audit mechanisms for non private-funded PPP-based infrastructure maintenance projects. *Construction Management and Economics, 25*(9), 915–923.

Ninth Malaysia Plan. (2006). Ninth Malaysia Plan (2006-2010). Retrieved March 31, 2016, from Economic Planning Unit (EPU), Ministry of Economic Affairs.

Ogunsanmi, O. E. (2013). Stakeholders' perception of key performance indicators (KPIs) of public private partnership (PPP) projects. *International Journal of Construction Supply Chain Management, 3*(2), 27-38.

Oyedele, L. O. (2013). Avoiding Performance Failure Payment Deductions in PFI/PPP Projects: A Model of Critical Success Factors. *Journal of Performance of Constructed Facilities, 27*(3), pp.283-294

Reh, J. (2018a). The Basics of Key Performance Indicators. Retrieved November 12, 2018, from The Balance Carreers: Management and Skills, https://www.thebalancecareers. com/key-performance-indicators-2275156.

Reh, J. (2018b). The Importance of Benchmarking in Improving Business Operations. Retrieved December 2, 2018, from The Balance Carreers: Management and Skills, https: //www.thebalancecareers.com/overview-and-examples-of-benchmarking-in-business-2275114.

Smith, M. (2001). *Getting construction back on track. Beyond the bottom line*. The Industrial Pioneer. Birmingham, U.K: Change Magazine.

UKAS. Public Private Partnership (PPP) Guideline (2009).

Yescombe, E. R. (2007). *Public-Private Partnerships, Principles of Policy and Finance (First Edit)*. England: Elsevier.

Yuan, J., Zeng, A. Y., Skibniewski, M. J., & Li, Q. (2009). Selection of performance objectives and key performance indicators in public–private partnership projects to achieve value for money. *Construction Management and Economics, 27*(3), 253–270.

CROSS-CULTURAL WORK ADAPTATION FOR MALAYSIAN CONSTRUCTION PROFESSIONAL EXPATRIATES IN FACING NEW CHALLENGES DURING LIFEWORK

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Abstract
Cross-cultural work adaptation is a crucial issue faced by Malaysian professional expatriates abroad. Difficulty in adapting a new environment is one of the problems that leads to expatriates' poor performance. One of the successful keys for expatriates to retain in their current position is the ability to adapt and perform in the new environment. The objectives of this paper are to identify the elements of cross-cultural work adaptation and the challenges they are facing that hinder their retainment in the new environment. Content analysis was used to analyse previous literature review to explore cross-cultural work adaptation. This study reveals a dimension of cross-cultural work adaptation elements that consist of socialisation, interaction/speaking and custom/culture. A dimension of cross-cultural work adaptation elements could contribute to the success of the organisation to enhance sustainability and well-being among Malaysian professional expatriates abroad.

Keywords: *Cross-cultural; work adaptation; professional; expatriates; construction.*

INTRODUCTION

Nowadays, the use of advanced technology can be seen in any developing country. This is due to the expertise of a person whereby a great technology is created and good infrastructure is produced. Professional expatriates are those who have experienced working abroad. They come from various industries and fields such as construction, electrical and electronic, business, services, education, medical, accountant, and technology. The continuous and rapid growth of development results in a high demand for knowledge workers. As the global economy begins, professionals are adapting to new realities with fresh experiences and work practices. This process allows them to accept modern ways of thinking and redefine a positive path forward.

This study highlighted the problems faced by professional expatriates in the construction industry. In 2020, the number of projects secured by Malaysian construction companies abroad was only 16 projects in 7 countries worth MYR 13.41 billion (CIDB, 2021). As compared to the last 10 years, a total of 48 projects were secured back then which shows a big difference (CIDB, 2011). This data shows the number of involvement of Malaysian Multinational Construction Companies with overseas projects has decreased as years passed by.

In order for multinational companies to succeed in their projects, it is necessary for them to gain support from their employees, particularly the professional workers. They must be able to accomplish their tasks in a foreign country. Hence, strategies need to be developed to allow them to operate successfully abroad (Sarpin et al., 2019). One of the important aspects

that the organization needs to consider is to retain qualified employees (Rony et al., 2017). Meanwhile, some companies are unable to retain talented workers, thus resulting in a loss of productivity and a rise in staff recruitment and training costs (Anderson & Chawana, 2020). Therefore, it is important to retain professional expatriates in order to achieve success for the multinational companies and also the vision of the nation.

A lot of research has been done on Malaysian professionals who had experienced working abroad (Liang, 2014). Malaysia has been facing the issues of brain drain since a long time ago (Shariff et al., 2018). The participation of Malaysian construction companies in the implementation of any new project would definitely affect the expatriate's adaptation in the host nation (Zainol, 2011). However, the real problems are the shortage of knowledge workers and the challenges of sustaining them. Such deficiencies reduce the output and productivity in the short run when high-potential companies are not able to hire the talents needed for development (World Bank Group, 2019).

According to Chen (2019), expatriates might not be familiar with an environment that is foreign to them, which may influence their work adaptation. According to Bahrollah and Parol (2018), human resource experts are more responsible for choosing the right individual for the correct international position. A failed international assignment can be very costly for both workers and the company. According to Schuler et al. (2011), the internationalisation talent challenges include challenges addressing talent shortages, talent surpluses, talent location and relocation, and compensation levels. It is also a challenge for expatriates to cope with the changing social and work environments in the host country (Zhang et al., 2017). International professionals would have to make a cross-cultural adaptation to address the degree of discomfort and difficulties they are facing in a host country that differs in its people's culture and expectations.

Adaptation or adjustment is related to the psychological comfort to perform tasks or job. According to Selmer (2007) and Brown (2008), it also can be referred to as the combination of job satisfaction, pay, work pressure, and position at work. According to Randstad Worldwide (2019), 85% of Malaysian employees will emigrate for a considerably higher salary. Stress is seen as a significant factor for shoddy work, failure in cross cultural adaptation and expatriates' turnover (Davies et al., 2019). Having a good position and career satisfaction abroad are the reasons why these professionals prefer to remain overseas rather than return to their own country. Malaysian professionals are usually talented and can demonstrate their expertise well.

The focus of this study is to identify the elements of cross-cultural work adaptation for Malaysian construction professional expatriates and highlight the challenges they face in order to retain them in a host country. The findings are provided to improve and assist the Malaysian government and related agencies on how to enhance professional expatriates in cross-cultural work adaptation in facing new challenges during lifework.

LITERATURE REVIEW

In 2020, the number of projects secured by Malaysian construction companies abroad was only 16 projects in 7 countries worth MYR 13.41 billion (CIDB, 2021). As compared to the last 10 years, the number of projects was higher which is 48 projects in year 2020 (CIDB,

2011). The establishment of market access, increased market share, improved networking, and gained experience are the reasons why Malaysian construction companies (MNC) took an active role in foreign countries. As reported by National Economic Action Council (2020), due to a lack of job opportunities and a shortage of highly skilled employment, Malaysia was unable to retain the local talent of all races or attract foreigners. Malaysian companies abroad could not retain their Malaysian professionals because other international companies offered better facilities and opportunities.

Expatriate adaptation involved differences in lifestyle, social status, and comfort when faced with a new situation (Mellahi et al., 2015). When people feel discomfort, sadness, and worrisome, it is a sign that they are unable to adapt to the new situation when performing their works. The switch in place and culture can trigger work adaptation (Davies et al., 2015). For every individual, life is an adaptation process to the existing situation and creating good communication with the environment. Andreeva (2009) defined socialisation as a process of integrating a person into the social environment, assimilation of social life experience, culture and social relationship.

Expatriates' interaction was positively linked to work adaptation (Sterle et al., 2018). Peltokorpi (2008) found wide cultural differences generate tension and require tolerance for divergent cultural values, thereby affecting interaction, adaptation to work cultural values and religious beliefs are essential to expatriates. Religious practice is the factor that they identified for work adaptation in the host country. When there are similarities between the home and host country in religious practice, they will accept the appointment to work abroad.

Cross-cultural Work Adaptation to Retain Professional Expatriates

When expatriates arrive in a culturally new environment, they may find it difficult to adapt because they stand out from the majority, as they look, sound and act differently from "locals", which could lead to stress. Halim et al., (2019) found that people's skills and personal characteristics, such as adaptability, flexibility, tolerance, and emotional maturity, are the two most desirable expatriate adaptation attributes. Also, the lack of personal or emotional maturity contributed to the failure in adapting to a foreign assignment.

The individuals need to adjust to the surrounding when they are in the new environment. Such exposure requires the ability to socialize in various factors such as interaction, communication and relationship with host nationals (Wanberg, 2012). According to Wang (2010), socialization in language can occur virtually anywhere. A study by Feldman and Bolino (2011) found that the amount of mentoring has had a positive feedback on expatriate socialization, which in turn results in positive impact work behaviour, intention to complete the expatriate assignment and increased awareness of global business issues. This indicates that when expatriates can adapt with socialization, it has positive impact in work adaptation and performance. Once expatriates feel satisfied and able to adapt during lifework, they tend to retain in the organization.

Social interaction such as maintaining close relationships is a part of the social needs among human beings (Zhou, 2018). Language and communication barriers are challenges in cross-cultural work adaptation during abroad (Domingo, 2017). According to Zakariya et al., (2019), expatriates' performance was found positively significant in both interaction

adaptation and work adaptation. This shows that interaction and communication are essential for professional expatriates to deal with people in the workplace or organization. The ability to interact makes it comfortable and easy for the expatriates to maintain their relationships and retain in the organization.

Another critical factor in the expatriate phase is the culture of Multinational companies (Kuada, 2016). The emergence of different cultural contexts exacerbates expatriates' uncertainties, though the response to uncertainty varies among expatriates (Kumar et al., 2018). When they work abroad, the expatriates could be dealing with various behaviours and different ways of work culture. For example, Indians tend to be more collectivistic and high in power distance at work. In comparison, Americans are individualistic and low in power distance (Vijayakumar & Cunningham, 2016). These disparities could likely pose adaptation challenges for expatriates. Culture also influences the work adaptation of professional expatriates in an organization.

In misfit work styles, individuals might engage in the adaptation of behaviours to increase their fitness by either acting with the environment or acting upon themselves (Bayl-Smith & Griffin, 2015). Engaging in work with host nationals in an organisation could lead to social adaptation of an individual. Thus, poor adaptation into the social environment could adversely affect employee's satisfaction, organisational commitment, and job performance.

Expatriates' Challenges

An expatriate who moves to another country for an international assignment often faces a number of challenges. Currently, Industry 4.0 is a vision for the future, because it involves many aspects, and faces many types of difficulties and challenges, including scientific challenges, technological challenges, economic challenges, social problems and political issues (Zhou et al., 2015). Expatriates need to tackle these challenges while being abroad in order to retain in the company.Socialisation is one of the expatriates' challenges in the host country (Zainol et al., 2017). A study by Liu and Lee (2008) found that job satisfaction and organisation socialisation played an important part in expatriate adaptation while working abroad. Therefore, the socialisation process resulted by increasing social integration and role performance would eventually assist expatriates to adjust in the workplace (Malik & Manroop, 2017).

Another challenge that expatriates face is language barrier in the host country. A study by Ramlan et al. (2018) found language barriers and communication styles have shown significant impact on expatriates' working performance. Expatriates living in developing countries face challenges with language barriers or cultural barriers (Kim et al., 2018). Hence, expatriates face stress in the host country due to these barriers. According to Tenzer and Schuster (2017), language barrier among employees of multinational corporations triggers negative emotional responses.A study by Chen and Lin (2019) found that expatriates who are proficient in English have positive performance and need to make less work adjustment in the host country. While, Selmer (2006) stated that the ability to communicate was favourably correlated with socio-cultural adaptation. For example, although the standard of English proficiency is rising in China, using English in conversations with Chinese host nationals may be difficult (Selmer, 2006).

Cultural misinterpretation and low ability to communicate result in language barriers, this is a key factor influencing acculturation in the host nation (Huang et al., 2020). While, a study by Ai et al. (2019) found that expatriates realised the importance of English or local language communication skills in transnational business spaces. With the diverse backgrounds of employees, language barrier raises the complexity and misunderstanding in workplace (Omar, Sallehuddin & Hua, 2019).Since living in foreign countries, unfamiliar culture is one of the challenges faced by expatriates (Oh & Jang, 2020). This is due to the difference in workers' background in the organization. Professional expatriates need to address the challenges to complete an assignment abroad.

METHODOLOGY

This study explores the relationship between cross-cultural and work adaptation elements using qualitative content analysis and literature review. The literature was retrieved from various sources including article journals, thesis, websites and reports. The search string uses terms such as 'cross-cultural', 'work adaptation', 'professional', 'expatriates' and 'construction'. All relevant references are examined regarding the use of existing theories on definitions, concepts, methods, and approaches. This study had collected 67 articles from 1991 to 2021. It also identified the challenges of retaining Malaysian Professional expatriates. The paper explains in detail about the cross-cultural work adaptation elements.

The methodology of this paper involved the identification of cross-cultural work adaptation, identification of expatriates' challenges and conceptualisation of the dimension between work elements and expatriate's cross-cultural adaptation.The identification of cross-cultural work adaptation elements was based on the experience of expatriates abroad from different cultures. The three elements are socialisation, interaction/speaking and custom/culture. Identification of expatriates' challenges are related to their adaptation. References used were taken from previous studies done. Conceptualising a dimension between work elements and expatriate's cross-cultural adaptation. The findings from the previous study were analysed and summarized. A review was able to contribute to work adaptation dimension. The limitation of this study is due to limited information and it does not show the experience of Malaysian professionals in construction industry.

FINDINGS AND DISCUSSION

Numerous studies on the expatriate adaptation indicate that work elements influence the expatriates while experiencing the new environment abroad. The study shows three elements that influenced expatriates' work adaptation. Among the elements are socialization, interaction and speaking, and custom and culture. These would also affect expatriates' work performance.

Socialisation has been found to be of considerable significance with cross-cultural adaptation (Kaur, 2018). This is because socialisation is not only to develop work adaptation but also to enhance the psychological among expatriates (Lacaze & Bauer, 2014). Socialisation process by increasing social integration and role performance would eventually help expatriates adjust in the workplace (Malik & Manroop, 2017). Quality for socialization is important in providing expatriates with social support (Kang & Shen, 2018). Moreover, the socialisation process can provide cohesive, close networks of communication within

organisation, thus promote the success of relationship performance (Fu et al., 2016). The importance of socialisation is to reduce expatriate turnover. It is also important for work satisfaction, organization and daily life and seeking information in host country.

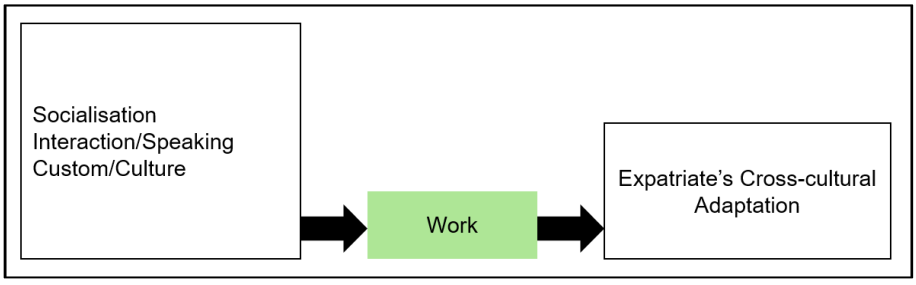

Figure 1. A dimension of Cross-Cultural Work Adaptation Elements

Interaction and speaking are also contributing factors for cross-cultural work adaptation. According to Zakariya et al. (2019), expatriates' performance was found positively significant in both interaction adaptation and work adaptation. In addition, interacting with the host country would influence expatriate work performance and contextual performance (Kraimer et al., 2001). This indicates interaction affects expatriate life during lifework and throughout being in the host country. Yeo and Pang (2017) revealed that expatriates face difficulties to interact, their adaptation would take a longer time, which in turn affects their job performance. In addition, expatriates need to interact with the environment to enable them to take positive actions and facilitate their local citizens' adaptations (Shay & Baack, 2006; Fisher et al., 2015). Making less interaction would be challenges to expatriate in host country. Interact during lifework does not involve a person but it involves many people in a multinational company.

Interaction with host nationals through communication is essential for expatriates. The ability to communicate effectively helps to connect with others and works well in the organisation. According Sit et al. (2017), expatriates feel stressed when speak in a foreign language while interacting or speaking in the host country. They prefer to use their own language that becomes the foundation of culture for a country. By having good communication skills with the local citizens, it shows that expatriates are trying to understand and adapt to the local culture This also gives a positive impact to lifework such as sharing knowledge. Frequent interaction could make an improvement in communication skills while being abroad (Martinsen, 2010). Thus, having good communication skills while being abroad will reduce the number of turnover among Malaysian professional expatriates.

Custom or culture are the elements contributing to cross-cultural work adaptation. According to Korzilius et al. (2017), living in a multicultural environment encourages an individual to adapt to the new culture easily. Although adapting to the new cultural values and religious beliefs are essential to expatriates, it does not mean that they forget the culture and custom of their origin country. To adapt in different cultural environments, individuals must be able to leave their comfort zones and engage in new circumstances (Templer, 2020). Customs and culture which are practised among Malaysians, are inevitable thus brought challenges to these expatriate adaptation (Tahir & Ismail, 2007). For example, Malaysian expatriates who adopt the custom and culture such as dress code, practice and norms in the host country, will feel comfortable living abroad.

Adaptation to the host country's culture is an adaptation to the cultural practice and the customs of the local citizens in the host country (Shin et al., 2007). This finding was also supported by Vance et al. (2016), that mentioned the expatriates' decision to remain there showed that they have successfully adapted to the host country environment and feel comfortable living there. Expatriates who successfully accept the custom and culture will feel good living abroad.Table 1 provides a clear understanding of the relationship between cross-cultural work adaptation elements and challenges for professional expatriates in facing new challenges during lifework. One of the issues regarding professional expatriates is the challenges adapting to a new environment.

Table 1. Relationship of Cross –Cultural Work Adaptation Elements and Challenges

Work Adaptation Elements	Expatriate Challenges	Cross-cultural Work Adaptation Elements to Retain Professional Expatriates
Socialisation	• Socialisation in organisation • Social support • Socialisation in language	Enhance psychological among expatriates, increased social integration and role performance, provide social support, provide cohesive and close networks.
Interaction/Speaking	• Language/communication barrier	Improvement in communication skills, Improve work performance, enable to take positive action.
Custom/Culture	Unfamiliar culture	Engage in new culture, understand and encourage to adapt in new culture.

Socialisation is one of the work adaptation elements that influences socialisation in an organisation, social support and language. Professional expatriates who are able to adapt to the challenges could enhance themselves psychologically, improve their social integration and performance, provide social support, and have a close network. Meanwhile, language and communication barriers are the challenges of interaction for the expatriates. If they can overcome these problems, they could improve their communication skills, work performance and enable them to take positive action. This is the result of their everyday interaction. The last work adaptation elements are custom and culture that influence the professional expatriates in an unfamiliar environment. Professional expatriates who can adapt to the challenges, engage and understand the new culture, may retain in the Malaysian company.

In summary, the focus of this study is to identify the elements of cross-cultural work adaptation and describe the expatriates' challenges in order to retain them. The findings are given to improve and assist the Malaysian government and related agencies in order to enhance professional expatriates in cross-cultural work adaptation in facing new challenges during lifework. However, due to limited information and experience of Malaysian professionals in construction industry, the number of professional Malaysian working abroad could not be determined.

CONCLUSION

The focus of this study is to identify the elements of cross-cultural work adaptation for Malaysian construction professional expatriates and highlight the challenges that they face in a host country. With the findings, the host company may be able to take necessary measures to retain them. Hence, the elements of work adaptation must be revealed to understand the real situation faced by these Malaysian professionals. If these professional expatriates are able to adapt, it will lead to a better adaptation and enhance their performance in the new

environment. Thus, these elements would help Malaysia provide a quality life, skill, and talent to prepare and propel towards vision 2020.

This is in line with the UN Sustainable Development Goals (SDG) No. 8 that promotes a sustain, inclusive and sustainable economic growth with full and productive employment. Thus, the policies would enhance productive capacities, productive employment and increase the productivity of human resources. As a result, the research findings contribute to retaining Malaysian brain drain in cross-cultural work adaptation in facing new challenges during lifework in construction industry abroad.Although these factors would assist in the construction industry, they can also be channels of information from employers to decision-makers, education and training providers, or individuals who are willing to invest in human capital. The cross-cultural work adaptation dimensions of this study could enhance the sustainability and well-being of Malaysian professional expatriates.

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REFERENCES

Ai, B., Cui, C., & Wang, L. (2019) "Language, Identity, and Transnational Communication: Chinese Business Expatriates in Africa,". IEEE Transactions on Professional Communication, 62(2):178-191.

Anderson & Chawana (2020) "Strategies to Retain Employees Within an Organization". Walden Dissertations and Doctoral Studies. 8436.

Andreeva, G. M. (2009) The Difficult Way of Social Psychology in Russia. Psychology in Russia: State of the Art:11-24.

Baghai, R., Silva, R., Thell, V. & Vig, V. (2016) Talent in Distressed Firms: Investigating the Labor Costs of Financial Distress. SSRN Electronic Journal:1-73.

Bahrollah, S. & Parol, S. (2018) Expatriates in India: The role of organisational and family support during international assignment. Mangalmay Journal of Management & Technology, 8(1):53-58.

Bayl-Smith, P. H. & Griffin, B. (2015) Measuring work styles: Towards an understanding of the dynamic components of the theory of work adjustment. Journal of Vocational Behavior, 90:132-144.

Brown, R. J. (2008) Dominant stressors on expatriate couples during international assignments. The International Journal of Human Resource Management, 19(6):1018-1034.

Chen, M. (2019) The Impact of Expatriates' Cross-Cultural Adjustment on Work Stress and Job Involvement in the High-Tech Industry. Frontiers in Psychology, 10(2228):1-10.

Chen, A. S. Y. & Lin, Y. C. (2019) Speak to your heart: The joint moderating effects of language proficiencies on cultural intelligence and expatriates' work performance. Corporate Management Review, 39(1):119-154.

Construction Industry Development Board (2021) CIDB International Project Database. Available from: http://international.cidb.gov.my/international/. [Accessed 10th January, 2021].

Construction Industry Development Board (2011) CIDB International Project Database. Available from: http://international.cidb.gov.my/international/. [Accessed 10th January, 2021].

Davies, S., Kraeh, A. & Froese, F. (2015) Burden or support? The influence of partner nationality on expatriate cross-cultural adjustment. Journal of Global Mobility: The Home of Expatriate Management Research, 3:169-182.

Davies, S. E., Stoermer, S. & Froese, F. J. (2019) When the going gets tough: the influence of expatriate resilience and perceived organisational inclusion climate on work adjustment and turnover intentions. The International Journal of Human Resource Management, 30(8):1393-1417.

Department of Statistics Malaysia (2018) Malaysia Statistical Handbook 2018. Available from https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=167&bul_id=SUNqdEtweXNJVVZSRFdEUnRHS29adz09&menu_id=WjJGK0Z5bTk1ZElVT09yUW1tRG41Zz09f.

Domingo, M. F. L. (2018) Exploring the Overseas Experience of Filipino Employees Working Abroad: A Qualitative Study on Cross Cultural Adjustment. The Reflective Practitioner, 2:64-90.

Feldman, D. C. & Bolino, M. C. (2011) The impact of on-site mentoring on expatriate socialization: a structural equation modelling approach. The International Journal of Human Resource Management, 10(1):54–71.

Fisher, K., Hutchings, K. & Pinto, L. H. (2015) Pioneers Across War Zones: The Lived Acculturation Experience of US Female Military Expatriates. International Journal of Intercultural Relations, 4:265-277.

Fu, C., Hsu, Y. S., Shaffer, M. A. & Ren, H. (2016) A longitudinal investigation of self-initiated expatriate organisational socialisation. Personnel Review Doherty, 46(2):182-204.

Halim, H., Bakar, H. A. & Mohamad, B. (2019) Expatriation in Malaysia: Predictors of Cross-Cultural Adjustment among Hotel Expatriates. International Journal of Supply Chain Management, 8(1):664-675.

Huang, H., Liu, H., Huang, X. & Ding, Y. (2020) Simulated home: an effective cross-cultural adjustment model for Chinese expatriates. Journal of Management Development, 36(9):1017-1042.

Kaur, R. B. (2018) Expatriatism and Cross Cultural Adjustment in Global Business World: A Case Study of Indian Expatriates in Japan. Research Review International Journal of Multidisciplinary, 3(12):1234-1238.

Kang, H. & Shen, J. (2018) Antecedents and consequences of host-country nationals' attitudes and behaviors toward expatriates: What we do and do not know. Human Resource Management Review, 28(2):164–175.

Kaye, M. & Taylor, W. (1997) "Expatriate culture shock in China: a study in the Beijing hotel industry". Journal of Managerial Psychology, 12(8):496-510.

Kim, H. Y., Kim, J. Y., Park, H. Y., et al. (2018) Health service utilisation, unmet healthcare needs, and the potential of telemedicine services among Korean expatriates. Globalisation and Health, 14(120):2-8.

Korzilius, H., Bucker, J. J. L. E. & Beerlage, S. (2017) Multiculturalism and innovative work behavior: The mediating role of cultural intelligence. International Journal of Intercultural Relations, 56:13–24.

Kraimer, M. L., Wayne, S. J. & Jaworski, R. A. A. (2001) Sources of Support and Expatriate Performance: The Mediating Role of Expatriate Adjustment. Personnel Psychology, 54(1):71–99.

Kuada, J. (2016) Global Mindsets: Exploration and Perspectives. New York:Routledge

Kumar, R., Budhwar, P., Patel, C. & Varma, A. (2018) Self-regulation and expatriate adjustment: The role of regulatory fit. Human Resource Management Review.

Lacaze, D. & Bauer, T. N. (2014) A positive motivational perspective on organisational socialisation. Rev. Interdiscip. Manag. Homme Entrep, 5:58–75.

Liang, W. L. T. (2014) Framing the Malaysian Brain Drain: A Comparison between the Reporting Styles of The Star Online vs Malaysiakini. The Journal of the South East Asia Research centre for Communications and Humanities, 6(1):97-121.

Liu, C. H. & Lee, H. W. (2008) A proposed model of expatriates in multinational corporations. Cross-Cultural Management: An International Journal, 15(2):176-193.

Malik, A. & Manroop, L. (2017) Recent immigrant newcomers' socialisation in the workplace Roles of organisational socialisation tactics and newcomer strategies. Equality, Diversity and Inclusion: An International Journal, 36(5):382-400.

Martinsen, R. A. (2010) Short-Term Study Abroad: Predicting Changes in Oral Skills. Foreign Language Annals, 43(3):504–530.

Mellahi, K., Frynas, G. J. & Collings, G. (2015) Performance Management Practices Within Emerging Market Multinational Enterprises: The Case of Brazilian Multinationals. The International Journal of Human Resource Management,1-30:876-905.

National Economic Action Council (2020) Malaysia Losing Skilled Talent. [Online] Available from: https://www.thestar.com.my/news/nation/2010/03/30/neac-malaysia-losing-skilled-talent. [Accessed 3rd January 2020].

Oh, S. Y. & Jang, K. (2020) "Self-initiated expatriate adjustment: South Korean workers in Vietnam". Career Development International, 26(1), 16-43

Omar, R., Sallehuddin, A. M. & Hua, T. K. (2019) Technology Transfer in Mass Rapid Transport (MRT) Project in Malaysia. MCRJ Special Issue, 8(3):163-176.

Peltokorpi, V. (2008) Cross-cultural adjustment of expatriates in Japan. The International Journal of Human Resource Management, 19(9):1588–1606.

Ramlan, S., Abashah, A., Samah, I., Rashid, I. & Radzi, W. (2018) The impact of language barrier and communication style in organisational culture on expatriate's working performance. Management Science Letters, 8(6):659-666.

Randstad Worldwide (2019) 90% of Malaysians would emigrate to improve career and work-life balance. Available from https://www.randstad.com.my/about-us/news/90-of-malaysians-would-emigrate-to-improve-career-and-work-life-balance/.

Rony, Islam, N., Suki, Mohd, N., Chowdhury & Amin, I. (2017) Examining Factors to Retain Human Talent in Oil and Gas Industry. Advanced Science Letters, 23(4): 2974-2977.

Sarpin, N., Ling, C. Y., Kasim, N., Noh, H. M., Omar, R. & Yahya, M. Y. (2019) Key Strategies in Embark on International Construction Project: Malaysian Contractors Perspective.,Malaysian Construction Research Journal, 8(3):94-106.

Shariff, N., Krishnaswamy, J., Abdullah, D. & Chau, A. W. (2018) The Influence of New Economic Model on Intention to Work Abroad: An Empirical Study to Address Brain Drain Issue in Malaysia. Journal of Sustainability Science and Management (Special Issue), 4:99-115.

Schuler, R. S., Jackson, S. E. & Tarique, I. (2011) Global talent management and global talent challenges: Strategic opportunities for IHRM. Journal of World Business, 46(4):506–516.

Selmer, J. (2006) Language ability and adjustment: Western expatriates in China. Thunderbird International Business Review, 48(3):347–368.

Selmer, J. (2007) Which Is Easier, Adjusting to a Similar or to a Dissimilar Culture? International Journal of Cross-Cultural Management, 7(2):185–201.

Shay, J. P. & Baack, S. (2006) An Empirical Investigation of the Relationships between Modes and Degree of Expatriate Adjustment and Multiple Measures of Performance. International Journal of Cross-Cultural Management, 6(3):275–294.

Shin, S. J., Morgeson, F. P. & Campion, M. A. (2007) What do you depends on where you are: Understanding how domestic and expatriate work requirements depend upon the cultural context. Journal of International Business Studies, 38(1):64-84.

Sit, A., Mak, A. S. & Neill, J. T. (2017) Does cross-cultural training in tertiary education enhance cross-cultural adjustment? A systematic review. International Journal of Intercultural Relations, 57:1–18.

Sterle, M. F., Vervoort, T. & Verhofstadt, L. L. (2018) Social Support, Adjustment, and Psychological Distress of Help-Seeking Expatriates. Journal of Belgian Association for Psychological Science, 58(1):297-317.

Tahir, A. H. M. & Ismail, M. (2007) Cross-Cultural Challenges and Adjustments of Expatriates: A Case Study in Malaysia. Turkish Journal of International Relations, 6(3&4):72-99.

Templer, K. J. (2020) "Self-enhancement and cross-cultural adjustment: overclaiming in a global mobility context". Journal of Global Mobility, 8(2):161-182.

Tenzer, H. & Schuster, T. (2017) Language Barriers in Different Forms of International Assignments. Expatriate Management: Bader B., Schuster T., Bader A. (eds) Expatriate Management. London: Palgrave Macmillan

The Star (2011) One million Malaysians Working Abroad. Available from: https://www.thestar.com.my/news/nation/2011/11/01/one-million-malaysians-working-abroad.

Vance, C.M., McNulty, Y., Paik, P. & D'Mello, J. (2016) "The expat-preneur: conceptualising a growing international career phenomenon,". Journal of Global Mobility, 4(2):202-224.

Vijayakumar, P. B. & Cunningham, C. J. L. (2016) Cross-cultural adjustment and expatriation motives among Indian expatriates. Journal of Global Mobility, 4(3):326-344.

Wang, C. (2010). Toward a Second Language Socialization Perspective: Issues in Study Abroad Research. Foreign Language Annals, 43(1):50–63.

Wanberg, C. R. (2012) Facilitating Organizational Socialization: An Introduction. New York:Oxford University Press, 17

World Bank Group (2019) Monitoring Occupational Shortages Lessons from Malaysia's Critical Occupations List. Social Protection and Jobs. Available from http://documents1.worldbank.org/curated/en/877271568138256 93/pdf/Monitoring-Occupational-Shortages-Lessons-from-MalaysiasCritical-Occupations-List.pdf.

Yeo, S. L. & Pang, A. (2017) Asian Multiculturalism in Communication: Impact of Culture in the Practice of Public Relations in Singapore. Public Relations Review, 43(1):112-122.

Zainol, H. (2011) Penyesuaian Eksekutif Ekspatriat Syarikat Pembinaan Malaysia Di Negara Tamu: Satu Analisis. Proceeding UiTM Sarawak Conference 2011: Academic Excellence Through Transformation and Innovation. Malaysia, 20-38.

Zainol, H., Isa, H. M. Alauddin, K. & Derus, M. M. (2017) The Contributing Factors of General Adjustment On Malaysian Expatriates in Construction Industry Overseas. Journal of Surveying, Construction and Property, 8(1):1-12.

Zakariya, N. H., Othman, A. K., Abdullah, Z. & Abdullah, S. S. (2019) The Relationship between Expatriate Adjustment and Expatriate Job Performance at Multinational Corporations in Malaysia. Academy of Entrepreneurship Journal, 25(2). 51-58.

Zhang, L. E., Harzing, A. W. & Fan, S. X. (2017) Conclusion: Expatriate Language and Identity Challenges and Recommendations for Expatriate Management. Managing Expatriates in China. 181-206.

Zhou, X. (2018) A Review of Researches Workplace Loneliness. Psychology, 9(5):1005-1022.

Zhou, K., Liu, T. & Zhou, L. (2015) Industry 4.0: Towards future industrial opportunities and challenges. 2015 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD). IEEE. Zhangjiajie, China.

ALTERNATIVE FOR SUSTAINABLE CONSTRUCTION MATERIALS: PHYSICAL PROPERTIES OF CONCRETE WITH RICE HUSK ASH (RHA) AS MINERAL ADMIXTURE AND CRUSHED CERAMIC TILES AS REPLACEMENT TO COARSE AGREGATES

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Abstract

Rice Husk Ash (RHA) is an agro-waste material that is produced in large amounts in Malaysia and contains high amorphous silica that can potentially improve the performance of the concrete. It is economical to be used in partial replacing, or as a mineral admixture in ordinary Portland cement. The waste from the ceramic tiles is also beneficial to be used in concrete as a coarse aggregate's replacement, primarily due to its hardness and durability. This study aims to investigate the effect of the physical properties of RHA as a mineral admixture for cement in concrete, and also the effect of the addition of crushed ceramic tiles (CCT). In this study, the RHA replaced 10% of the mass of cement as a mineral admixture, with various percentages of CCTs as coarse aggregates (0, 5, 10 and 15%). Workability, density and water absorption tests were conducted to investigate the physical properties of the concrete. The result from physical properties showed that 5 % is the optimum percentage for CCTs in concrete with 10% of RHA.

Keywords: *Rice husk ash; crushed ceramic tiles; concrete; aggregates.*

INTRODUCTION

Concrete is a composite substance that contains several elements such as cement, water, coarse aggregate and fine aggregate. Cement is a powder that has cementitious properties and a binding agent for the aggregates and water (Han et al., 2018). Recently, recycled material has been widely used in concrete, to overcome environmental problems. The recycled material is also beneficial when used in concrete, to provide a good management of waste disposal, instead of disposing of it. Most of the waste material has its own value, depending on how it is utilized. Rice Husk Ash (RHA) has been utilized in concrete as a mineral admixture in cement, primarily due to its pozzolanic properties. Nithyambigai (2005) stated that RHA is a pozzolanic material that contains 85% silica content. RHA was also added as a partial replacement of cementitious characteristics that enhances the strength of the concrete.

On the other hand, waste disposal such as ceramic tiles can be used as a coarse aggregate replacement in concrete. The production of the solid waste increases due to its high demand in the construction industry. The replacement of crushed ceramic tiles (CCT) is potentially applied as an aggregate replacement in large amounts. This concept can decrease the demand for natural aggregate such as riverbed stone or pulverized stone, which would be derived from the earth and transported for utilization in concrete (Anderson et al., 2016). Ceramic tile waste also contributes to industrial waste disposal solutions and helps to maintain the resources of

the aggregates (Osuji et al., 2018; Mat Don et al., 2009). Several research works focus on utilizing RHA and CCT in concrete. However, the majority of the works did not combine the utilization of RHA together with CCT in concrete. Dhrolwala et al. (2018) analyzed the mix design of concrete using ceramic waste and RHA by replacing ceramic tile as coarse aggregates and fine aggregates at certain percentages. They also produced several mix designs for concrete with RHA and ceramic waste, to investigate the mechanical properties of various mixed designs.

This research was conducted by partial replacement of CCT in concrete with RHA as a mineral admixture by mass of cement, to investigate the physical properties of concrete. The researchers also attempt to reduce environmental stresses to ensure sustainable construction by using cheap materials, but without reducing the performance of the concrete (Umapathy et al., 2015). In this research, concrete grade 25 was designed, and the RHA was replaced at 10% by mass of cement as a mineral admixture, with various percentages of CCT as coarse aggregate (0, 5, 10 and 15%). The number of 60 cubes and 30 beams sample were prepared to investigate the physical and mechanical properties of the concrete. However, the authors only discuss the physical properties of the concrete in this paper. The sample was cured in water for 7 and 28 days. The physical properties were examined by conducting workability, water absorption and density tests. The mechanical properties of compressive strength and flexural strength of the concrete will be discussed in other stages of the research.

METHODOLOGY

Materials

The materials used in this work are ordinary Portland cement (OPC), RHA, fine aggregates and coarse aggregates of CCT, and tap water. The grade of OPC used are 42.5 and the RHA was obtained from a rice mill. Re-combustion of RHA was performed using a furnace at 550 °C for 2 hours. RHA was used as mineral admixture at 10% by mass of the cement. The coarse aggregates with relative density of aggregate (SSD) according to JKR standards were used in this work, and the maximum aggregate size used was 20mm. The desired size of gravel was obtained by using a sieving machine in the laboratory. Similarly, CCT was crushed manually by hammer until the maximum size was 20mm. Then CCT were sieved in the sieving machine similarly as to aggregates. Broken and rejected ceramic tiles were collected from Acfirst Ceramic Sdn. Bhd, located in Jitra, Kedah.

Methodology

All materials were prepared and weighed carefully, according to the mix proportions designed with 0.54 water cement ratio. The concrete was mixed using a concrete mixer. The mass of each material for different percentages of CCT is shown in Table 1. Slump test was performed on the fresh concrete, once the concrete mixing was ready to be checked in terms of consistency and workability, before it was set by using a tamping rod, slump cone and steel plate. The slump cone was placed on the plate and was filled up with three layers of fresh concrete. Each layer was tamped with a standard 16mm diameter steel rod. The cone was held firmly at the base during the tamping procedure, which was performed 25 times. The last layer at the top of the cone was levelled using a trowel. Then the cone was lifted up carefully and placed beside the concrete to measure slump that occurred. The free concrete that had no

support was slumped and reduced in height. Measurement was taken from the center of the slumped concrete. The standard use for the slump test is based on BS 1881-102 (1983). The concrete was then placed in a mould, followed by compacting using a concrete vibrator. After 24 hours, the concrete was hardened, removed from mould and continued with the curing process for 7 and 28 days. The water absorption was carried out according to BS 1881-122 (1983), while the density test was carried out according to BS 1881-114 (1983). Meanwhile, the dimension for density test cube was fixed at 100mm x 100mm x 100mm which according to the size of the mould used.

Table 1. Mix Proportion for Each Mix

Mix Code	Cement (kg)	RHA		Water (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	CCT	
		%	Mass (kg)				%	Mass (kg)
C	4.56	0	0	2.46	10.08	11.82	0	0
CCT0	4.10	10	0.46	2.46	10.08	11.82	0	0
CCT5	4.10	10	0.46	2.46	10.08	11.17	5	0.59
CCT10	4.10	10	0.46	2.46	10.08	10.58	10	1.18
CCT15	4.10	10	0.46	2.46	10.08	8.26	15	1.76

RESULT

Workability

The workability of the concrete was determined by a slump test, to indicate whether the concrete was acceptable. The acceptable slump for concrete with 0.54 water cement ratio was 60mm to 80mm reduction in height. Figure 1 shows the slump values for the concrete at different CCT percentages. The slump value decreases as the percentage of the CCT increases. The highest slump can be seen in the control sample, while the lowest slump obtained by the sample occurred with 15% replacement of CCT. From the Figure 1, it shows that the slump of the fresh concrete decreases as the replacement of CCT increases. This is due to the RHA absorbing more water, causing the fresh concrete to become dryer. However, the difference was not explicitly shown by each of the samples. This result is also supported by Pitarch et al. (2017), who show that the slump of concrete with CCT replacement tends to decrease as the percentage increases.

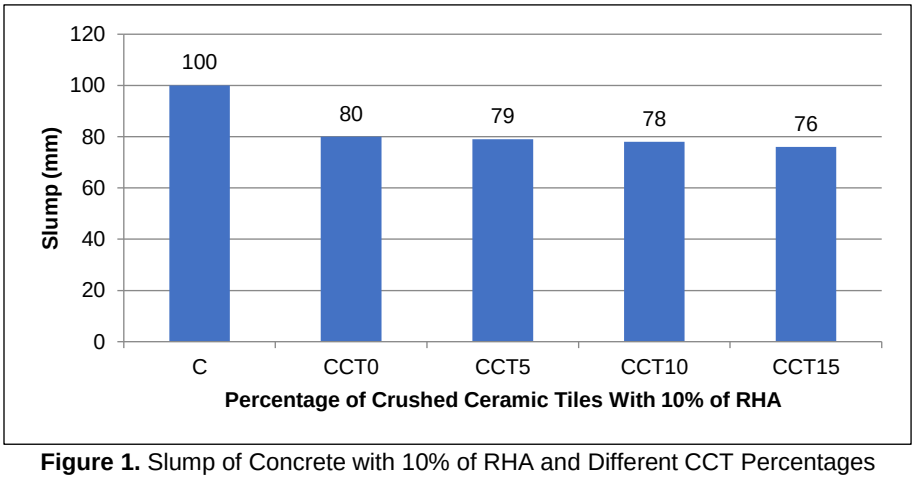

Figure 1. Slump of Concrete with 10% of RHA and Different CCT Percentages

Density

Density test was performed on the cube by recording its weight at room temperature. The sample was removed from the curing tank. The density test was carried out for an average of three samples. Figure 2 shows the results of the density for the concrete. The density drops after the replacement of 10% RHA with 0% CCT aggregates. The density of the concrete slowly decreases as the percentage of the CCT increases. This is because the density of the natural coarse aggregates is greater than the density of CCT. Other than that, the replacement of RHA also reduces the overall concrete weight. However, there is only a small difference in density between 0, 5, 10 and 15% of CCT replacement.

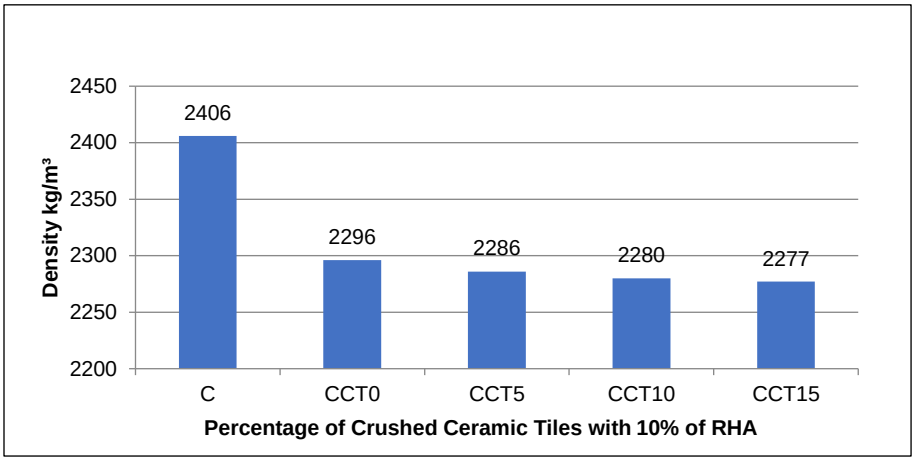

Figure 2. Density of Concrete with 10% of RHA and Different Percentage of CCT

According to Wadie et al. (2017), the density of the concrete with CCT without any replacement with other raw materials decreases as the percentage of CCT increases. Hence, there a slight difference in this work, since the RHA as a mineral admixture by 10% mass of cement was replaced. This has led to a decrease in the concrete weight, since the RHA (Specific Gravity: 1.55) is lighter than Portland cement (Specific Gravity: 2.99). This also because the distribution of the CCT in the concrete for each cube was not exactly the same, since the mix was performed in a large portion. Pitarch et al. (2017) mentioned that the density of concrete with partial replacement with ceramic tile waste as coarse aggregates decreases as the percentage replacement of CCT aggregates increases.

Water Absorption

A total of 30 cubes were tested for water absorption. The test was carried out after 7 and 28 days of curing. Figure 3 shows the results for the water absorption of concrete with 10% RHA and different CCT percentages. The percentage of water absorption increases at 10% RHA and 0% crushed ceramic tiles for 7 and 28 days of curing. This is correlated with the finding by Tutur and Noor (2018), who stated that as the percentage of RHA increases, the water absorption will also increased. However, after 5% replacement of crushed ceramic tile aggregates, the water absorption tends to decrease slowly for 7 and 28 days of curing. According to Prasad et al. (2016), the water absorption decreases when increasing the CCT aggregates in the concrete.

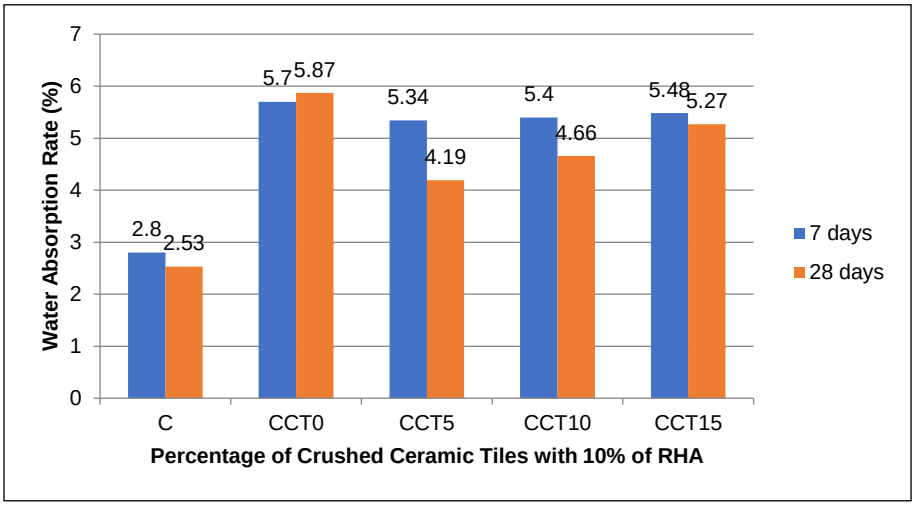

Figure 3. Rate of Water Absorption of Concrete with 10% of RHA and Different Percentage of CCT

However, the results in this work show that after the replacement of CCT increases, the water absorption increases. Prasad et al. (2016) found that when coarse aggregates and ceramic tiles as a fine aggregates replacement were considered, the results show that as the percentage of replacement for both fine and coarse aggregates increases, the water absorption increases at 7 and 28 days. In this work, a partial replacement of CCT in concrete with 10% RHA decreases the water absorption, compared to concrete with 10% RHA only, where the percentage of crushed ceramic tiles aggregates increases. The water absorption at 7 days of curing for 15% replacement of CCT is the highest. The reason behind this is due to the appearance of pores in the cube surface caused by vibration effects during the placement of the concrete.

In terms of water absorption, overall, it can be seen that concrete absorbs more water at the curing age of 7 days compared to 28 days, since the chemical reaction between RHA and the cement starts at 28 days, and the particle of the pozzolanic material of RHA fills the empty spaces in the concrete.

CONCLUSION

Overall, this study aims to investigate the effect of physical properties of RHA as mineral admixture with crushed ceramic tiles for cement. The optimum percentage of CCT in concrete with RHA were determined by conducting tests on the physical properties of the concrete. It can be concluded that the workability of the concrete from this research obviously showed that control sample is the best sample. However, in integrating for sustainable alternatives materials, additional of RHA is acceptable at the percentage of 10%. Meanwhile, additional of 5% of CCT replacement in the concrete showed the highest slump among the concrete samples that contained RHA with crushed ceramic tiles. Hence, optimum percentage for CCT as partial replacement of coarse aggregates in the concrete is said to be 5%. On the other hand, the density and water absorption of concrete also indicate that control sample is the best sample. But, in line with this research of incorporating sustainable construction materials, the optimum percentage of CCT is at 5%. The density result shows that 5% of CCT replacement providing a significant value of (2286kg/m^3) as compared to other concrete samples contained

RHA and CCTs. On top of that, the control sample also indicates the lowest water absorption whereas the best sample of 5% CCT and 10%RHA (CCT5) shows increasing of 5.34% and 4.19% of water absorption rate. Nevertheless, this sample was considered the best sample among the other RHA with CCT samples. Therefore, particularly for physical properties of RHA as mineral admixture and CCT as replacement to coarse aggregates, the optimal value of CCT was 5 %.

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REFERENCES

Anderson, D. J., Smith, S. T., & Au, F. T. K. (2016). Mechanical properties of concrete utilizing waste ceramic as coarse aggregate. Construction and Building Materials, 117, pp.20-28

BS 1881, Part 102, 1983, "Method for determination of slump".British Standard BS1881

BS 1881, Part 118, 1983, "Method for determination of flexural strength". British Standard BS1881

BS 1881, Part 119, 1983, "Method for determination of compressive strength using portions of beams broken in flexure (equivalent cube method)". British Standard BS1881

BS 1881, Part 122, 1983, "Method for determination of water absorption". British Standard BS1881

BS 1881, Part 144, 1983, "Methods for determination of density of hardened concrete". British Standard BS1881

Dhrolwala, M. F., Kanani, K., Patel, D., & Soni, D. (2018). Analysis of Mix Design of Concrete Using Ceramic Waste and Rice Husk Ash, 1, 381–373 retrieved from https://doi.org/10.29007/724m.

Han L.C., Amaludin A.E.,Amaludin H.Z.,Ladin M.A. Dullah,S (2018). Use of Quarry Dust as Sand Replacement in Structural Concrete: A Review. Malaysia Construction Research Journal Special Issue, Vol 5(3), 28-42

Mat Don. M., Abdullah. W.N.L.M., Abu Bakar. B. H., Mohd Zain., M. Z. (2009). Chemical and Mineralogical Studies of Concrete Based-Waste Materials from Demolition Sites. Malaysia Construction Research Journal, Vol 5(2), 2-9

Nithyambigai. G. (2015). Effect of Rice Husk Ash in Concrete as Cement and Fine Aggregate. International Journal of Engineering Research, V4(05), 934–936. https://doi.org/10.17577/ijertv4is050978

Pitarch, A. M., Reig, L., Tomás, A. E., & López, F. J. (2017). Effect of Tiles, Bricks and Ceramic Sanitary-Ware Recycled Aggregates on Structural Concrete Properties. Waste and Biomass Valorization, 0(0), 1–15. https://doi.org/10.1007/s12649-017-0154-0.

Prasad, N. N., Hanitha, P., & Anil, N. C. (2016). Partial Replacement of Coarse aggregate by Crushed Tiles and Fine aggregate by Granite Powder to improve the Concrete Properties, 13(6), 168–176. https://doi.org/10.9790/1684-130605168176.

Tutur, N., & Noor, R. N. H. R. M. (2018). The potential of rice husk ash (Rha) and coconut fiber (Cf) as partial replacement of cement. AIP Conference Proceedings, 2020(October 2018). https://doi.org/10.1063/1.5062687

Wadie, E. H., Sadek, E. F., & Wahab, M. M. A. (2017). The Use of Ceramic Tile Waste as Aggregate in Concrete. International Journal of Scientific & Engineering Research, 8(11), 1461–1468.

MACHINE LEARNING PREDICTIVE MODEL FOR GREEN BUILDING PRICE

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Abstract
In the era of Industrial Revolution 4.0 (IR 4.0), many issues in the industries can be solved with implementation artificial intelligence approaches, including machine learning model. Designing an effective machine learning model for prediction and classification problems is a continuous effort. In addition, time and expertise are important factors needed to adapt the model to specific problem such as green building housing development. However, there is a lacking in the implementation of machine learning model on green building valuation features for building price prediction. Hence, this paper provides an empirical study that shows building price prediction that are based on green building and other general determinants. This experiment used five common machine learning algorithms namely 1) Linear Regressor, 2) Decision Tree Regressor, 3) Random Forest Regressor, 4) Ridge Regressor and 5) Lasso Regressor that was tested on real estate data-set of Kuala Lumpur District, Malaysia. Three set of experiments were conducted based on the different feature selections and purposes. The result shows that the implementation of sixteen (16) variables based on Experiment 2 has given a promising effect on the model compared to the other experiment. The Random Forest Regressor by using the Split approach for training and validating data-set outperform other algorithms compared to Cross-Validation approach. The research will provide an appropriate model in predicting the price of a green building which is beneficial to the various government agencies and industries.

Keywords: *Machine learning model; algorithm; green building; property features.*

INTRODUCTION

The green building can be defined as the approach that enhances the efficiency performance of the building and sites using energy, water and natural materials.It can reduce the negative impact on human, the environment and health by improving the operation of a system, maintenance, design of a building, the construction and relocation of a longer building life cycle (MGBC, 2019; Ojo-Fafore et al., 2018; Uparwat et al., 2012; TH Jasimin & RC Amat, 2015).

In the real estate industry, there are several "conventional methods" in valuation, which are commonly used to determine property value. As in the case of determining the value, it can be referred to as the most probable price reasonably obtainable in the market on the date of valuation in keeping with the Market Value definition. These methods are comparison method, investment method, residual method, profit method, cost method and Discounted Cash Flow (DCF) (Malaysian Valuation Standard, 2019) . However, all of these methods have their own limitations to different types of property categories (Pagourtzi et al., 2003; Pitts & O.Jackson, 2008). To highlight, evidence from several cohort studies suggests that there is no definitive evidence for the latest and most appropriate evaluation method for the green building (Del Giudice & De Paola, 2016; W. Lee et al., 2018; Mattia et al., 2018; Nejad et al., 2017; Pagourtzi et al., 2003) although conventional methods may apply. Therefore, it is

important for the author to find a more reliable method of predicting prices for green building. Along with that, new methods and techniques have been discovered such as the machine learning models.

However, despite the rapid use of machine learning in building property price predicting and valuation, there is no direct study that investigates the price of green building based on machine learning model. To our knowledge, previous reports related to property valuation have been conducted on many aspects of prediction without green building elements such as as conventional building (Borde et al., 2017; Ma et al., 2018; Shinde and Gawande, 2018; Valle, 2016), property pricing appraisal research (Chaphalkar and Sandbhor, 2013; Núñez Tabales et al., 2013; Rahman et al., 2019), real estate price prediction cases (J.-H. Chen et al., 2017; Lin & Chen, 2011; Mu et al., 2014), price prediction of apartment (Čeh et al., 2018; Oladunni and Sharma, 2017), land appraisal under Geographic Information System (Yalpir & Unel, 2017), energy consumption of commercial building based on gradient boosting model (Touzani et al., 2018).Given this situation, machine learning is a model that is so promising in solving this kind of problem and has been proven effective in various predictions and classification problems (Kaytan & Aydilek, 2017). However, the accuracy of the results produced by the model is highly dependent on many factors including the algorithms, hyper-parameters tuning and different group of features selection.

Therefore, this paper aims to report the design and implementation of machine learning model based on the auto hyper-parameters tuning and different feature selection groups. The study focuses on predictive matter because to the author intend to predict the prices of green building. The structure of this paper is as follows. Part II focuses on the research background related to machine learning in real estate and potential use. Part III describes the research methodology followed by a discussion of the result in Part IV. The closing remarks are written in the last part.

RESEARCH BACKGROUND

Machine Learning in Real Estate Valuation

Machine Learning Model has been used in other disciplines such as business, computer engineering, industrial engineering, bioinformatics, medical, pharmaceuticals, physicals, and statistics to gather knowledge and predict future events (Singh et al., 2007). With the recent growth in the real estate market, Machine Learning plays an important role to predict the price of a property. However, few researchers have experimented on the selling price for real estate properties using Machine Learning (Borde et al., 2017; Shinde & Gawande, 2018). However, none of the studies reported the use of this method in condominium green building studies.

The Machine Learning Model which are commonly used in real estate studies in predicting the real estate price are Linear Regression (Borde et al., 2017; Dimopoulos et al., 2018; Wezel & Potharst, 2005), Decision Tree (Baldominos et al., 2018; Ma et al., 2018; Shinde & Gawande, 2018; Wezel & Potharst, 2005), Random Forest (Borde et al., 2017; W. Lee et al., 2018; Valle, 2016), Ridge Regression (Xin & Khalid, 2018) and Lasso Regression (Lu et al., 2017; Shinde & Gawande, 2018), Support Vector Machine, Neural Network (Borde et al., 2017; Dimopoulos et al., 2018; Xin & Khalid, 2018). The basic function of all these algorithms is to accurately predict the price of real estate data-set.

Potential Use of Machine Learning Model in Real Estate Market

Accurate evaluation of property price is crucial for real estate, the stock market, tax sector, the economy and the power of purchasers (Pagourtzi et al., 2003). The conventional method is limited to the scope of current systems data that needs to be considered. Normally, predicting a property price is often done through basic comparative market analysis of similar real estate in the same area to provide an approximate price for a particular property (Kummerow, 2003). However, in green building context, the other features that can contribute or give positive impact or added values to the green building price should also be considered to produce an accurate result in the price and to reflect the current market value (Abdullah & Mohd, 2018). This will only happen if the valuer considers other features that influence the green building price.

Machine learning model is seen to have the potential in considering those features and problems. By considering the others features in predicting the price of green building using machine learning model, the price produced will be more accurate and is reflective of the current market value. Predicting the accurate price of green property within certain areas might be able to help the country, government, owner of the property in decision making, such as maintenance purpose, preservation giving a huge benefit for investors and property developers as or simply giving the ownera better price.

METHODOLOGY

Dataset

The dataset used in the study is a collection of residential green building prices in 2018 for condominium property type with seventeen features from Valuation and Property Department (JPPH). Table 1 shows a set of features to develop the machine learning model with Transaction Price as the Dependent Variable.

Table 1. Features in the Dataset

Features	Description
Transaction Price	Dispose price/sqf (RM)
Date of Transaction	Building Transaction/Months
MFA	Main Floor Area
Lot area	Lot area
Tenure	Freehold/Leasehold
Type of Property	Residential/Commercial
No of bedroom	Number of bedrooms
Level Property	Level Property Unit
Floor	Building Floor
Building Façade	City/Park/Lake/Klcc
Age of Building	Age of Building
Distance	Distance to Central Business District
Accessibility	Ease of accessibility
Mukim	Mukim
Certificate	Green Certificate
Density	Population Density
Security	Security of Building
Infrastructure	Infrastructure Development

Features Selection

Features are the variables used for the machine learning Model. Feature selection is the identification of which variables to use as Independent Variable (IV) for the model. The author has reported that the performances of machine learning can be influenced by the features of the model (Abuzneid et al., 2018; Langley, 1994) One of the basic techniques for features selection refers to the correlation among the variables of the IVs (Hall, 1999). In this research different feature selections were executed in different set of experiments based on the purposes as illustrated in Figure 1 below. The identification that the security building features is the most influential in determining the price of green building was based on the results of correlation and Multiple Linear Regression model in the SPSS Software.

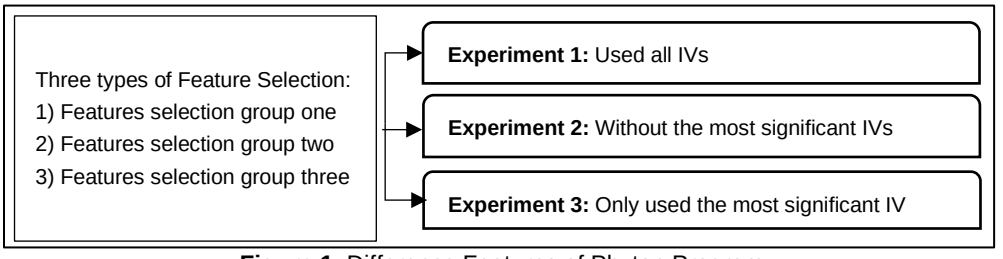

Figure 1. Difference Features of Phyton Program

As for example, Figure 2 shows the features (TransactionPrice) that were not used for the features can be dropped in Machine learning. Figure 2 shows the features selection for Experiment 1.

```
1. X_train=training.drop(["TransactionPrice"], axis=1.values.
2. Y_train= training(["TransactionPrice'].values
3. X_test=testing..values.
4. Y_test=testingprice["TransactionPrice"].values.
```

Figure 2. Used All IV

Machine Learning Algorithms with Auto-Hyper Parameter Tuning

This research used Python Sklearn Library and one of the advantages of using the this library is that it has the function of Auto Hyper-Parameters Tuning. This function will help the author to get the most optimal Hyper-Parameters setting through the process that is known as parameters optimization. Before validating the prediction result through five common algorithms that were used in this study namely Linear Regressor, Random Forest Regressor, Decision Tree Regressor, Ridge and Lasso, a suitable parameter configuration is identified first based on the training data-set by calling the *"best_estimator" approach*. This approach is provided in the Phyton Sklearn library to conduct the grid search optimization of hyper-parameter tuning on the given Machine learning algorithms. This is a useful way for unexpected data scientists to obtain parameter configuration suggestions for a model. To summarize, below are the steps of implementing the auto Hyper-Parameters tuning:

1. Call the Regressor algorithm.
2. Create dictionary and define parameters for the algorithm with the corresponding set of values.
3. Call the grid search method by passing the created dictionary. Grid search is the model for auto hyper-parameters optimization used in the Sklearn auto approximation.
4. Do preliminary training for the algorithm with the grid search instance and get the parameters estimator.
5. Set the algorithm with the suggested parameters and conduct another fitness with the parameters.
6. Perform another training with the suggested parameters.
7. Validate the prediction value produced by the algorithm and get the score.

Training and Validation Set

It is a common practise to split the training dataset with the validation dataset. In this study, the separation has been aligned to 70:30 ratio of training and validation sets by using two training approaches which is Split and Cross-Validation. Figure 3 show technique splitting approach for this study.

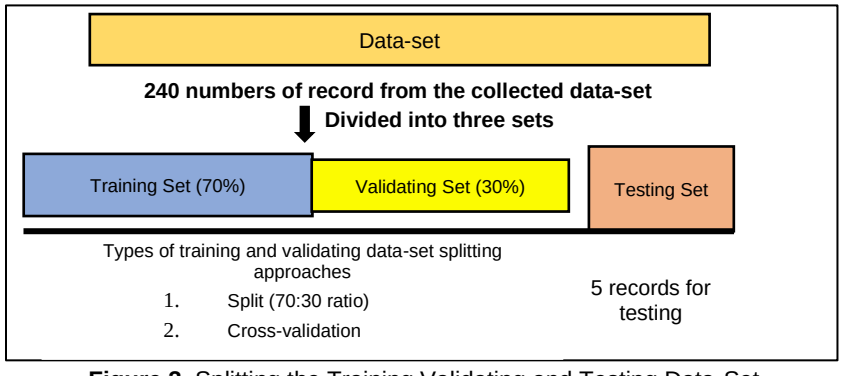

Figure 3. Splitting the Training Validating and Testing Data-Set

Futhermore, the experiment codes were developed with Pyhton 3.6 Jupyter Notebook platform and implemented in the processor of Intel i7 7th Generation processor, 16 GB RAM. Each model was run for five times of experiments and the average results of metrics were calculated for comparison. The metrics to present the performances of Machine learning algorithms are R squared (R^) and root mean squared error (RMSE). The R^ can explain how well the selected features in predicting the dependent variable while RMSE represents the sample standard deviation difference between the predicted and real values. The range of values for R^ is between 0.1 with higher is better. Meanwhile, RMSE with lower value shows lower errors or differences in the prediction results.

RESULT

The results are presented in different tables according to the three groups of features selection namely Used all IVs, without the security building features and only used the security building features. The average results from the five times experiments of each machine learning model were calculated and recorded. The results of R^2 and RMSE for

features selection Group One that has considered all the 17 variables for the Machine learning algorithms are depicted according to the two training approaches as seen in Table 2.

Table 2. Accuracy Results of the Five Machine Learning Algorithms with Features Selection Group One

No.	Algorithm	Split		Cross-Validation	
		R^2	RMSE	R^2	RMSE
1	Random Forest Regressor	0.962	393892.1	0.663	1010579.0
2	Decision Tree Regressor	0.894	664294.1	0.721	918429.4
3	Linear Regressor	0.885	504882.2	0.480	1254698.0
4	Ridge Regressor	0.796	921761.2	0.445	1296588.0
5	Lasso Regressor	0.781	954258.9	0.413	1332991.0

All five algorithms generated better results with the split training approach and the outperform algorithm is Random Forest Regressor. This can be presented by the highest R^2 value 0.962 of the model, which implies the relationship between all the 17 features and the target price that can be accounted by the Random Forest Regressor with 96% of the variation. Additionally, the model of Random Forest Regressor with Split training approach has achieved the best accuracy result with the lowest error value presented by the RMSE (393892). This is followed by Decision Tree Regressor as the second-highest model. The third highest coefficient of R^2 is 0.885 under Linear Regressor. Meanwhile, Ridge Regressor has the second lowest of R^2 value 0.796 with the highest of RMSE 921761.2. Finally, Lasso Regressor has the lowest R^2 value and the highest RMSE.

The following Table 3 presents Features selection Group Two that takes into consideration all 16 variables to develop the Machine learning Regressor Models. The 16 variables were not inclusive of the variable namely security of building.

Table 3. Accuracy Result of the Five Machine Learning Algorithm with Features Selection Group Two

No.	Algorithm	Split		Cross-Validation	
		R^2	RMSE	R^2	RMSE
1	Random Forest Regressor	0.963	389249.3	0.629	1059404.0
2	Decision Tree Regressor	0.905	627070.4	0.363	1389184.0
3	Linear Regressor	0.848	580528.2	0.317	1438139.0
4	Ridge	0.731	1058462.0	0.307	1448546.0
5	Lasso	0.715	1090277.0	0.255	1502699.0

Similarly, Random Forest Regressor algorithm with Split approach for training and validating data-set outperformed other models compared to Cross-Validation approach. However, the R^2 and RMSE values for Random Forest Regressor are slightly better than the value in Table 2. Meanwhile, the performance of Decision Tree Regressor increased when it was only dependent on the features without the security of building. Furthermore, not much difference could be seen from the other model. Lastly Table 4 list the result of Features selection Group Three which only considered one variable, which is the security of building.

The implementation of the only security of building features into the model do not show a significant increase in each of the test models. All results are lesser than the results obtained from the experiment of Group One and Group Two. In view of that, this experiment from Group Three will not be compared for testing the prediction prices of Green Building for condominium property type.

Table 4. Accuracy of Result from the Five Machine Learning Algorithms with Features Selection Group Three

No.	Algorithm	Split		Cross-Validation	
		R^2	RMSE	R^2	RMSE
1	Random Forest Regressor	0.215	1808990.0	0.084	1666258.0
2	Decision Tree Regressor	0.242	1777426.0	0.107	1644604.0
3	Linear Regressor	0.076	1434889.0	0.107	1644604.0
4	Ridge	0.237	1783934.0	0.108	1643834.0
5	Lasso	0.242	1777430.0	0.107	1644604.0

CONCLUSION

Within the scope of this research, the implementation of 16 variables that can increase the price of green building based on (Experiment 2), showed that green building condominium prices produce higher value without the use of security building features compared to (Experiment 1) with 17 variables. This can be determined by the R^2 result by looking at the difference between R^2 of Experiment 1 and Experiment 2. Moreover, the worst results of all algorithms produced by the model with single security of building features. It can be concluded that the security of building features does not significantly affect the model performances. Hiwever, the result of Multiple Linear Regression Model states that security of building is a major feature that affects green building price. Futhermore, among the five selected Machine learning algorithms, it is decided Random Forests Regressor algorithms be chosen as it presents the best performance by using the Split approach for training and validating data-set. However, the finding is limited to the tested dataset and therefore requires further investigationsfor different perspectives of Green Building in future work.

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REFERENCES

Abdullah, L., & Mohd, T. (2018). Green Building Valuation ; From a Valuers ' Perspective. *Advances in Civil Engineering and Science Technology*, *October*, 3–9. https://doi.org/10.1063/1.5062690

Abuzneid, A., Faezipour, M., Abdulhammed, R., AbuMallouh, A., & Musafer, H. (2018). Effective Features Selection and Machine Learning Classifiers for Improved Wireless Intrusion Detection. *International Symposium on Networks, Computers and Communications (ISNCC)*, 1–6. https://scholarworks.bridgeport.edu/xmlui/handle/123456789/4134

Baldominos, A., Blanco, I., Moreno, A., Iturrarte, R., Bernárdez, Ó., & Afonso, C. (2018). Identifying Real Estate Opportunities Using Machine Learning. *Applied Sciences*, *8*(11), 2–24. https://doi.org/10.3390/app8112321

Borde, S., Rane, A., Shende, G., & Shetty, S. (2017). Real Estate Investment Advising Using Machine Learning. *International Research Journal of Engineering and Technology (IRJET)*, *4*(March), 1821–1825.

Čeh, M., Kilibarda, M., Lisec, A., & Bajat, B. (2018). Estimating the Performance of Random Forest versus Multiple Regression for Predicting Prices of the Apartments. *ISPRS International Journal of Geo-Information*, *7*(5), 1–12. https://doi.org/10.3390/ijgi7050168

Chaphalkar, N. B., & Sandbhor, S. (2013). Use of Artificial Intelligence in Real Property Valuation. *International Journal of Engineering and Technology (IJET)*, *5*(3), 2334–2337.

Chen, J.-H., Ong, C. F., Zheng, L., & Hsu, S.-C. (2017). Forecasting Spatial Dynamics of the Housing Market using Support Vector Machine. *International Journal of Strategic Property Management*, *21*(3), 273–283. https://doi.org/10.3846/1648715x.2016.1259190

Del Giudice, V., & De Paola, P. (2016). The Contingent Valuation Method for Evaluating Historical and Cultural Ruined Properties. *Procedia - Social and Behavioral Sciences*, *223*, 595–600. https://doi.org/10.1016/j.sbspro.2016.05.360

Dimopoulos, T., Tyralis, H., Bakas, N. P., & Hadjimitsis, D. (2018). Accuracy Measurement of Random Forests and Linear Regression for Mass Appraisal Models that Estimate the Prices of Residential Apartments in Nicosia , Cyprus. *The Creative Commons Attribution 4.0 License*, *November*, 1–6. https://doi.org/10.5194/adgeo-1-1-2018

Hall, M. A. (1999). Correlation-Based Feature Selection for Machine Learning. *The University of Waikato, NewZealand*, 1–147.

Kaytan, M., & Aydilek, I. B. (2017). A Review on Machine Learning Algorithms, Task and Application. *International Journal of Advanced Research in Computer Engineering & Technology*, *October*, 1548–1551. https://doi.org/10.1109/idap.2017.8090257

Kummerow, M. (2003). Theory for Real Estate Valuation : An Alternative Way to Teach Real Estate Price Estimation Methods. *Land Economy and Valuation, Curtin University, Perth*, 1–29. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.123.12&rep=rep1&type=pdf

Langley, P. (Institute for the S. of L. and E. (1994). Selection of Relevant Features in Machine Learning. *In Proceedings of the AAAI Fall Symposium on Relevance*, *184*, 245–271. https://doi.org/10.1.1.43.4648

Lee, W., Kim, N., Choi, Y., Kim, Y. S., & Lee, B. (2018). Machine Learning based Prediction of the Value of Buildings. *KSII Transactions on Internet and Information Systems*, *12*(8), 3966–3991.

Lin, H. Y. U., & Chen, K. (2011). Predicting Price of Taiwan Real Estates By Neural Networks and Support Vector Regression. *Recent Researches in System Science*, *July*, 220–225. http://www.wseas.us/e-library/conferences/2011/Corfu/SYSTEMS/SYSTEMS-34.pdf

Lu, S., Li, Z., Qin, Z., Yang, X., Siow, R., & Goh, M. (2017). A Hybrid Regression Technique for House Prices Prediction. *Conference Paper: Institute of High Performance Computing (IHPC)*, *August 2018*, 1–5. https://doi.org/10.1109/IEEM.2017.8289904

Ma, Y., Zhang, Z., Ihler, A., & Pan, B. (2018). Estimating Warehouse Rental Price using Machine Learning Techniques. *International Journal Of Computers Communications & Control ISSN*, *13*(April), 235–250.

Malaysian Valuation Standard. (2019). Board of Valuer, Appraisers, Estate Agent & Property Managers. In *Malaysian Valuation Standards: Vol. Sixth edit*.

Mattia, S., Oppio, A., & Pandolfi, A. (2018). Contingent Valuation Method and Market Value : Applying Stated Preference Methods in Real Estate Market. *Building Environment Science & Technology*, *October*, 1–15.

MGBC. (2019). *Malaysia Green Building Council*. Retrieved From. https://new.greenbuildingindex.org/how/system

Mu, J., Wu, F., & Zhang, A. (2014). Housing Value Forecasting Based on Machine Learning Methods. *Hindawi Publishing Corporation*, *2014*, 1–8. https://doi.org/10.1155/2014/648047

Nejad, M. Z., Lu, J., & Behbood, V. (2017). Applying Dynamic Bayesian Tree in Property Sales Price Estimation. *2017 12th International Conference on Intelligent Systems and Knowledge Engineering (ISKE)*, 1–5. https://doi.org/10.1109/iske.2017.8258810

Núñez Tabales, J. M., Caridad Y Ocerin, J. M., & Rey Carmona, F. J. (2013). Artificial Neural Networks for Predicting Real Estate Prices. *Revista de Metodos Cuantitativos Para La Economia y La Empresa*, *15*(1), 29–44. http;//www.ipo.es/RevMetCuant/art.php?id=67

Ojo-Fafore, E., Aigbavboa, C., & Remaru, P. (2018). Benefits of Green Buildings. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, *2018-March*(March), 2289–2297.

Oladunni, T., & Sharma, S. (2017). Hedonic Housing Theory - A Machine Learning Investigation. *Proceedings - 2016 15th IEEE International Conference on Machine Learning and Applications, ICMLA 2016*, 522–527. https://doi.org/10.1109/ICMLA.2016.103

Pagourtzi, E., Assimakopoulos, V., Hatzichristos, T., & French, N. (2003). Real Estate Appraisal: A Review of Valuation Methods. *Journal of Property Investment & Finance*, *21*(4), 383–401. https://doi.org/10.1108/14635780310483656

Pitts, J., & O.Jackson, T. (2008). Green Buildings: Valuation Issues and Perspectives. *The Appraisal Journal, Spring 2008*, 115–118.

Rahman, S. N. A., Maimun, N. H. A., Najib, M., Razali, M., & Ismail, S. (2019). The Artificial Neural Network Model (ANN) for Malaysian Housing Market Analysis. *Planning Malaysia Department*, *17*(1), 1–9. https://doi.org/10.21837/pmjournal.v17.i9.581

Shinde, N., & Gawande, K. (2018). Valuation of House Prices Using Predictive Techniques. *International Journal of Advances in Electronics and Computer Science, ISSN:2393-2835*, *Volume-5*,(6), 34–40.

Singh, Y., Bhatia, P., & Sangwan, O. (2007). A Review of Studies on Machine Learning Techniques. *International Journal of Computer Science and Security*, *1*(1), 70–71.

TH Jasimin., RC Amat. (2015). Modelling The Relationship Between IEQ Towards Economic Aspect of Sustainability for Malaysian Green Commercial Office Building Using Structural Equation Modelling Technique. *Malaysia Construction Research Journal (MCRJ)*, vol.6/No.1/2019.

Touzani, S., Granderson, J., & Fernandes, S. (2018). Gradient Boosting Machine for Modeling the Energy Consumption of Commercial Buildings. *Energy and Buildings Conference Paper, 158*, 1533–1543. https://doi.org/10.1016/j.enbuild.2017.11.039

Uparwat, A. A., Gawatre, D. W., & Shahezad, M. (2012). Advantages of Green Building. *International Journal of Scientific Research*, *2*(4), 68–70. https://doi.org/10.15373/22778179/apr2013/56

Valle, M. A. (2016a). Property Valuation using Machine Learning Algorithms : A Study in a Metropolitan-Area of Chile. *International Conference on Modelling and Simulation Santiago de Chile (Chile), May 2017*, 1–133.

Valle, M. A. (2016b). Property Valuation using Machine Learning Algorithms : A Study in Metropolitan Area of Chile. *Selection at the AMSE Conference Santiago/Chile*, *January*, 97–103.

Wezel, M. Van, & Potharst, R. (2005). Boosting the Accuracy of Hedonic Pricing Models. *Econometric Institute Report EI 2005-50*, *2*(December), 1–18.

Xin, S. J., & Khalid, K. (2018). Modelling House Price Using Ridge Regression and Lasso Regression. *International Journal of Engineering & Technology*, *7*, 498–501.

Yalpir, S., & Unel, F. B. (2017). Use of Spatial Analysis Methods in Land Appraisal ; Konya Example. *5th International Symposium on Innovative Technologies in Engineering and Science*, *2017*(September), 1574–1582.

SEM-PLS ANALYSIS ON THE ASSOCIATION BETWEEN THERMAL COMFORT AND VISITORS' SATISFACTION IN SHOPPING COMPLEXES

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Abstract
This research aims to examine the association between thermal comfort and visitors' satisfaction in shopping complexes. The survey was conducted in selected shopping complexes located in Penang, Malaysia. This research employed a questionnaire survey, administrated to 176 visitors in the selected buildings. Respondents were asked to indicate their preferences based on a five-point Likert scale of agreement and satisfaction. This research used PLS-SEM: SMART PLS Version 3.2 to analyse the questionnaire's reliability and validity. Results indicated a significant relationship between thermal comfort and visitors' satisfaction in shopping complexes, especially concerning air movement in the building. The results also highlighted the importance of thermal comfort conditions for visitors' satisfaction in hot and humid climate shopping complexes.

Keywords: *Satisfaction; shopping complexes; thermal comfort; visitors.*

INTRODUCTION

The comfortable feeling in the built environment is slightly hard to achieve. The term "comfort" means satisfaction of some degree, so it addresses psychological satisfaction as much as physiological satisfaction. Thermal comfort is the subjective state of mind satisfaction with the thermal environment and is assessed subjectively (ASHRAE, 2017). Providing a comfort zone to make everyone satisfied, which depends on human psychology variations, changing from one person to another, can be quite a challenge considering that analysing human comfort is also rather difficult (Singh et al., 2016; Attia & Carlucci, 2015; Rudge & Gilchrist,2007; Auliciems, 1981). Consequently, it is one of the main issues that need to be focused on by architects frequently. Despite focusing on buildings' aesthetic aspect, a comfort zone should be provided by enlarging indoor air quality, light intensity, acoustic balance, and hygiene, which is essential for creating a conducive comfort zone. Suppose all of the aspects of designing an interior building environment fulfilling thermal comfort are achieved. Hence, to increase the awareness and standard of living, aspects such as environmental quality and thermal comfort have gained importance in the construction industry. Both indoor environmental quality and thermal comfort directly affect the occupants' health, productivity and space utilisation (Kamaruzzaman et al., 2017 & Crump, 2011). Therefore, thermal comfort has been regarded as one of the most crucial aspects of indoor environmental quality. Thus, this research paper aims to identify the relationship between thermal comfort variables and occupants' satisfaction in shopping complexes, thus determining the main thermal comfort factors positively influencing occupants' satisfaction.

LITERATURE REVIEW

Generally, environmental conditions affect the comfort of people. It refers to a situation in which people feel comfort visually, thermally, auditorily, physically, emotionally, and psychologically (ASHRAE, 2017). Sunlight is precisely one of the deciding factors influencing people's comfort, allowing people to interpret their environment (Najafabadi, 2013). Typically, thermal comfort is connected to a person's condition, communicating comfort or discomfort in the climatic conditions (Esther & Sagada, 2014). Thermal comfort can also be defined as the state of mind, expressing satisfaction and thermal environment. People have strived for centuries to create a thermally comfortable environment not just in shopping complexes but also in almost every enclosed building in existence. Thermal comfort can also be defined as a condition that individual reprocesses, involving many inputs influenced by physical, physiological, and other factors. However, the buildings' diversified space creates a different thermal environment and thermal comfort to the fully occupied areas. Hou (2016) indicated that the indoor climate has a critical effect on people and their health and competitiveness, resulting in people staying indoors more nowadays. Consequently, accomplishing the excellent quality indoor environment is a prevailing challenge of structural development in architecture. The individual's characteristics, including attitude, culture, institution, and sociological relationships, affect thermal comfort. Thermal comfort is not a state condition, as concurred by Hou (2016) and Najafabadi (2013). It is a state of mind that impact people's health and performance and involves many physical and physiological influences concerning what they feel. Hence, as stated in previous research by Mydin (2017) thermal comfort generally comprises of the following elements:

Indoor Air Temperature (Dry Bulb)

The air temperature is clearly reflected the thermal condition of the space however the thermal comfort condition is also affected strongly by relative humidity and air movement, with least air humidity. Therefore, Esther and Sagada (2014) stated that the temperature and relative humidity are the two local climatic factors that affect indoor comfort while building envelop, orientation, shading, glazing type and size, vegetation, thermal mass are the design dependent parameters that contribute to the thermal comfort in the buildings.

Mean Radiant Temperature

Enescu (2017) states that, the mean radiant temperature is the changes of the temperature with the same amount of thermal radiation with a human and the surroundings of the human.

Relative Humidity

The relative humidity is the ratio between the measured (actual) water vapour pressure in the air and the maximum quantity of water vapour pressure contained by the air at a known temperature. In indoor buildings, the main variable used to ensure thermal comfort is the internal air temperature and relative humidity. The relative humidity suggested by different organisational ranges concerning thermal comfort for humans is between 30–60%, if the relative humidity higher than 70%, it will affect thermal discomfort for humans (Enescu, 2017). In addition, according to Enescu (2017), the relative humidity effect is considered to affect thermal comfort, perception of indoor air quality, health of the occupants and energy

consumption. It has a big influence on the heat balance for the human body at high metabolic rates in hot environment conditions.

Air Velocity

Velocity is a measure of the scatter of the instantaneous air velocity around the mean air velocity in a frequency distribution, defined as the square root of the arithmetic average of a set of square values of the difference between the instantaneous air velocity and the mean air velocity. The standard deviation is based on individual values of air speed that represent an average over no more than two seconds each. Suitable air flow can help to maintain people's thermal comfort in warm seasons during long-term stay in indoor environment. The cooling effect of air flow can raise the indoor set temperature to a certain degree, therefore effectively reduce a building's energy consumption.

Hence, shopping complexes nowadays have gone beyond their initial role as centres of purchasing goods to becoming centres for social and recreational activities. Kusumowidagdo, Sachari, and Widodo (2016) stated that the development of shopping complexes or malls first began in the U.S in 1950. At that moment, the number of shopping complexes offering services for leisure activities and transactional had grown in Western countries. The shopping complexes have created a new lifestyle and a change in occupants' behaviour, becoming more demanding in their shopping expectations. However, in 2000, the growth of such shopping complexes slowed down in the West. Comparatively, the establishment of the enclosed shopping complexes has rapidly grown in Asia. For example, fast economic growth, globalisation, and high urbanisation rate have created a booming market for the development of quality, first-class shopping complexes in Malaysia. Thus, today, shopping complexes are becoming important entertainment centres while their traditional retail occupants are now considered secondary. As pointed out, it may be difficult for one to discern nowadays when inside a shopping complex or a theme park due to the creative and exciting image shopping complexes present. In Malaysia, the situation is such that shopping complexes have surpassed their initial roles as centres of economic activities to become a meeting point for the young and the old for social and recreational activities (Uche et al., 2015).

The development of shopping complexes can be separated by several factors, such as cultural shifts, technology, global climate change, and physical or environmental changes (Kusumowidagdo, Sachari, and Widodo, 2016). These factors encourage the enhance use of spaces, especially public spaces, in shopping complexes for various activities. However, Kusumowidagdo, Sachari, and Widodo (2016) stated that general public spaces in shopping complexes are categorised as quasi-public areas. They have a low degree of accessibility and openness because these are privately owned, built, managed, and controlled under high-quality, comfortable, and safe environmental conditions regardless of the environment itself. Some shopping complexes are also integrated with city transportation systems; thus, their function as nodes in urban areas increases their public spaces' usage value. Today, the transformation in function and the increased number of public spaces are considered typical phenomena in industrial cities and Asian cities.

Subsequently, visitors' satisfaction is a critical issue for both visitors and shopping complex management. It is an essential concept within general retail, marketing, and consumer research. For example, the long-standing core belief of marketing principles in

marketing literature states that recognising potential customers' desires and requirements and competently producing the desired satisfactions are the secrets in accomplishing the institutional objectives (Anselmsson, 2006). A person's emotional response to the personal evaluation of the entire encounters at a shopping complex can be considered as visitors' satisfaction towards the shopping complex. Therefore, this research paper examines the relationship between thermal comfort conditions in shopping complexes with visitors' satisfaction.

RESEARCH FRAMEWORK AND HYPOTHESIS

This research's conceptual framework illustrates the relationship of thermal comfort variables, namely temperature, heat transfer, relative humidity, and air movement, with visitors' satisfaction in shopping complexes, as shown in Figure 1.

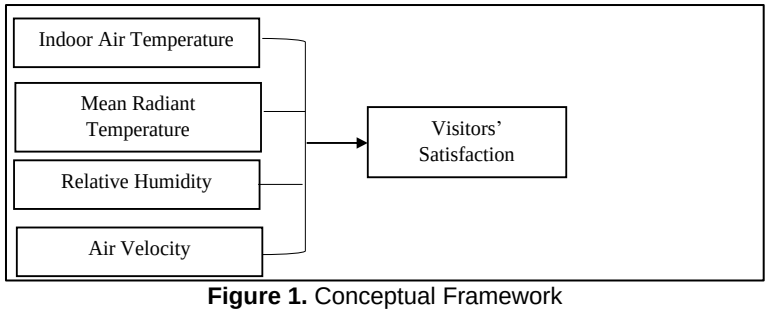

Figure 1. Conceptual Framework

Primary hypothesis: There is a significant association between thermal comfort and visitors' satisfaction in shopping complexes.

H1: There is a significant association between indoor air temperature and visitors' satisfaction in shopping complexes.
H2: There is a significant association between mean radiant temperature and visitors' satisfaction in shopping complexes.
H3: There is a significant association between relative humidity and visitors' satisfaction in shopping complexes.
H4: There is a significant association between air velocity and visitors' satisfaction in shopping complexes.

METHODOLOGY

The researchers used a questionnaire survey to gather data for this study. The questionnaire sets were formatted and distributed to be filled up by survey respondents. The unit analysis of this research is visitors of shopping complexes in Penang, Malaysia. The study's population was the visitors of the two (2) selected shopping complexes in Penang. This research employed Krejcie and Morgan (1970) formula to determine the sample size. The population size of the study was N=50,000. Therefore, based on Krejcie and Morgan (1970) formula, the total sample was S=381 in which the visitors were randomly selected as samples for the questionnaire distribution.

Table 1. Questionnaire Distribution Sample Size

Sample Size (Distributed)	Percentage (%)	Expected Return	Respondents Returns for the Research
381	20	77	176

(Source: Krejcie & Morgan, 1970)

According to Nulty (2008), the acceptable response rate is 20%. Based on Table 1, 176 respondents returned the questionnaires, exceeding the minimum 20% of the response rate; thus, the number of samples reached adequate data collection. The questionnaire designed for this study comprised three (3) parts. The first part addressed thermal comfort, the independent variable (IV) of the study, and its dimensions; air temperature, heat transfer, relative humidity, and air movement. Meanwhile, the second part focused on visitors' satisfaction, the study's dependent variable, in shopping complexes. The study employed a five-item scale to measure items in both the first and second parts. The third part gathered data concerning the respondents' demographic. According to Jasimin and Che Amat (2019), since this study is a confirmatory research type Structural Equation Modelling (SEM) was employed during the analysis process by analyzing the regression path coefficient or regression weights for the model in order to validate the research hypothesis formulated for this study.

ANALYSIS

The study used SPSS 24 and SmartPLS 3.2 to test the reliability and validity of the questionnaire's data; hence preliminary testing the research hypotheses. Besides, SPSS and SmartPLS were also used to analyse and measure the respondents' demographic and the conceptual framework's structural model, respectively. The main advantage of SmartPLS is that it generates latent variable score while testing the reliability and validity of the study, preventing the small sample size issue and managing complex models of many variables efficiently (Henseler et al., 2009).

Demographic Profile of the Respondent

The percentage of female and male respondents was almost equal, 55% and 45%, respectively, based on the demographic analysis. Concerning the respondents' age, 43% were visitors aged lesser than 21 years old. 34% of respondents, based on the analysis, also revealed that they frequented shopping complexes a few times in a month while 24% a few times in a week. Finally, in sum, 86% of respondents acknowledged spending 2-4 hours in shopping complexes during each visit, as tabulated in Table 2.

Table 2. Demographic Profile

NO.	DEMOGRAPHIC	PERCENT (%)	FREQUENCY
1.	Gender		
	Male	44.9 %	79
	Female	55.1 %	97
2.	Age		
	< 21 years old	43.2%	76
	21-35 years old	36.4%	64
	36-51 years old	17.6%	31
	> 51 years old	2.8%	5

NO.	DEMOGRAPHIC	PERCENT (%)	FREQUENCY
3.	Describe the weather today		
	Very Warm	48.3%	85
	Warm	31.8%	56
	Neutral	18.2%	32
	Cool	11.7%	3
	Very Cool	0.0%	0
4.	How often have you visited this shopping complex?		
	Once a Week	15.3 %	27
	Once a Month	26.7 %	47
	Few times per Week	23.9 %	42
	Few times per Month	34.1 %	60
5.	How long do you stay in the shopping complex?		
	< 30 minutes	8.0 %	14
	1-2 hours	46.6 %	82
	2-4 hours	40.3 %	71
	> 4 hours	5.1 %	9
6.	How do you feel at the moment?		
	Very Cold	5.1 %	9
	Cool	43.2 %	76
	Neutral	42.6 %	75
	Warm	8.5 %	15
	Very Warm	0.6 %	1

Measurement Model Analysis

Table 3 summarises the results of the conceptual study framework's measurement model after a few adjustments made.

Table 3. Measurement Model

Construct	Item	Convergent Validity		Internal Consistency Reliability		Discriminant Validity	
		Cross Loading	AVE	Cronbach's Alpha	Composite Reliability	HTMT	VIF
		>0.50	*>0.50*	*0.60-0.90*	*0.60-0.90*	*Confidence Interval Does Not Include 1*	*<5.00*
Indoor Air Temperature (AT)	2	0.902-0.923	0.833	0.800	0.909	Yes	2.325
Mean Radiant Temperature (MRT)	2	0.877-0.907	0.726	0.746	0.887	Yes	2.699
Relative Humidity (RH)	2	0.856-0.914	0.784	0.729	0.879	Yes	3.305
Air Velocity (AV)	2	0.918-0.934	0.858	0.835	0.924	Yes	2.306
Occupants' Satisfaction (OS)	3	0.858-0.906	0.789	0.865	0.865	Yes	

(Source: Table adapted from Hair et al., 2016)
AVE: Average Variance Extracted; HTMT: Heterotrait-Monotrait Ratio; VIF: Collinearity Statistic

A few tests and figures are to be established within their appropriate measurement range to test the conceptual model goodness and correct its validity as an instrument for the actual data collection. Reliability and validity tests are the two (2) most common tests to be taken into account when measuring the model goodness. According to Sekaran and Bougie (2010), reliability and validity measure the instruments' accuracy and show established instruments' well-being in testing a particular study concept.

Reliability

The measurement model reliability can be assessed using Cronbach's alpha coefficient and composite reliability; the former with a value of more than 0.6 when considering inter-item consistency while the latter with an acceptable value of 0.7 and above (Fornell and Larcker, 1981). Concerning this study, Table 3 indicates that the measurement model values' internal consistency reliability ranged from 0.729 to 0.865 for Cronbach's Alpha and from 0.879 to 0.924 for composite reliability, respectively; thus, it is acceptable to measure the instruments consistently.

Validity

The validity test, testing convergent validity and discriminant validity, primarily aims to assess the theory fitness of the test developed (Sekaran and Bougie, 2010). The measurement model's convergent validity is measured by analysing its factor loading, composite reliability, and average variance extracted (AVE) results (Hair et al., 2016). Table 3 shows that the factor loading of each item in the construct exceeds the endorsed value of 0.5, as stated by Hair et al. (2014). The model's composite reliability, as Table 3 demonstrates, exceeds the proposed value of 0.7, ranging from 0.879 to 0.924 (Hair et al., 2016). Concerning the AVE, the cumulative amount of the latent construct item variance is indicated by the value ranging from 0.726 to 0.858, exceeding the recommended value of 0.5 (Fornell & Larcker, 1981; Barclay et al., 1995; Hair et al., 2016). The model's convergent validity result is, therefore, acceptable.

The discriminant validity test is another test to be taken into account. It measures the extent to which an absolute value of a variable in a model is not a representation of another variable. The test can also be demonstrated by a low correlation between items of various constructs, as Cheung and Lee (2010) indicated, and by analysing the variance inflation factor (VIF) value. There is no collinearity issue between the proposed conceptual model constructs since the VIF values for all constructs are less than 5, as shown in Table 3. It is highly suggested that discriminant validity is measured using PLS-SEM to analyse the model's discriminant validity status better. It is accomplished by verifying the items of all constructs measure various constructs in the model according to Fornell-Larcker Criteria. It can be demonstrated by ensuring the statistical confidence interval value does not comprise the value of 1 for the constructs' whole combination, as summarised in Table 4, indicating the model's lack of discriminant validity.

Based on the discussion concerning the measurement model's findings, due to factor estimates and statistical significance, it can be concluded that air temperature, heat transfer, relative humidity, and air movement are valid measures of thermal comfort constructs. In sum, the measurement model has formed an acceptable reliability and validity standard concerning the data collection in this study.

Table 4. Fornell-Larcker Criterion

Dimension	AT	MRT	RH	AV	OS
Indoor Air Temperature (AT)	**0.912**				
Mean Radiant Temperature (MRT)	0.687	**0.892**			
Relative Humidity (RH)	0.716	0.753	**0.886**		
Air Velocity (AV)	0.707	0.730	0.745	**0.888**	
Occupant's Satisfaction (OS)	0.613	0.664	0.727	0.800	**0.926**

(Source: Authors' Research, 2020)

Structural Model Analysis

This study tested and analysed the structural model and subsequently, tested the formulated hypotheses. Table 5 shows that three (3) hypotheses, namely H1, H2, and H4, are supported. The p-value of each supported hypothesis is less than 0.05, indicating the positive influences of indoor air temperature, mean radiant temperature, and air velocity on visitors' satisfaction in shopping complexes. Nevertheless, Table 4 also shows that relative humidity does not significantly positively correlate with visitors' satisfaction due to the facts that the building is fully mechanical ventilated (air condition) where the relative humidity is controlled at average level of below 50%.

Table 5. Structural Model

Hypothesis	Relationship	Coefficient	p-value/ t-value	Result
H1	Indoor Air Temperature → Visitors' Satisfaction	0.212	0.004/2.927	Supported
H2	Mean Radiant Temperature→ Visitors' Satisfaction	0.195	0.011/2.553	Supported
H3	Relative Humidity → Visitors' Satisfaction	0.113	0.152/1.436	Not Supported
H4	Air Velocity → Visitors' Satisfaction	0.458	0.000/7.626	Supported

CONCLUSION

This study emphasises the importance of thermal comfort in providing shopping complexes with an environment that can increase visitors' satisfaction. Therefore, the analysis was supported by the previous case study by Hou (2016) and Anselmsson (2006), stating that visitors' satisfaction level is influenced by thermal comfort in shopping complexes. The study attempted to highlight the interaction between the five (5) main research variables: 1. Indoor Air Temperature, 2. Mean Radiant Temperature, 3. Relative Humidity, 4. Air Velocity, and 5. Visitors' Satisfaction. The findings of this research showed that air temperature, heat transfer, and air movement contributed to visitors' satisfaction. However, there was no significant relationship between relative humidity and visitors' satisfaction with regards that the building is provided with fully air condition. Therefore, with the helps from this mechanical ventilation, the relative humidity in the building set at average of below 50%. Apart from that, the relative humidity is an element that difficult to be measured by respondents via questionnaire survey. Hence, the result may be due to the small number of respondents. This study tested a conceptual framework based on thermal comfort satisfaction literature. The instrument used in this study fulfilled the acceptable requirements for reliability and validity analyses. The outcome of the path model analysis confirmed that thermal comfort is significantly correlated with visitors' satisfaction. Hence, future research is recommended to cover the overall aspects of indoor environmental quality, including

thermal comfort, acoustic comfort, and visual comfort, and indoor air quality concerning shopping complex occupants' satisfaction by targeting population and samples from Peninsular Malaysia.

REFERENCES

Anselmsson, J. (2006). Sources of Customer Satisfaction with Shopping Malls: A Comparative Study of Different Customer Segments. *The International Review of Retail, Distribution and Consumer Research,* 16(1), 115– 138.

ASHRAE. Standard 55: 2017, Thermal Environmental Conditions for Human Occupancy; ASHRAE: Atlanta, GA, USA, 2017.

Attia, S., & Carlucci, S. (2015). Impact of Different Thermal Comfort Models on Zero Energy Residential Buildings in Hot Climate. *Energy & Buildings,* 102, 117-128.

Auliciems, A. (1981). Towards a Psycho-Physiological Model of Thermal Perception. *International Journal of Biometeorology,* 25(2), 109-122

Barclay, D., Higgins, C., & Thompson, R. (1995). The Partial Least Squares (PLS) approach to causal modelling: Personal computer adoption and use as an illustration. *Technology Study,* 2 (2), 285-309.

Cheung, C. M., & Lee, M. K. (2010). A Theoretical Model of intentional Social Action in Online Social Networks. *Decision Support Systems,* 49(1), 24-30.

Esther, M. M. & Sagada, M. L. (2014). An Evaluation of Thermal Comfort Conditions in an Urban Entertainment Centre in Hot-Dry Climate Of Nigeria. *International Journal of Energy and Environmental Research* (IJEER), 2(1), 55–74.

Enescu, D. (2017) 'A review of thermal comfort models and indicators for indoor environments', *Renewable and Sustainable Energy Reviews*. Elsevier Ltd, pp. 1353–1379.

Esther, M. M. and Sagada, M. L. (2014) 'An Evaluation of Thermal Comfort Conditions in an Urban Entertainment Centre In Hot-Dry Climate Of Nigeria', *International Journal of Energy and Environmental Research (IJEER*), 2(1), pp. 55–74.

Fornell, C., & Larcker, D. F. (1981). Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. *Journal of Marketing Research*, 18, 39-50.

Hair, J. F., Hult, G. T., Ringle, C. M., & Sarstedt, M. (2010). A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM). 126- 145.

Hair, J. F., Hult, G. T., Ringle, C. M., & Sarstedt, M. (2014). A Primer on Partial Least Squares Structural Equation Modelling (PLS-SEM), 60-78.

Henseler, J., Ringle, C. M., & Sinkovics, R. R. (2009). The Use of The Partial Least Square Path Modeling in International Marketing. New Challenges to International Marketing Advances in International Marketing, 20, 277-319.

Henseler, J., Ringle, C. M., & Sarstrdt. M. (2014). A New Criterion for Assessing Discriminant Validity in Variance-Based Structural Equation Modeling. *Journal of the Academy of Marketing Science*, 43, 115-135.

Hou, G. (2016). An investigation of Thermal Comfort and the use of Indoor Transitional Space. Thesis for the degree of Doctor of Philosophy, 1–275

Hussain, S. & Oosthuizen, P. H. (2012). Numerical Investigations of Buoyancy- Driven Natural Ventilation in a Simple Atrium Building and its Effect on the Thermal ComfortConditions. *Applied Thermal Engineering*, 40, 358–372.

Jasimin, T.H. & Che Amat, R. (2019). Modelling The Relationship Between IEQ Towards Economic Aspect Of Sustainability For Malaysian Green Commercial Office Building Using Structural Equation Modelling Technique. *Malaysian Construction Research Journal*, 6 (1), 65-76.

Kamaruzzaman, S.N., Razali, A., Ahmad Zawawi, E.M. and Riley, M. (2017). Factors Affecting Indoor Environmental Quality and Potential Health Risks of Housing Residents. e-Proceedings National Innovation and Invention Competition Through Exhibition (iCompex) 2017

Krejcie, R.V., & Morgan, D.W., (1970). Determining Sample Size for Research Activities. Educational and Psychological Measurement., Educational and Psychological Measurement, 30, pp. 607-610

Kusumowidagdo, A., Sachari, A. & Widodo, P. (2016). Visitors' Perceptions on The Important Factors of Atrium Design in Shopping Centers : A study of Gandaria City Mall and Ciputra World in Indonesia. *Frontiers of Architectural Research*, 5(1), 52–62

Kwok, A. G. & Rajkovich, N. B. (2010) 'Addressing Climate Change in Comfort Standards', Building and Environment, 45(1), pp. 18–22.

Lazrak, F., Rietveld, P. & Rouwendal, J. (2014) The Market Value of Cultural Heritage in Urban Areas: An Application of Spatial Hedonic Pricing. *Journal of Geographical System*, 16(1), 89-114.

Mysin, M.A.O., Nawi, M.N. & Che Munaaim, M.A. (2017) Appraisal of Workplace Indoor Environmental Quality in Office Building at Penang Island. *Malaysian Construction Research Journal*, 2 (2), 223-231.

Najafabadi, F. A. (2013). Effect of Atrium on Thermal Comfort. Master Thesis (July) 1–165.

Nulty, D. D. (2008). The Adequacy of Response Rates To Online And Paper Surveys: What can be done? Assessment and Evaluation in Higher Education, 33(3), 301–314.

Rudge, J., & Gilchrist, R. (2007). Measuring the health impact of temperature in dwellings: investigating excess winter morbidity and cold homes in the London Borough of Newham. *Energy & Buildings*, 39(7), 847- 858

Sekaran, U. & Bougie, R. (2013). Research Methods for Business: A Skill- Building Approach. New York: John Wiley & Sons, Inc. The Center for the Built Environment (CBE), Available at: http://cbe.berkeley.edu/

Singh, M., Attia, S., Mahapatra, S., & Teller, J., (2016). Assessment of Thermal Comfort in Existing Pre-1945 Residential Building Stock. *Energy*, 98, 122-134

ECONOMIC BENEFIT ANALYSIS OF RAINWATER HARVESTING SYSTEM: A CASE STUDY ON ACADEMIC BUILDING

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Abstract
Rainwater Harvesting System (RWHS) is proposed to address the water scarcity problem and as an alternative water supply for non-potable water usage. This paper attempts to evaluate the economic benefits of RWHS for toilet flushing uses in one academic building at Politeknik Sultan Azlan Shah (PSAS) namely Civil Engineering Department (CED) block. The daily rainfall data employed in this work were obtained from the nearest rainfall station at Felda Gedangsa and the water demand was obtained from the building's occupant through a questionnaire survey combined with data obtained from PSAS's documents. A daily water mass balance model was adopted as the simulation approach. The economic benefits of RWHS in terms of percentage of reliability (R) and payback period (PBP) for the academic block were examined. In addition, the effects of two type's rainwater tank sizes on PBP were also evaluated which are High-Density Polyethylene (HDPE) tank and Fibre-reinforced Plastic (FRP) sectional tank. It was found that the percentage of reliability (R) for Civil Engineering Department block is between 82.22% to 100% by using tank size ranges from 10 m³ to 150 m³. Interestingly, for tank sizes up to 60 m³, the cost of HDPE tank is lower than FRP sectional tank with the PBP ranging from 11 to 19 years and 13 to 20 years, respectively. However, for tank size 100 m³ onwards, the cost of HDPE tank becomes more expensive than the cost of FRP sectional tank with PBP ranging from 23 to 38 years and 23 to 29 years, respectively.

Keywords: *Academic buildings; economic benefits; toilet flushing uses; reliability; payback period.*

INTRODUCTION

Water is a vital necessity for the life of mankind. Humans can still live without oil, but humans cannot survive without water to drink. The global water crisis is among the issues of concern in the present where freshwater sources around the world are getting tighter since the release of carbon gas from fossil fuels has warmed the surface of the earth and affected the rain. According to Mekonnen & Hoekstra (2016), at least in one month per year, more than half of the world's population are living in water scarcity areas. It is predicted that by year 2025, almost two-thirds of the world's population could experience water shortage and almost 1.8 billion people are expected to live in countries or regions that experiencing absolute water shortages (United Nation Educational, Scientific and Cultural Organization (UNESCO), 2012).

Based on the aforementioned water shortages problems, many researchers and policymakers have developed alternative water resource strategies in meeting the water demands (Rockström and Falkenmark, 2015). Rainwater Harvesting System (RWHS) is one of the solutions to overcome the shortage of water resources faced globally and helps to save water for non-potable uses (Silva, Sousa, and Carvalho (2015). RWHS is a system that provides options in conserving water in buildings (Domènech and Saurí., 2011). Belgium,

France, Germany, Japan, New Zealand, Singapore, and the United States have used this system mainly to complement conventional systems for non-potable uses such as for toilet flushing uses (Schets, Italiaander, Van Den Berg and de Roda Husman 2010). Among all, the toilet flushing consumes the highest water consumption that is around 63% of the domestic water consumption (Hamid and Nordin, 2011).

To ensure the efficiency of RWHS, an appropriate system design is needed. In order to design an effective RWHS installation method and stable harvested water supply, several parameters must be considered. It is well established that the performance of this system depends on the rainfall pattern, roof area, water demand and the storage tank used (Guo and Baetz (2007); Kim and Yoo (2009); Imteaz, Shanableh, Rahman and Ahsan (2011); Mun and Han (2012); Campisano, Cabot Ple, Muschalla, Pleau, and Vanrolleghem (2013) Morales-Pinzón, Rieradevall, Gasol, and Gabarrell (2015); Temesgen, Han, Park, and Kim (2015); de Gois, Rios and Costanzi, (2015), Wallace, Bailey and Arabi, (2015) and Guo and Guo, (2018) have highlighted that, the sizing of storage is the most important element to be considered in designing the RWHS. Morales-Pinzón et al. (2012), de Gois et al. (2015), Andrade, Maia and Lucio. (2017) and Guo and Guo (2018) indicated that the performance of RWHS mainly depends on the rainfall event characteristic. Catchment area will influence the reliability of RWHS (Mun and Han, 2012; NAHRIM, 2014; de Gois et al., 2015; Wallace et al., 2015; Lani, Syafiuddin, Yusop, and Mat Amin 2018a). Water demand is important for obtaining the ideal tank capacity and estimating the potential of the potable water savings (Silva and Ghisi, 2016; Campisano and Lupia, 2017; Guo and Guo, 2018).

The last two decades have seen a growing worldwide trend towards studies on RWHS to verify its advantages. Lani, Yusop and Syafiuddin, (2018b) in their study prove that RWHS can provide many useful benefits for the environment, economy, technology and society. In terms of environmental, RWHS is capable for reducing the dependency on treated water sources (Coombes, Kuczera, Kalma and Argue, 2002), helping to minimize flash flood events (Kim and Yoo, 2009) and reducing emissions of greenhouse gas resulting from the use of pumps to distribute the treated water to the consumers (Coombes, 2007). RWHS also provides effective stormwater control as it can be considered as flood mitigation technology (Farahbaksh, Despins and Leidl, 2009). On the economic aspect, RWHS can reduce the bill of treated water supply by the local water supply companies (Tam, Tam and Zeng, 2010). Furthermore, RWHS can also reduce the government's burden of adding water supply infrastructure to meet the increasing water demand (Che-Ani et al., 2009; Coombes et al., 2002). In terms of the technology and social aspect, one of the advantages that is given by RWHS installation includes better water quality resulted from filter features applied such as first flush technology that can reduce water-related health risk (Baguma and Loiskandl, 2010).

Considering the aforementioned advantages, it is also possible to implement the RWHS for academic buildings. This is because the academic buildings generally offer large catchment areas and high-water consumption. Studies on RWHS show that the implementation of RWHS in educational buildings has encouraging results on its reliability and the economic benefit. For example, Appan (1999) revealed that implementation of RWHS at Nanyang Technological University (NTU) campus in Singapore has reduced the potable water consumption by saving up to S$18,500.00 per year in potable water expenditure. It also reduced 12.4% of potable water consumption. Temesgen et al., (2015) have evaluated the performance of RHWS at a university building in Ethiopia, South Korea and found that

RWHS has the possibility to be an alternative water source for the building. Similarly, Sarker and Ahmed (2015) has studied the potential of RWHS at the University of Asia Pacific in Bangladesh and found that RWHS can fulfill up to a maximum of 66% of their monthly water demand for drinking, washing, and sanitation with 9.5 years payback period. In addition, a study on the quality of harvested rainwater in educational hostel in Malaysia, which carried out by Asman, Halim, Hanafiah, and Ariffin, (2017) also found that the harvested rainwater is safe to be used for the students. Besides, RWHS also can be the solution for the freshwater issue in Malaysia where a study by Afshar and Suhaimi, (2018) found that in 2030, one region in Malaysia which is Sarawak will face the freshwater scarcity problem due to climate change.

Therefore, it is the right time to evaluate the potential of RWHS for academic building in Malaysia by considering its reliability and economic advantages since this country receives high average rainfall amount where the current data released by The World Bank (2018) revealed that the average rainfall historic data in Malaysia from 1991 to 2015 is around 3098.4 mm yearly. The precipitation in Malaysia also shows an increasing trend where it increases approximately 20.15 mm and 12.44 mm in 10 years and 30 years' respectively from year 2005 to 2040 (Afshar and Suhaimi, 2018).

Hence, this study aims to evaluate the economic benefits of RWHS for toilet flushing uses for one academic building at Politeknik Sultan Azlan Shah (PSAS) namely Civil Engineering Department (CED) block in terms of percentage of reliability (R) and payback period (PBP). In addition, the effects of two type's rainwater tank sizes which are High-Density Polyethylene (HDPE) tank and Fibre-reinforced Plastic (FRP) sectional tank on PBP were also evaluated, to find the most economical tank for the proposed RWHS.

METHODS AND DATA

Potential Rainwater Harvested

The potential harvested rainwater is calculated to get the Water Released (WR) by considering the area of the roof, the rainfall amount, and the runoff coefficient (Silva et al., 2015). The potential rainwater that can be harvested in this study was estimated by using a formula adopted by Lani et al. (2018a) and can be mathematically expressed as below:

$$PRH = ART\ x\ RC\ x\ DR$$

PRH is the Potential Rainwater Harvested (m^3), *ART* is the area of rooftop (m^2), *RC* is the runoff coefficient (-) and *DR* is the daily rainfall (m).

The catchment area considered in this study is the CED block rooftop area at Politeknik Sultan Azlan Shah (PSAS). PSAS is situated at 03º77'00" N 101º45'01"E, Behrang Station , Perak which covers an area of 44.5 hectares. Generally, the weather in the area is relatively high where the average maximum temperature is 32.7ºC and the average minimum temperature is 24ºC. The average humidity of the state is high at around 81.2%. The roof area of the Civil Engineering Department block which is concrete roof tiles pitch roof was calculated by using the following formula:

$$ART\ =\ (LRT\ x\ WRT)\ x\ PRT$$

ART is the rooftop area (m²), *LRT* is the length of the rooftop (m), *WRT* is the width of the rooftop (m) and *PRT* is the pitch of the rooftop (º).

For this study, a 10-year daily rainfall record from year 2009 to 2018 recorded at the Felda Gedangsa rain station was used to obtain the average daily rainfall data. The rainfall records were obtained from the Department of Irrigation and Drainage Malaysia (DID) and Felda Gedangsa's rain stations were chosen because they were the closest to the case study area which located about 13.8 km from PSAS.

In addition, the runoff coefficient (RC) or the water loss of the roof catchment area considered in this study is 0.90 which is referred to NAHRIM Technical Guide No. 2 (2014).

Water Demand

In this study, only the water demand for toilet flushing uses is considered which is calculated by considering the toilet usage frequency, number of building occupants and the water closet cistern capacity. The data for toilet flushing frequency was obtained through a questionnaire survey which was distributed to students and staff in CED block, while the numbers of building occupants and cistern capacity were obtained from PSAS's documents. The water demand estimated in this study can be mathematically expressed as follow:

$$DT = B\ x\ FT\ x\ FW$$

DT is the daily demand for toilet flushing uses, *B* is the total number of building occupants, *FT* is the flushing time per day and *FW* is the water volume needed per flush.

Simulation Model

In the simulation model, the mass balance computation for the storage capacity is done by using Microsoft Excel. The simulation is calculated with various ranges of possible storage tank sizes until the reliability of the system reaches 100%. The simulation model formula applied in this study was adopted from Rahman et al. (2012), Lani et al. (2018a) and Lani et al. (2018c) and can be mathematically expressed as below:

$$R_t = \begin{cases} D_t & \text{if } WI_t + WS_{t-1} \geq D_t \\ WI_t + WS_{t-1} & \text{if } WI_t + WS_{t-1} < D_t \end{cases}$$

Rt is the daily water released (m³), *Dt* is the daily water demand (m³), *WI* is the inflow (volume of rainfall captured from the roof) (m³), *WSt –1* is the tank storage at the end of the previous day (m³) and *t* is the time (day).

Economic Indicators

In this study, the economic benefits of the proposed RWHS were evaluated by using two economic indicators which are the percentage of reliability (R) and the payback period (PBP). These two economic indicators are adopted from Lani et al. (2018a) and can be mathematically expressed as below:

$$\mathrm{R}\ (\%) = \frac{\mathrm{WR}}{\mathrm{D}}\ x\ 100\%$$

$$\sum_{t=0}^{s} StPt - It - Ot$$

R is the reliability of the RWHS (%), WR is the annual water release (m³), D is the annual water demand (m³), *St* is the volume of public water saved over a period of time *t* (m³), *Pt* is the cost of the public water supply (RM), *It* is the installation cost required over a period of time (RM), *Ot* is the operational cost over a period of time (RM), *s* is the system lifespan (year) and *t* is the system operation period (year).

The isometric drawing for the proposed RWHS for CED block is shown in Figure 1. In the proposed system, seven components were considered to estimate the system's installation cost which are the catchment area (roof of the CED block), gutters, rainwater downpipes, first flush filter, storage tank, header tanks and water pump. In addition, the operational cost assumed for the proposed system was estimated by using a formula adopted by Lani et al. (2018a) and can be mathematically expressed as below:

$$\mathrm{OC} = \frac{\mathrm{Ws}}{\mathrm{PFS}}\ Pe\ Et$$

OC is the annual operation cost (RM), *Ws* is public potable water saved (m³), *PFS* is the pump speed (m³/min), *Pe* is the pump energy (w) and *Et* is the current electricity tariff (RM/w).

In addition, in estimating the PBP of the RWHS, two types of RWHS storage tank which are High Density Polyethylene (HDPE) tank and Fiber-reinforced Plastic (FRP) sectional tank were proposed to provide an alternative to the selection of the tank and to find the most economical tank for the proposed RWHS.

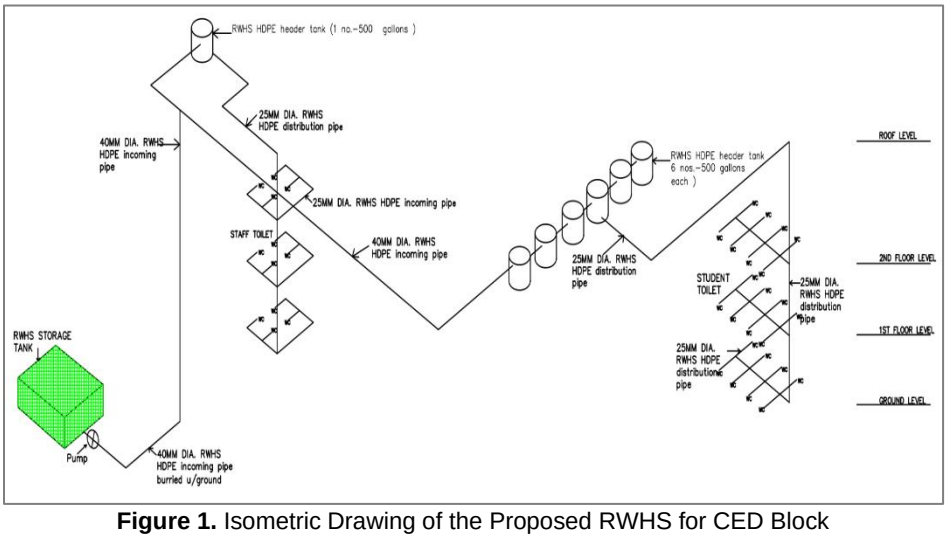

Figure 1. Isometric Drawing of the Proposed RWHS for CED Block

RESULTS AND DISCUSSION

Potential Rainwater Harvested

The potential rainwater harvested (PRH) is calculated by considering the rooftop area, runoff coefficient and daily rainfall amount. Result shows that the PRH for CED block are varied from month to month depending on the amount of rainfall received as shown in Figure 2. It can be seen that the highest PRH is in November (35.85 m³) and the lowest PRH is in September (20.85 m³).

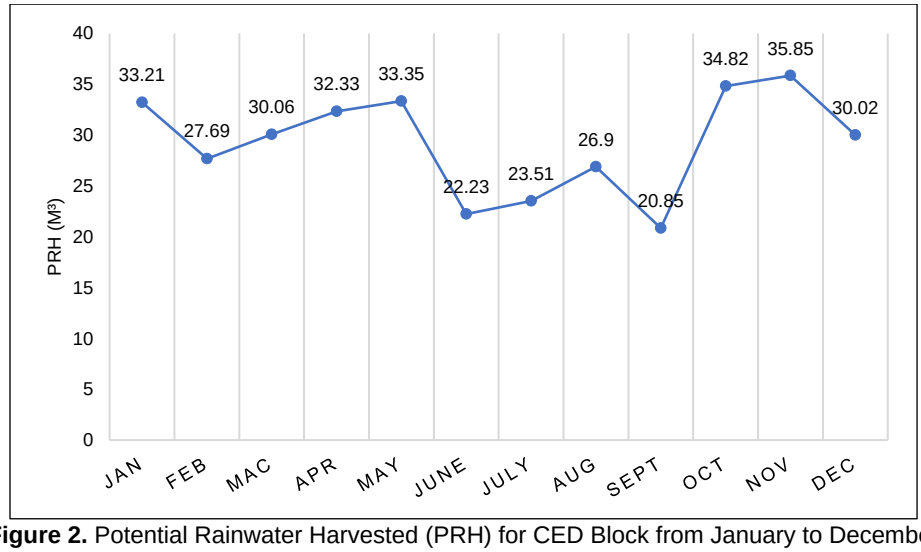

Figure 2. Potential Rainwater Harvested (PRH) for CED Block from January to December

Water Demand

Water demand is calculated by considering the number of CED occupant, the toilet flushing frequency and the water closet cistern capacity. It was found that the total daily water demand for toilet flushing usage for CED block is 16.05 m³, resulting from 772 numbers of building occupants, 4 times of average toilet flushing frequency per day and 6 liters water closet cistern capacity.

RWHS Reliability

RWHS Reliability (R) is the ratio of the annual PRH which is Water Released (WR) and annual water demand (D) calculated from the daily mass simulation model using Formula 5. It was found that the annual WR is 6412 m³ and the annual D is 3672 m³ which means that the rainwater supply can fully meet the water demand with the use of suitable tank size. Figure 3 shows the effects of rainwater tank sizes on the percentage of reliability for the proposed RWHS as the simulation is carried out with possible storage tank sizes until the maximum reliability is achieved. It can be seen that the maximum reliability (100%) of the proposed RWHS can be achieved with the use of 150 m³ tank size.

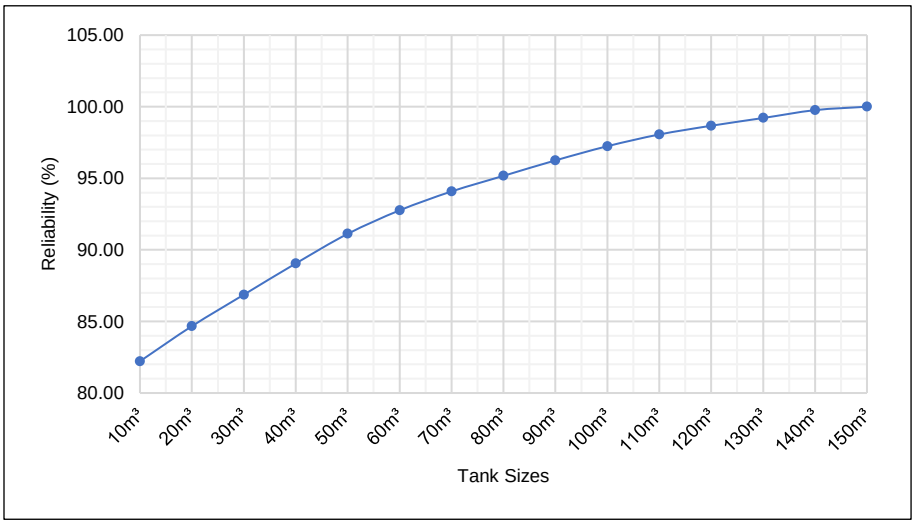

Figure 3. Percentage of Reliability for Proposed RWHS For CED Block According to Various Tank Sizes

Payback Period

In evaluating the PBP of the proposed RWHS, two types of RWHS storage tanks which are HDPE tank and FRP sectional tanks were proposed as an alternative to the tank selection and to find the most economical tank. The potable water savings, installation cost and operational cost for both tanks were analyzed by using a cash flow created in Microsoft Excel for 30 years duration, which is the expected system lifespan. Figure 4 shows the PBP of the HDPE tank and FRP sectional tanks which are plotted with the percentage of reliability. It can be seen that for tank sizes up to 60 m³, the cost of HDPE tank is lower than FRP sectional tank with the PBP ranging from 11 to 19 years and 13 to 20 years respectively. Interestingly, with a 90 m³ tank, the PBP for both types of tanks is the same which is 23 years. However, the cost of HDPE tank becomes more expensive than the cost of FRP sectional tank for tank sizes of 100 m³ onwards with PBP ranging from 23 to 38 years and 23 to 29 years, respectively. Hence, the maximum reliability of RWHS with the 150 m³ tank size for this block can be achieved with FRP sectional tank but cannot be achieved with the HDPE tank. In addition, the reliability percentage for the proposed RWHS is between 82.22% to 100% by using the tank size from 10 m³ to 150 m³. However, within the system lifespan, which is 30 years, the maximum reliability (100%) can only be achieved with the use of FRP tank where the PBP is 29 years.

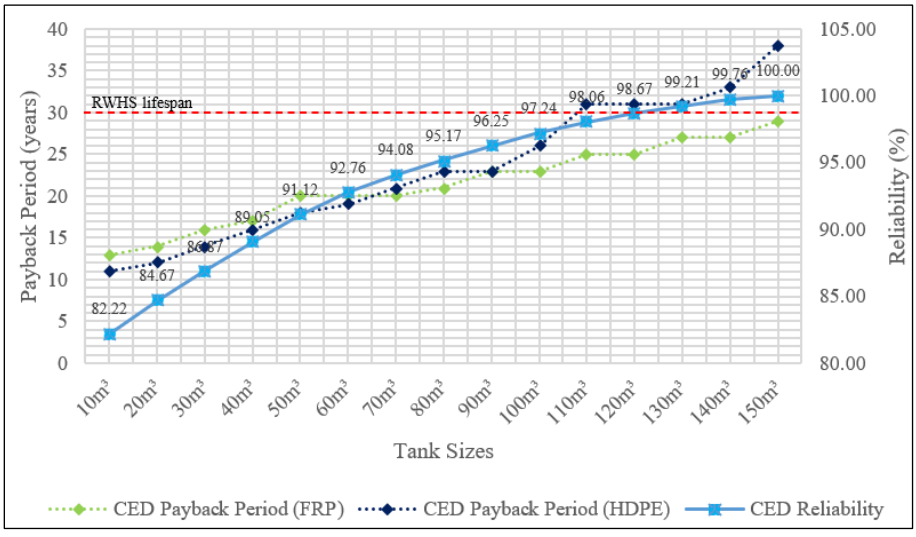

Figure 4. RWHS payback period for FRP and HDPE tank installation cost and Percentage of Reliability for CED Block

Generally, the present analysis shows that the high percentage of Reliability for the proposed RWHS is due to the high potential rainwater harvested which is influenced by the rainfall characteristic within the area, size of the CED block's roof area, and also the combination of the suitable tank sizes. In addition, the higher amount of potential rainwater harvested than the water demand also has contributed to the high percentage of reliability of the system. This finding corresponds with the study done by Guo and Baetz (2007), Kim and Yoo, (2009), Imteaz et al. (2011), Mun and Han (2012), Campisano et al. (2013), Morales-Pinzón et al., (2015) and Temesgen et al., (2015) which claim that the performance of RWHS depends on the rainfall pattern, roof area, water demand, and the storage tank use.

In addition, in term of PBP for the proposed RWHS, it can be concluded that different sizes and types of tanks will directly affect the initial cost and duration to reimburse the expense. Besides, the reliability of the system also will be affected by the sizes of the tank chosen where bigger tank will produce higher system reliability, and higher reliability also means longer PBP for the system. It can be said that storage tank has a strong influence in determining the economic benefit of the RWHS and the selection of the tank materials and sizes must be carefully planned to ensure the economic benefit of the system can be achieved.

This analysis also verify that the tank selection is very crucial in designing the RWHS due to the cost implication on the system as claimed by Li, Boyle and Reynolds (2010), Mun and Han (2012), Temesgen et al. (2015), Pelak and Porporato (2016), Zavala et al. (2018), Lani et al. (2018a) and Lani et al. (2018b).

CONCLUSION

The aim of the present works was to evaluate the economic benefit of RWHS for toilet flushing uses in academic building. It was found that the percentage of reliability (R) for CED block is between 82.22% to 100% by using the tank size from 10 m³ to 150 m³. For tank sizes up to 60 m³, the cost of HDPE tank is lower than FRP sectional tanks with the PBP ranging from 11 to 19 years and 13 to 20 years, respectively. However, for tank size 100 m³ onwards,

the cost of HDPE tank becomes more expensive than the cost of FRP sectional tank with PBP ranging from 23 to 38 years and 23 to 29 years, respectively. These findings prove that RWHS is economical to be implemented in academic buildings with careful consideration on the types and sizes of the tank being choose. If the maximum reliability is given priority, the larger tanks can be used. However, if a shorter PBP is required, the smaller tanks can be selected as the reliability of the system is still considered high. For future studies, it would be interesting to evaluate RWHS by diversifying the use of harvested rainwater such as for general cleaning and irrigating the landscape, which may offer higher economic benefits.

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REFERENCES

Appan, A. (1999). Trends in water demands and the role of rainwater catchment systems in the next millennium. In 9ª Conferência Internacional sobre Sistemas de Captação de Água de Chuva. Anais....(Cd-rom). Petrolina–PE.

Andrade, L. R., Maia, A. G., & Lucio, P. S. (2017). Relevance of hydrological variables in water-saving efficiency of domestic rainwater tanks: Multivariate statistical analysis. Journal of Hydrology, 545, 163-171.

Asman, N. S., Halim, A. A., Hanafiah, M. M., & Ariffin, F. D. (2017). Determination of rainwater quality from rainwater harvesting system at Ungku Omar College, UKM Bangi. Sains Malaysiana, 46(8), 1211-1219.

Afshar, N. R., & Suhaimi, D. N. (2018). Climate Change Impact On Water Resources Availability In Kuching Sarawak. Malaysian Construction Research Journal (MCRJ), 105.

Baguma, D., & Loiskandl, W. (2010). Rainwater harvesting technologies and practises in rural Uganda: a case study. Mitigation and adaptation strategies for global change, 15(4), 355-369.

Coombes, P. J., & Barry, M. E. (2007). The effect of selection of time steps and average assumptions on the continuous simulation of rainwater harvesting strategies. Water Science and Technology, 55(4), 125-133.

Che-Ani, A. I., Shaari, N., Sairi, A., Zain, M. F. M., & Tahir, M. M. (2009). Rainwater harvesting as an alternative water supply in the future. European Journal of Scientific Research, 34(1), 132–140.

Coombes, P. J., Kuczera, G., Kalma, J. D., & Argue, J. R. (2002). An evaluation of the benefits of source control measures at the regional scale. Urban water, 4(4), 307-320.

Campisano, A., Cabot Ple, J., Muschalla, D., Pleau, M., & Vanrolleghem, P. A. (2013). Potential and limitations of modern equipment for real time control of urban wastewater systems. Urban Water Journal, 10(5), 300-311.

Campisano, A., & Lupia, F. (2017). A dimensionless approach for the urban-scale evaluation of domestic rainwater harvesting systems for toilet flushing and garden irrigation. Urban Water Journal, 14(9), 883-891.

Domènech, L., & Saurí, D. (2011). A comparative appraisal of the use of rainwater harvesting in single and multi-family buildings of the Metropolitan Area of Barcelona (Spain): social experience, drinking water savings and economic costs. Journal of Cleaner production, 19(6-7), 598-608.

de Gois, E. H., Rios, C. A., & Costanzi, R. N. (2015). Evaluation of water conservation and reuse: a case study of a shopping mall in southern Brazil. Journal of Cleaner Production, 96, 263-271.

Farahbakhsh, K., Despins, C., & Leidl, C. (2009). Developing capacity for large-scale rainwater harvesting in Canada. Water Quality Research Journal, 44(1), 92-102.

Guo, R., & Guo, Y. (2018). Stochastic modelling of the hydrologic operation of rainwater harvesting systems. Journal of hydrology, 562, 30-39.

Guo, Y., & Baetz, B. W. (2007). Sizing of rainwater storage units for green building applications. Journal of Hydrologic Engineering, 12(2), 197-205.

Hamid, T. A., & Nordin, B. (2011). Green campus initiative: Introducing RWH system in Kolej Perindu 3 UiTM Malaysia. In Sustainable Energy & Environment (ISESEE), 2011 3rd International Symposium & Exhibition in (pp. 135-138)

Imteaz, M. A., Shanableh, A., Rahman, A., & Ahsan, A. (2011). Optimisation of rainwater tank design from large roofs: A case study in Melbourne, Australia. Resources, Conservation and Recycling, 55(11), 1022–1029. https://doi.org/10.1016/j.resconrec.2011.05.013

Kim, K., & Yoo, C. (2009). Hydrological modeling and evaluation of rainwater harvesting facilities: case study on several rainwater harvesting facilities in Korea. Journal of Hydrologic Engineering, 14(6), 545-561.

Lani, N. H. M., Syafiuddin, A., Yusop, Z., & bin Mat Amin, M. Z. (2018a). Performance of small and large scales rainwater harvesting systems in commercial buildings under different reliability and future water tariff scenarios. Science of The Total Environment, 636, 1171-1179.

Lani, N. H. M., Yusop, Z., & Syafiuddin, A. (2018b). A review of rainwater harvesting in Malaysia: Prospects and challenges. Water (Switzerland), 10(4), 1–21.

Lani, N. H. M., Syafiuddin, A., & Yusop, Z. (2018c, September). Comparison of Cost Benefits of New Installation and Retrofitted Rainwater Harvesting Systems for Commercial Buildings. In International Conference on Urban Drainage Modelling (pp. 169-174).

Li, Z., Boyle, F., & Reynolds, A. (2010). Rainwater harvesting and greywater treatment systems for domestic application in Ireland. Desalination, 260(1-3), 1-8.

Morales-Pinzón, T., Rieradevall, J., Gasol, C. M., & Gabarrell, X. (2015). Modelling for economic cost and environmental analysis of rainwater harvesting systems. Journal of Cleaner Production, 87, 613-626.

Morales-Pinzón, T., Lurueña, R., Rieradevall, J., Gasol, C. M., & Gabarrell, X. (2012). Financial feasibility and environmental analysis of potential rainwater harvesting systems: A case study in Spain. Resources, Conservation and Recycling, 69, 130-140.

Mekonnen, M. M., & Hoekstra, A. Y. (2016). Sustainability: Four billion people facing severe water scarcity. Science Advances, 2(2), 1–7. https://doi.org/10.1126/sciadv.1500323

Mun, J. S., & Han, M. Y. (2012). Design and operational parameters of a rooftop rainwater harvesting system: definition, sensitivity and verification. Journal of Environmental Management, 93(1), 147-153.

NAHRIM, (2014). NAHRIM Technical Guide No . 2 : The Design Guide for Rainwater Harvesting System, National Hydraulic Research Institute of Malaysia. 88pp.

Pelak, N., & Porporato, A. (2016). Sizing a rainwater harvesting cistern by minimizing costs. Journal of Hydrology, 541, 1340-1347.

Rahman, A., Keane, J., & Imteaz, M. A. (2012). Rainwater harvesting in Greater Sydney: Water savings, reliability and economic benefits. Resources, Conservation and Recycling, 61, 16-21.

Rockström, J., & Falkenmark, M. (2015). Agriculture: increase water harvesting in Africa. Nature, 519(7543), 283-285.

Silva, C. M., Sousa, V., & Carvalho, N. V. (2015). Evaluation of rainwater harvesting in Portugal: Application to single-family residences. Resources, Conservation and Recycling, 94, 21–34.

Silva, A. S., & Ghisi, E. (2016). Uncertainty analysis of daily potable water demand on the performance evaluation of rainwater harvesting systems in residential buildings. Journal of Environmental Management, 180, 82-93.

Schets, F. M., Italiaander, R., Van Den Berg, H. H. J. L., & de Roda Husman, A. M. (2010). Rainwater harvesting: quality assessment and utilization in The Netherlands. Journal of water and health, 8(2), 224-235.

Sarker, M. H., & Ahmed, F. (2015). Climate Change Vulnerability of Drinking Water Supply. by: IUCN, International Union for Conservation of Nature, Dhaka, Bangladesh: Shoilpik Choa, 74 pp.

Temesgen, T., Han, M., Park, H., & Kim, T. I. (2015). Design and technical evaluation of improved rainwater harvesting system on a university building in Ethiopia. Water Science and Technology: Water Supply, 15(6), 1220-1227.

The World Bank (2018). Average precipitation in depth. www. data.worldbank.org. Retrieved from: https://data.worldbank.org/indicator/AG.LND.PRCP.MM on 1 August 2018.

Tam, V. W., Tam, L., & Zeng, S. X. (2010). Cost effectiveness and tradeoff on the use of rainwater tank: An empirical study in Australian residential decision-making. Resources, Conservation and Recycling, 54(3), 178-186.

United Nation Educational, Scientific and Cultural Organisation (UNESCO) (2012). United Nation World Water Assessment Programme (WWAP). www.unesco.org. Retrieved from http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/wwdr/wwdr4-2012/

Wallace, C. D., Bailey, R. T., & Arabi, M. (2015). Rainwater catchment system design using simulated future climate data. Journal of Hydrology, 529, 1798–1809. https://doi.org/10.1016/j.jhydrol.2015.08.006

Zavala, M. Á. L., Prieto, M. J. C., & Rojas, C. A. R. (2018). Rainwater harvesting as an alternative for water supply in regions with high water stress. Water Science and Technology: Water Supply, 18(6), 1946-1955.

AN EMPIRICAL STUDY ON THE DRIVING FACTORS OF PRACTICING ENERGY EFFICIENCY IN MALAYSIAN PUBLIC UNIVERSITY BUILDINGS

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Abstract
Energy is the main element in building operations. Thus, it is crucial to ensure that the building operations and services are able to function effectively. In Malaysia, the overall energy demand is rising at an average annual rate of 6.3 per cent due to expected higher growth in Gross Domestic Product (GDP). However, high energy consumption will cause buildings to release carbon dioxide (CO_2), thereby resulting in greenhouse gas (GHG) emissions. In Malaysia, university campuses are reported to be among the types of buildings that have energy efficiency issues due to the increasing usage of building energy every year. Consequently, it is vital to practice energy efficiency (EE) in building operations to ensure minimum energy consumption and maximum output during operation. Thus, this research aims to identify the barriers in implementing EE and to determine the driving factors that facilitate the implementation of EE in public university buildings. A quantitative approach via a questionnaire survey was adopted. A purposive sampling technique was chosen, which listed 69 respondents who were directly involved in building maintenance and energy efficiency. The data were analysed using the Statistical Package for the Social Sciences (SPSS) version 25 quantitative software. The results revealed that eleven (11) factors were identified as barriers in the implementation of EE in public university buildings. In relation to that, ten (10) driving factors were found to have facilitated the implementation of EE in Public University buildings and helped overcome the barriers in practicing EE in building operations. The findings of this research may be beneficial to practitioners in promoting EE practices in order to attain cost reduction through low-energy usage.

Keywords: *Barriers; driving factors; energy; energy efficiency; public universities.*

INTRODUCTION

Energy is the main element in the operational period of a building. A rise in world energy demand rose by 39 per cent between 1990 and 2008, and by 40 per cent between 2007 and 2030 (Mohd Salleh et al., 2016). This showed that energy is a crucial aspect in a building process to ensure efficient building operations or services. Generally, the energy produced from fossil fuels will undergo several processes before energy is generated. High energy consumption will cause building to release carbon dioxide (CO_2), which results in greenhouse gas (GHG) emissions. In Malaysia, buildings consume a total of 48% of electricity generated in the country (Hassan et al., 2014). In addition, energy usage in buildings has been identified to contribute up to 40% of the total world energy consumption (Mohd Salleh et al., 2016).

In construction industry, energy efficiency (EE) is crucial and becoming more important, as global anthropogenic CO_2 emissions need to be significantly reduced (IPCC, 2007). According to the United Nations Environment Programme (UNEP) (2007), 30 per cent to 40 per cent of all primary energy is used in buildings worldwide. Therefore, to execute EE in one building is no easy task, where many factors such as building material and design, environmental suitability, and payback period need to be considered to ensure that these tasks are achieved. EE can be practiced in a building to ensure that the building consumes minimum

energy and produce maximum output during operation. Generally, buildings that practice EE has more advantages, for instance: energy-saving for the building, safe environment, and air quality. Gerarden et al. (2017) mentioned that EE offer condsiderable for reducing the financial cost and reduced the impact on environment associated with energy use. This is in-line with the WWF European (2005), which stated that EE is now viewed as one of the most cost-effective ways for society to boost energy protection from greenhouse gases and other contaminants.

Abd Rahman et al. (2019) reported that Malaysia is one of the prominent energy consumers in Asia. Thus, it is important to for the country to practice EE in building due to its ability to conserve limited resources such as fossil fuels. The abovementioned work also reported that EE and renewable energy have a similar or shared goal of reducing energy demand, controlling the use of natural fossil fuels and protecting the environment from harmful emissions. Building EE in Malaysia is critical, as it accounts for 13 per cent of Malaysia's total energy consumption and 48 per cent of Malaysia's electricity consumption. High economic development in Malaysia over the past three decades has contributed to a significant increase in energy consumption. Several studies have concluded that electricity consumption has a positive connection with economic growth. Total electricity consumption and domestic product (GDP) rose from 1980 to 2009 by 9.2% and 6.2%, respectively (S.Sadrzadehrafiei et al., 2009). This is inline with Sharif Ali et al. (2020) which is increasing electricity consumption is driven by improvement of GDP. Malaysia is increasingly dependent on conventional energy sources, such as fossil fuels, with its rapid industrialisation. Hassan et al. (2014) mentioned that buildings consume up to 40% of the total global energy and by the year 2030, the consumption is expected to increase to 50%. Commercial buildings consume up to 38,645 Gigawatt hours (GWh), while residential buildings consume 24,709 GWh (Hassan et al., 2014).

The issue of EE in commercial buildings has been frequently debated due to the increasing use of building energy every year (Jomoah et al., 2013). For instance, university campuses are often the main focus related to EE issues. This has been supported by Lo (2013) who stated that university campus involve high energy consumers, high energy costs, and contributes to climate change. This is caused by the large number of users in university campus (i.e., students and staffs), its large area, and complex operating activities. Thus, it is considered a small town. As a building with a variety of complex activities, waste of energy often occurs in various spaces such as lecture auditoriums, offices, computer rooms, and laboratories. Therefore, practicing EE in buildings is crucial to avoid excess usage of energy. Even though EE has been practiced in a building for several years, there are many barriers in practicing EE in a building. This has been expressed by Soares et al. (2015), that reduction energy consumption in buildings depends on the awareness of the users on the energy consumption. Therefore, user's awareness on EE is crucial because it will indirectly become an obstacle in practicing EE in buildings. Hence, to ensure that EE can be practiced in all buildings, factors that drive towards improving EE implementation are essential.

LITERATURE REVIEW

Issues of Energy Consumption in Malaysia

In Malaysia, the construction sector is one of the main sources of economic growth. As such, many buildings have been constructed, especially in strategic areas, causing a high consumption of energy from year to year. However highest consumption energy arise after construction stage known as operational stage. As mentioned by to Yüksek & Karadayi (2017), every phase of building life cycle has energy consumption, however the highest consumption of energy is happen during the operational stage because the building at least has 50-year lifespan. The excessive consumption of energy will cause the environmental pollution due to more carbon dioxide (CO_2), Nitrous oxide and other toxic emission that harming the environment and public health (Haseeb et al., 2019). Even though numerous researches have been conducted concerning EE in construction industry, issues on the implementation of EE in construction industry are continuously debated; some of them are as follows:

Lack of Implementation in EE

Due to an increase in energy demand, conventional buildings did not take account in applying energy efficiency in a building. As mentioned by Abd Rahman et al. (2019), Malaysia's final energy consumption rose from 13 million toe in 1990 to an approximately 41 million toe in 2010, reflecting an average annual growth rate of 6 per cent. Malaysia showed no improvement with respect to energy consumption and conservation. Hence, the majority of the conventional buildings were built for functional purposes and not for EE. In addition, implementing EE in a building was considered difficult because it required high initial cost, expertise, and suitable material for construction. However, conventional contract buildings gave less emphasis on EE implementation. In fact, these building had used very high energy consumption in daily operations. Thus, these buildings should also implement EE to reduce the environmental impact. Increased demand for energy in buildings could be reduced by improving the implementation of EE. Nevertheless, Mohd Salleh et al. (2016) mentioned that the implementation of EE is rather challenging.

Lack of Awareness in Implementation of EE

Normally, building that uses a high consumption of energy in industrial field is manufacturing premises. Other than that, the educational premises utilise high energy for its daily consumption. Sorrell et al. (2004) mentioned that universities were 60 per cent more energy-intensive than commercial offices and more than twice as power-intensive as production facilities. This led to the high cost of building operations. By choosing the method and the right strategy, the problem of increasing energy consumption buildings could be curbed (Mohd Salleh et al., 2016). Thus, a need to determine the driving factors in order to implement energy efficiency in public universities, which is crucial to reduce energy usage and save the environment.

Barriers in Practicing EE in a Building

Sorrell et al. (2004) defined the barrier of energy efficiency as a mechanism that limits a decision or action that appears to be effective, as well as economically efficient. Meanwhile, Worrell et al. (2011) defined that barriers to the end-use of energy is explained as forces or instruments that can be observed to move in different markets in a manner that prevents activities or investments that would increase energy efficiency. Thus, the implementation of EE in a building can be difficult due to the many barriers that exist. Sorrell et al. (2004) mentioned that different sectors and regions have different barriers. Therefore, there is a need to observe specific regional and sectorial studies in order to identify these barriers. Morrissey et al. (2014) stated that barriers in practicing EE may arise from risk perceptions, knowledge gaps, lock-in impacts, continuity of existing activities and behaviour, fragmented incentives, and market power. Besides that, several cultural, economic, and institutional barriers must be considered when applying EE to a building (Alyousef and Varnham, 2010). In relation to that, several issues from previous research have been discovered, which relate to the barriers in EE practice in a building. Table 1 presents the variables of barriers in practicing EE, as discussed in previous researches. There are eight (8) variables of barriers discovered, all of which lead to the difficulties in practicing EE in a building.

Table 1. Barriers in Implementing EE in a Building

Item	Barriers	Authors
1	High cost consideration in implementation of EE	International Energy Agency (2007); SuPer Building (2012) Apeaning and Thollander (2013); Maiorano and Savan (2015); and Johnson and Andersson (2016)
2	Lack of information in EE	Sorrell et al. (2004); Schleich (2007); International Energy Agency (2007); Johnson & Andersson (2016); Backman (2017)
3	Unstable organisation in terms of implementing energy efficiency	Backman (2017)
4	Lack of awareness towards EE and environmental	Neumayer (2001); and Nkosi and Pretorius (2017)
5	Risk and uncertainty in applying EE	Sorrell et al. (2004); and Schleich (2007)
6	Split incentives	Sorrell et al. (2004); and International Energy Agency (2007)
7	Organisational related factors	Lee (2015); Johnson and Andersson (2016); and Nkosi and Pretorius (2017)
8	Lack of technology	Maiorano and Savan (2015); Nkosi and Pretorius (2017); and Backman (2017)
9	Lack of budget funding and access to implement energy efficiency.	Apeaning and Thollander (2013)
10	Lack of time and resources, in the implementation of energy efficiency.	Backman (2017)
11	Lack of technical skills towards energy efficiency.	Backman (2017)

Factors that Facilitate the Implementation of EE in a Building

Applying EE in a building will contribute many benefits to the buildings and building owners. Thus, it is important to encourage building owners to implement EE in a building by determining the factors that can facilitate the practice of EE. Building owners should take this opportunity to ensure that the benefits and profits can be fully gained in the implementation of EE. According to Lee (2015), the important factors in EE consist of cost savings, energy tax, and energy. A driving force could be seen as a factor that can minimise or resolve an

obstacle; thus, in this sense, a driving force refers to any factor that motivates or encourages cost-effective, energy-efficient investment. Meanwhile, Thollander and Ottosson (2008) categorised the driving factors into different types, namely, market-related driving forces, current and potential energy policies, as well as organisational behavioural factors. Nevertheless, there are many other driving factors that influence building owners in implementing energy efficiency in a building.

According to Cooremans & Schönenberger (2019), the highest rank for driving forces in energy efficiency is cost reduction due to the lower usage of energy. Besides that, Lawrence et al. (2019) also stated the "cost reduction from lower energy use" was the most essential driving force representing the economy, while tax exemption is the third-ranked for the most important driving force. As mentioned by Lee (2015), increasing the energy prices is one of the most influential factors to force building owners in applying EE. Thus, by increasing the energy prices, the building authority will find alternatives on how to limit the energy usage in a building. Building owners are forced to pay a higher cost of electric bill if the energy usage is not monitored well.

According to Cagno et al. (2015), a long-term strategy can be a driving force in resolving strict control of investment. Investments will only be made profitable if they are paid back quickly enough, as reflected in the annual report. The implementation of EE in a building is very valuable if building owners have a long-term energy strategy such as overcoming strict investment monitoring. Moreover, Rohdin et al. (2007) stated that a real ambition is one of the major driving forces for implementing EE in a building. Organisations that want to achieve higher benefits and profits will attempt to implement EE in their building even though it takes a long time to acquire the benefits desired. Apeaning and Thollander (2013) specified that improving the working condition is one of the initiatives to facilitate people in implementing EE. By implementing EE, the environment and internal building will be more guaranteed. This is due to the fact that EE for a building will produce maximum energy without bringing high risk to the environment due to the reduction of carbon dioxide (CO_2) in the air. Thus, improving the working condition will indirectly improve comfort for building occupants and simultaneously lead to increased working efficiency for employees (Umar et al., 2012).

Rohdin and Thollander (2006) and Apeaning and Thollander (2013) mentioned that environmental management system is one of the factors that can force the implementation of EE in a building. This factor is a set of processes and practices that allow an organisation to reduce its environmental impacts and increase the efficiency of its operation. Another relevant factors mentioned by Lawrence et al. (2019) is having correct information. Correct information is the most important driving force, where it represents information that is accessible to internal competence with knowledge of the process and knowledge of daily operations. However, insufficient information will lead to people losing their interest in EE and their negative perception towards it.

Sufficient technology in the market is a driving factor for implementing energy efficiency. Technology is very important and innovations are developed from time to time. Mostly, green buildings will use efficient technology because it can reduce energy consumption and maintain good performance. As stated by Cagno and Trianni (2013), sufficient technology such as turbines and motors can be applied in building for certain operations such as to generate the electricity for the building, which aims to reduce the energy usage.

RESEARCH METHODOLOGY

A quantitative method via questionnaire survey was conducted. This corresponded with professionals and experts that were involved in managing EE in building operations. The questionnaire survey was distributed to building operators involved in managing EE in public universities and the building operators should has an experience in handling the maintainance of the buildings. Besides, building operators also should atleast has diploma certified in related field. It involved 69 building operators selected through purposive sampling technique within thirteen (13) Universiti Teknologi MARA (UiTM) branches. The building operators were selected based on their responsibility in carrying out and handling all maintenance activities of the buildings. A total of 50 questionnaires was returned out of 69 of questionnaires distributed. The data obtained from this questionnaire survey were analysed using descriptive analysis via the Statistical Package for the Social Sciences (SPSS) version 25.

The levels of agreement of the implementing energy efficiency were classified into 5 different scales which were 'strongly disagree, disagree, moderate, agree, and strongly agree'. The scales will indicate the difference between the levels of agreement among the respondents. 1st scale'strongly disagree' range mean is $1.00 \leq$ Median ≤ 1.50 which is catogery as low. 2nd 'disagree' range mean is $1.50 \leq$ Median ≤ 2.50 which is catogery as low. 3rd 'moderate' range mean is $2.50 \leq$ Median ≤ 3.50 which is catogery as medium. 4th 'agree' range mean is $3.50 \leq$ Median ≤ 4.50 which is catogery as high. 5th 'strongly agree' range mean is $4.50 \leq$ Median ≤ 5.00 which is catogery as high.

RESULTS AND DISCUSSION

Barriers in Implementing EE in Public Universities

Table 2 shows the results for barriers in implementing EE in public universities. Eleven (11) variables had been determined in order to identify the barriers in the implementation of EE in public universities. According to Table 2, the average score mean is 4.43. This shows that most of the respondents agreed with all the statements of barriers that prevented them from implementing EE. Referring to Table 2, there were eleven (11) variables that had been determined in order to identify the barriers in the implementation of EE in public universities. The average mean collected is 4.43 after analysing the data. This shows that most of the respondents agreed with all the statements of barriers that prevented them from implementing energy efficiency.

Most universities have had several barriers that prevented them to implement EE in a building. Based on Table 2, the top five mean values had been highlighted. The highest score mean for barriers in implementing EE is 4.58 on average. This score represented three variables, which are the lack of time and resources in the implementation of energy efficiency, lack of awareness towards energy efficiency and environmental, and split incentives. The result indicated that most of the public universities was under the assumption that green efficiency materials were limited and most suppliers would charge expensively for green materials. Besides that, most public universities were not interested in EE environment. Furthermore, they were not willing to spend more for a comfortable environment. This was supported by Backman (2017), which stated that the lack of time and other priorities were the

main barriers in implementing EE. However, this finding contradicts with Maiorano and Savan (2015), which mentioned that more money and capital access were needed to implement EE.

Table 2. Rank of Barriers in Implementing EE in Public Universities

SECTION B	STATEMENT OF BARRIERS	MEAN	STANDARD DEVIATION	RANK
1.	High cost consideration in implementation energy efficiency.	4.56	0.501	2
2.	Lack of budget funding and access to implement energy efficiency.	4.54	0.503	3
3.	Lack of information in energy efficiency.	4.34	0.798	4
4.	Lack of time and resources, in the implementation of energy efficiency.	4.58	0.499	1
5.	Unstable organisation in terms of implementing energy efficiency.	4.30	0.789	6
6.	Lack of technical skills towards energy efficiency.	4.32	0.794	5
7.	Lack of awareness towards energy efficiency and environmental.	4.58	0.499	1
8.	Risk and uncertainty in applying energy efficiency.	4.34	0.772	4
9.	Split Incentives.	4.58	0.499	1
10.	Organisational related factors that prevent implementation of energy efficiency.	4.28	0.757	7
11.	Lack of technology and innovation in implementing energy efficiency.	4.26	0.803	8
	AVERAGE MEAN	**4.43**	**0.656**	

Furthermore, another barrier that prevented public universities in implementing EE was high-cost consideration in implementing EE. The score mean for this barrier was 4.56 and it was considered as the second-highest of factor in this survey. This could illustrate that most of public universities refused to spend more cost in EE. This might be due to low initial costs in practising a conventional way. So, they were unwilling to spend high initial cost as they must spend a large amount of cost and period to gain profit which takes time. According to the International Energy Agency (2007), financing costs were needed in implementing energy efficiency because there was innovation in technology with no exception.

In addition to that, the lack of budget funding and access to implement EE became the third-highest ranking with score mean 4.54. To gain funding and access to implement EE was not an easy task and it took a long time and process to implement EE. There was limited funders to spend their cost on practicing EE especially on educational buildings. This is due to the fact that they were looking to gain profit. Normally, they were willing to spend on a commercial office building because this place was a gathering place for many people compared to the educational building in which the occupants were fixed and the payback period was too long. This was supported by Apeaning and Thollander (2013) which mentioned that a lack of budget funding and access to capital was one of the major barriers in the implementation of EE. However, contradicted to Rohdin and Thollander (2006) who stated that access to capital was not a major barrier in implementing EE.

Furthermore, the results from this survey showed that the lack of information, risk and uncertainty in applying EE were also among the top five factors that hinder the implementation of EE. Lack of interest in EE environment might be due to the lack of information in EE. This was because people were not aware and did not know the benefits of

implementing EE in a building. They also did not know that the output of implementing EE was similar as the conventional method. This was supported by Sorrell et al. (2004) where inadequate information makes people uninterested to practice EE in a building. Furthermore, this might also be due to high risks because a lot of money must be spent to adopt this EE especially when they did not have experience in implementing EE. According to Schleich (2007), financial risk and market uncertainty were the main reason for people not interested in EE, this was because EE in a building takes a long duration for the payback period.

However, the lowest barrier among public universities was the lack of technology and innovation in implementing EE with score mean of 4.26. The results indicated that lack of technology is not a major barriers that hinder the buiding's owner in practicing EE. This is due to the development of technology worldwide that is too fast and easy to be apply. Nowadays, all this technology can be gained by importing from oversea but it needed a high cost for transporting green material, energy-efficient appliances, and others. According to Backman (2017) and Maiorano and Savan (2015), technological problems was not a major barrier in the implementation of EE because there were many alternatives that can be applied. Besides that, there were many technology and innovation introduced to control the electrical use and managing it efficiently. Therefore, this technology had been adopted in public universities. For innovation, there was another innovation for EE such as windows. For example, most public university buildings use casement window compared to the louvre windows. Casement windows will allow sunlight (i.e. natural lighting) into the building and it reduces the energy consumption during the day.

Driving Factors that Facilitate in Practicing EE In Public Universities

Table 3 presented the results for the questionnaire survey. Most of the variables indicated that the respondents agreed with all the factors that facilitate in practicing EE in public universities. There were ten (10) variables that had been determined in order to identify the driving factor that facilitate the implementation of EE in public universities. The average mean of the data collected was 4.55. The results showed that most of the respondents agreed with all the statements of driving factors that facilitate the implementation of EE. Besides that, all factors showed a score mean above 4.00. The lowest standard deviation as presented in Table 3 was 0.479 which reflected the statement for *sufficient technology to be implement in a building* and it presented the highest mean score of 4.66. This was followed by the highest standard deviation 0.772 which was for the statement *people with real ambition and desire to implement energy efficiency* and this variable presented the lowest mean score of 4.34.

Many driving factors encouraged universities to implement EE. Based on the result, the highest score mean for driving factors in implementing EE was *sufficient technology to be implement in a building* (4.66). Technology was improved from time to time to fulfill the requirement of the consumer. The result indicated that sufficient technology was the main factor that facilitated public universities to implement EE. Technology adoption in universities needed high investment because the cost consideration of skills labour, material and expertise were high. For example, universities could implement water harvesting, solar panel, and other technology. According to Thollander and Ottoson (2008), sufficient technology such as turbines could facilitate the implementation of EE because the payback periods were in the short term. However, it contradicted with Lawrence et al. (2019) which mentioned that the main factor in implementing EE was the availability and sufficient

information. It is due to the importance of available information sources as an effective way to facilitate the implementation of EE.

Table 3. Rank for Driving Factors that Facilitate in Practicing EE in Public Universities

ITEM	STATEMENT OF DRIVING FACTORS	MEAN	STANDARD DEVIATION	RANKING
1.	Cost reduction due to lowered use of energy.	4.56	0.501	3
2.	Various benefits can be gain by implementing energy efficiency in a building.	4.54	0.503	4
3.	Increase the energy prices (electric bill) during the operation period by monitoring or limit the energy usage of the building.	4.54	0.503	4
4.	Long term strategy (energy efficiency) for long term benefit.	4.58	0.499	2
5.	People with real ambition and desire to implement energy efficiency.	4.34	0.772	5
6.	Practicing energy efficiency for improving working conditions.	4.58	0.499	2
7.	Adoption of environmental management system in implementing energy efficiency in a building.	4.54	0.503	4
8.	Reduce environmental impacts through reduction of carbon dioxide (CO_2) emission.	4.58	0.499	2
9.	Sufficient and availability of information will encourage in practicing energy efficiency.	4.58	0.499	2
10.	Sufficient technology to be implement in a building.	4.66	0.479	1
	AVERAGE MEAN	**4.55**	**0.526**	

Furthermore, the result obtained stated that four (4) variables had the same score mean of 4.58. These four (4) variables were, *long term strategy (energy efficiency) for long term benefit, practicing energy efficiency for improving working conditions, reduce environmental impacts through reduction of carbon dioxide (CO_2) emission, and sufficient and availability of information would encourage practicing energy efficiency*. The result indicated that long term strategy (EE) was one of the main driving factor as implementing EE in a building garnered many profit and benefits. The maintenance cost could also be reduced as compared to a conventional building. According to Rohdin and Thollander (2006), long term strategy could be a driving force in resolving strict control of investment and these driving factors usually gave an effect in a long-term period.

Meanwhile, practicing EE could *improve working conditions* and simultaneously *reduce environmental impact*. These two variables were related because EE produced energy by maintaining the maximum output. For example, by using the efficient machine in a building, the emission of carbon dioxide could be reduced. So, higher air quality can be maintained and the impact on the surrounding can be reduced. This was supported by Apeaning and Thollander (2013) which mentioned that environmental surroundings and the internal building would be more guaranteed. Buildings that implementd EE would produce energy without bringing high risk to the environment due to the reduction of carbon dioxide in the air. Universities that wished for a title of 'green building' would focus more on this driving factor. In addition, sufficient and availability of information was also the top two ranking of driving factors. This factor was important because insufficient information would make someone interested to implement EE. By knowing EE, people could understand the benefit, outcome and profit by implementing EE. However, it was contradicted with Thollander and Ottosson (2008) which argue that the information was not the major factor that facilitate the implementation of EE in buildings.

Besides that, another one of the top-five driving factor was *cost reduction due to lowered use of energy* with a mean score of 4.56. Cost reduction attracted many building owners to implement EE. This was because the operational cost could be reduced. Most conventional buildings would spend high costs during the operational period due to the high production of electricity. According to Thollander and Ottosson (2008), cost reduction was the most important driving factor because more profits could be gained rather than spending high costs in the operation period. This was supported by Lawrence et al. (2019) which revealed that the cost reduction from the lowered use of energy as the main driver that facilitated the implementation of EE.

Furthermore, it was also clarified that *various benefits could be gained by implementing EE in a building*, *increasing the energy prices (electric bill) during operation period by monitoring or limit the energy usage of the building* and *adoption of the environmental management system in implementing EE in a building*. These three (3) variables had a mean score of 4.54 which was ranked as number four (4). By implementing EE, various benefits could be gained such as cutting the operational cost, gaining more profit, reduce environmental pollutions and others. Moreover, increasing the electric bill was one of the driving factors to implement EE, this was because the building owners were unwilling to spend high electric costs especially during the operational period. So they intended to implement energy efficiency to spend lower costs during the operational period and focused for more profit. This was supported by Thollander and Ottosson (2008), increasing the energy prices was one of the most influential factors to force building owners in applying EE. Moreover, the adoption of an environmental management system was one of the driving forces in implementing EE. In universities, the environmental management system could be adopted at offices, labs and other facility rooms. This system could control negative impacts such as air pollution and the emission of other harmful gases. According to Rohdin and Thollander (2006), the environmental management system was one of the driving forces and it played a significant role in promoting the adoption of technologies and practices.

Other than that, the least mean score was 4.34 which was *people with real ambition and desire to implement EE*. This driving force appeared in-self which was considered 'real ambition' and this made it difficult to be influenced by people surrounding. People with real ambition wanted to gain many benefits and profit from their building. In addition, some people cared about environmental and health so this encouraged them to implement energy efficiency in building. According to Rohdin and Thollander (2006) and Rohdin et al. (2007), there were several people being successful in adopting energy efficiency because of their ambitious driving force.

CONCLUSION

In conclusion, controlling the greenhouse gas (GHG) emission was crucial to ensure that the environment can be sustained and maintained in good condition. There were many driving factors that facilitated EE in public universities. Based on the research, implementation of sufficient technology in building would attract the building owners in implementing EE and became the major factor in executing EE in buildings. The other factors were long term benefit that would be gained by implementing EE; sufficient information and reduced carbon dioxide (CO_2) emission. Reduction of of cost during the operation period was also one of the driving

factors in implementing EE. Most of the building owner that implemented EE could reduce the operation cost besides the consumption of energy with the same output as the conventional method. This research had also identified that people with real ambition and desire was the lowest factor in implementing EE due to subjective notions that depends on the people's behavior. The implementation of EE was viewed as the most important factor in reducing the environmental impact. It could be attained by determining factors that facilitated practitioners in implementing EE. Thus, it can be concluded that by determining the driving factors, it could encourage the practitioners in practicing and implementing EE effectively especially towards the university buildings.

REFERENCES

Abd Rahman, N. A., Kamaruzzaman, S. N. and Akashah, F. W. (2019). *Scenario and Strategy towards Energy Efficiency in Malaysia: A Review*. MATEC Web of Conferences, 266, 02012.

Alyousef, Y. and Varnham, A. (2010). Saudi Arabia's National Energy Efficiency Programme: description, achievements and way forward. *International Journal of Low-Carbon Technologies, 5*: 291–297.

Apeaning, R. W. and Thollander, P. (2013). Barriers to and Driving Forces for Industrial Energy Efficiency Improvements in African Industries - A case study of Ghana's largest Industrial Area. *Journal of Cleaner Production, 53*(1):204–213.

Backman, F. (2017). Barriers to Energy Efficiency in Swedish Non-Energy-Intensive Micro- and Small-Sized Enterprises - A Case Study of a Local Energy Program. *Journal of Energies, 10*,100.

Cagno, E., & Trianni, A. (2013). Exploring drivers for energy efficiency within small- and medium-sized enterprises: First evidences from Italian manufacturing enterprises. *Applied Energy*, *104*, 276–285. https://doi.org/10.1016/j.apenergy.2012.10.053

Cagno, E., Trianni, A., Abeelen, C., Worrell, E., & Miggiano, F. (2015). Barriers and drivers for energy efficiency: Different perspectives from an exploratory study in the Netherlands. *Energy Conversion and Management*, *102*, 26–38. https://doi.org/10.1016/j.enconman.2015.04.018

Cooremans, C., & Schönenberger, A. (2019). Energy management: A key driver of energy-efficiency investment? *Journal of Cleaner Production*, *230*, 264–275. https://doi.org/10.1016/j.jclepro.2019.04.333

Gerarden, T. D., Newell, R. G., & Stavins, R. N. (2017). Assessing the Energy-Efficiency Gap, *55*, 1486–1525.

Haseeb, M., Kot, S., Hussain, H. I., & Jermsittiparsert, K. (2019). Impact of Economic Growth, Environmental Pollution, and Energy Consumption on Health Expenditure and R&D Expenditure of ASEAN Countries. *Energies*, *12*(3598), 1–21.

Hassan, J.S, Zin, R. M., Abd Majid, M. Z., Balubaida, S., Hainin. M. R. (2014). Building Energy Consumption in Malaysia: An Overview. *Jurnal Teknologi (Sciences & Engineering), 70*:7(1): 33–38.

International Energy Agency, (2007). Mind the Gap, Quantifying Principal-Agent Problems in Energy Efficiency. International Energy Agency (IEA), 224 .

Intergovernmental Panel on Climate Change (IPCC), (2007). Impacts, Adaptaion and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, 976 pp.

Johnson, H. and Andersson, K. (2016). Barriers to Energy Efficiency in Shipping. *WMU Journal of Maritime Affairs, 15*(1): 79–96.

Jomoah I.M., Al-Abdulaziz A.U., Sreerama K. (2013). *Energy Management in the Building of a University Campus in Saudi Arabia-A Case Study*. International Conference on Power Engineering, Energy and Electrical Drives, Istanbul, Turkey. 659-663.

Lawrence, A., Nehler, T., Andersson, E., Karlsson, M., Thollander, P. (2019). Drivers, Barriers and Success Factors for Energy Management in The Swedish Pulp and Paper Industry. *Journal of Cleaner Production, 223*: 67–82.

Lee, K. H. (2015). Drivers and Barriers to Energy Efficiency Management for Sustainable Development. *Journal of Sustainable Development, 23*(1): 16–25.

Lo K., (2013). Energy Conservation in China's Higher Education Institutions. *Energy Policy, 56*, 703–710

Maiorano, J. and Savan, B. (2015). Barriers to Energy Efficiency and The Uptake of Green Revolving Funds in Canadian Universities. *International Journal of Sustainability in Higher Education, 16*(2): 200–216.

Mohd Salleh, M. N., Kandar, M. Z. and Md Sakip, S. R. (2016). Benchmarking for Energy Efficiency on School Buildings Design: A Review. *Procedia - Social and Behavioral Sciences, 222*(1): 211–218.

Morrissey, J., Dunphy, N. and MacSweeney, R. (2014). Energy Efficiency in Commercial Buildings: Capturing Added-Value of Retrofit. *Journal of Property Investment and Finance, 32*(4):396–414.

Neumayer, M. D. E. (2001). Overcoming Barriers to Campus Greening. *International Journal of Sustainability in Higher Education, 2* (2): 139-160.

Nkosi, S. B. and Pretorius, J. H. C. (2017). *Challenges and Strength of Current Industrial Energy Efficiency Management Practices in Steam Industries*. IOP Conference Series: Earth and Environmental Science, 73(1).

Rohdin, P. and Thollander, P. (2006). Barriers to and Driving Forces for Energy Efficiency in the Non-Energy Intensive Manufacturing Industry in Sweden. *Energy, 31*(12):1836–1844.

Rohdin, P., Thollander, P. and Solding, P. (2007). Barriers to and Drivers for Energy Efficiency in The Swedish Foundry Industry. *Policy, 35*(1): 672–677.

Schleich, J. (2007). *The Economics of Energy Efficiency: Barriers to Profitable Investments*. EIB Papers, ISSN 0257-7755, European Investment Bank (EIB), Luxembourg, 12(2): 82-109.

Sadrzadehrafiei, S., Sopian, K., Mat, S., Lim, C. (2009). Energy Consumption and Energy Saving in Malaysian Office Building. *Energy Policy. 37*(10): 4104–4113.

Sharif Ali, S. S., Razman, M. R., & Awang, A. (2020). The nexus of population, gross domestic product growth, electricity generation, electricity consumption and carbon emissions output in Malaysia. *International Journal of Energy Economics and Policy, 10*(3), 84–89. https://doi.org/10.32479/ijeep.8987

Soares, N., Pereira, L. D., Ferreira, J., Conceição, P., Silva, P. P. (2015). Energy Efficiency of Higher Education Buildings: A case study. *International Journal of Sustainability in Higher Education, 16*(5): 669–691.

Sorrell, S., O'Malley, E., Schleich, J., Scott, S. (2004). The Economics of Energy Efficiency: Barriers to Cost-Effective Investment. *The Economics of Energy Efficiency, 14*(1): 186–192.

SuPerBuilding, (2012). Sustainability and Performance Assessment and Benchmarking of Buildings Final Report. VVT: 466 pp.

Thollander, P. and Ottosson, M. (2008). An Energy Efficient Swedish Pulp and Paper Industry-Exploring Barriers and Driving Forces For Cost-Effective Energy Efficiency Investments. *Energy Efficiency, 1*(1): 21–34.

Umar, U. A., Khamidi, M. F. and Shika, S. A. (2012). *Building Energy Efficiency For Sustainable Development in Malaysia.* Proceedings of International Conference on Innovation & Research in Technology for Sustainable Development (ICIRT 2012). India 7-10.

United Nations Environment Programme (UNEP), (2007). Buildings and Climate Change: Status, Challenges and Opportunities. United Nations Environment Programme (UNEP), Paris. 79 pp.

Worrell, E. (2011). Barriers to Energy Efficiency: International Case Studies on Successful Barrier Removal. United Nations Industrial Development Organization - Development policy, Statistics & Research branch 14(1): 1-19.

WWF European, (2005). The Energy Efficiency Business Challenge. WWF European Policy Office , Belgium: 11 pp.

Yüksek, I., & Karadayi, T. T. (2017). Energy-Efficient Building Design in the Context of Building Life Cycle. *INTECH*, 93–123.

A META-ANALYSIS OF THERMAL COMFORT STUDIES IN SOUTHEAST ASIA EDUCATIONAL BUILDING

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Abstract
Thermal comfort in a classroom plays an essential role in a student's life as it affects the student's comfort, well-being, and learning success. Students spend much of their time in class and at school. Therefore, the classroom's thermal comfort must be seriously considered due to the high density of occupants and the detrimental effect that the thermal climate may have on the students' satisfaction and learning performance. This paper presents an overview of thermal comfort studies in educational buildings over the last twenty years in countries within the South East Asia region. These countries share the same tropical climates, which is generally warm throughout the year. The study used Systematic Literature Review (SLR) method and it is divided into two sections; the first section reviews the variables measured to determine thermal comfort and the second section reviews results based on the educational stage, and the applied thermal comfort approach. The finding shows that almost all reviewed studies used similar method and parameter. It also shows the thermal comfort studies were mostly done in university level. However, almost all studies concluded that thermal expectations of students were not within the comfort spectrum offered by the guidelines. Thus, this study will provide strong evidence that there is a need for thermal comfort studies for students by considering their various age and educational level.

Keywords: *Educational building; learning performance; South East Asia Region; systematic literature Review; thermal comfort.*

INTRODUCTION

Students spend more time at the educational building, school, or class than any other buildings (Almeida, Ramos, & De Freitas, 2016; Hassan Abdallah, 2017). The school is a central location for students and teachers to spend their days studying and learning (Ramli et. Al, 2019) Therefore, the school's environmental condition is considered important because it influences not only comfort and health, but also working and learning efficiency (Zomorodian, Tahsildoost, & Hafezi, 2016). Not only air pollutant that presents in the building, but temperature also influence students' performance (Heracleous & Michael, 2019). It is also supported by Jiang, Wang, Liu, Xu, & Liu (2018), stating that high and low temperature can cause thermal discomfort and negatively impact the students' learning performance and well-being. Mishra & Ramgopal (2015) reported that the classroom's thermal environment would affect students' ability to grab instruction.

Many studies on thermal comfort were conducted worldwide, but the investigated buildings were mostly residential and office (Zhang, Zheng, Yang, Zhang, & Moschandreas, 2007; Wang, Li, Ren, & He, 2014). According to Kim & de Dear (2018), most existing research investigating indoor thermal environmental conditions was based on adult subjects' office situations. Mors et al. (2011) even suggested that more research is needed on children's thermal comfort since adults' assessment method does not seem applicable.

This paper focuses on the literature review on thermal comfort studies in the educational building in South East Asia countries (Malaysia, Indonesia, Singapore, Thailand, Laos, Vietnam, Myanmar, Brunei, Timor-Leste, Philippines, and Laos). The countries share the same tropical climate, which is generally warm throughout the year. Many research has been conducted to investigate thermal comfort within these countries. However, there is still a lack of studies on the classroom's thermal comfort. Therefore, this paper will review previous literature regarding thermal comfort in two sections, which are i) Variables to measure thermal comfort in an educational building, and ii) Study results based on the educational level and the applied thermal comfort approach.

LITERATURE REVIEW

Thermal Comfort in the Educational Building

As defined by ASHRAE, thermal comfort is the condition of mind that expressed satisfaction with the thermal environment. Yatim, Zain, Darus, & Ismail (2011) stated that thermal comfort is an important aspect of establishing comfort in a building. Šenitková (2017) added on through research that thermal comfort affects peoples' physical and physiological health.The educational building's primary goal is to provide students from age 2 to 26 years old with a favourable mood or atmosphere in a classroom to ensure an effective teaching and learning process to take place. The educational system involves different levels across the globe, and each level spent a certain amount of time in the classroom more than any other buildings. Therefore, educational buildings, especially classrooms, should provide a stimulating environment to enhance the learning process.

Numerous research published has proved a strong correlation between classroom air quality and thermal comfort with students' performance and well-being. According to Jiang, Wang, Liu, Xu, & Liu (2018), the high and low temperature can cause thermal discomfort and negatively impact the students' learning performance and well-being. Mishra & Ramgopal (2015) reported that the classroom's thermal environment would affect students' ability to grab instruction. Wargocki & Wyon (2013) investigated how classroom condition affects the children schoolwork performance. Improving the ventilation resulting in improved air quality leads to performance increase by 14% while reducing the indoor temperature leads to performance improvement by 4%. It becomes evident that thermal comfort in educational buildings is important as the thermal comfort in any other buildings.

Thermal Comfort in Educational Building in South East Asia

Southeast Asia comprises 11 countries of diversity in religion, culture, and history: Brunei, Myanmar, Cambodia, Timor-Leste, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, and Vietnam. Southeast Asia's climate can be described as tropical; the weather tends to be the hot and humid most of the year. A significant number of thermal comfort studies carried out in the recent decades have been devoted to determining thermally comfortable temperatures in various settings within this region. However, there were still lack found since most of the studies were focusing on residential building and adult comfort level, which does not apply to children.

Thermal comfort approaches and variables

In the reviewed papers, surveys have been conducted in both field measurement (objective survey) and questionnaire (subjective survey) following ISO 7730 or the ASHRAE 55 standard regulations. However, some studies used Computational Fluid Dynamic simulation to measure the thermal comfort level (Ge, Xu, Poh, Ooi, & Xing, 2019; Suhaila et al., 2019). The study periods were varied from less than a week to the whole year, considering the dry season and rainy season. The interrelation between objective and subjective data was shown by using statistical analysis techniques. The studied educational buildings were also differed in architectural (e.g., room dimensions, window wall ratio, shadings), constructional (thermal envelope properties), and mechanical (heating, cooling, and ventilation system) parameters. The studied cases were mainly air-conditioned and mechanically ventilated by fans with a few cases studying naturally ventilated room.

Different physical parameters are measured based on the studies' purposes. However, in almost all studies, similarities can be seen, measuring four environmental factors (air temperature, relative humidity, air velocity, and the radiant temperature) and two personal parameters (insulation and metabolic rate). Besides, there were also studies measuring the illumination level, the concentration of carbon dioxide, noise level (Angeles, Ho, Le, Gillott, & Rodrigues, 2016; Kamaruzzaman & Samsul Bin Mohd Tazilan, 2013; Mao, Chen, & Sun, 2017; Othman, Zaki, Ahmad, & Razak, 2019; Samad, Aziz, & Isa, 2017; Talarosha, Satwiko, & Aulia, 2020). On the other hand, some studies added wind direction and solar radiation in the measurement since the case studies involved outdoor and semi-outdoor areas (Othman et al., 2019).

Subjective surveys (questionnaires) were mostly assessed thermal sensations and preferences, but air humidity and air velocity are also currently being questioned. Most surveys use descriptive scales, such as the seven-point and five-point Likert scale, ASHRAE or the Bedford scales, to rate thermal sensation. The number of respondents in the reviewed studies differed from the smallest of 20 to the biggest of 1415 respondents, with the most common age of 18 years old and above. Questionnaires were different according to age groups; for instance, the survey for primary students contained coloured pictures, and the questions were limited to ensure data accuracy.

Educational Levels

Educational levels can be divided into three: 1. Primary level, (aged 7 to 11 years old), 2. Secondary level (aged 12 to 17 years old), and 3. University level (aged 18 to 28 years old). Among all the thermal comfort studies carried out in the South East Asian region for the past ten years, the university level was mostly conducted (57%), followed by the primary level (36%) and the secondary level (7%). Almost all studies at the university level were conducted in the air-conditioned room or lecture hall in which students have control of the system. It resulted in more acceptance and satisfaction of the thermal comfort. Furthermore, students at the university level were not regulated with uniforms than the primary and secondary schools. However, there was also a study by Amin, Akasah, & Razzaly (2015) that found students experienced sick building syndrome, such as running nose, dry skin, and flu-like symptom while utilising universities laboratories using the centralised air-conditioned system.

Most of the studies conducted in primary and secondary schools were either conducted naturally ventilated or mechanically ventilated. The students also were restricted with the uniforms rule. Similarly, all reviewed papers on primary and secondary levels reported dissatisfaction concerning the students' thermal comfort. Almost none of the classroom investigated fell on the thermal comfort of ASHRAE- 55 standard (Kamaruzzaman & Tazilan, 2013; Wong & Khoo, 2003). A study by Mao et al. (2017) in the Philippines showed that their public elementary school classrooms' environmental conditions are not conducive for learning based on the thermal, acoustical, and lighting standards. On the other hand, a study by Le, Gillott, & Rodrigues (2017) reported that children in Vietnam already adapted to a hot climate and had higher thermal comfort tolerance than adults. The study suggested no need to use air conditioning systems all year round to achieve sustainability in the educational system without compromising the students' thermal comfort level.

METHODOLOGY

According to Nawi et al. (2011), literature review involved describing, summarizing, evaluating and clarifying the content of information. Similarly, the Systematic Literature Review (SLR) is a literature review collecting and critically analysing multiple research studies or papers through a systematic process. SLR consists of four phases (Figure 1).

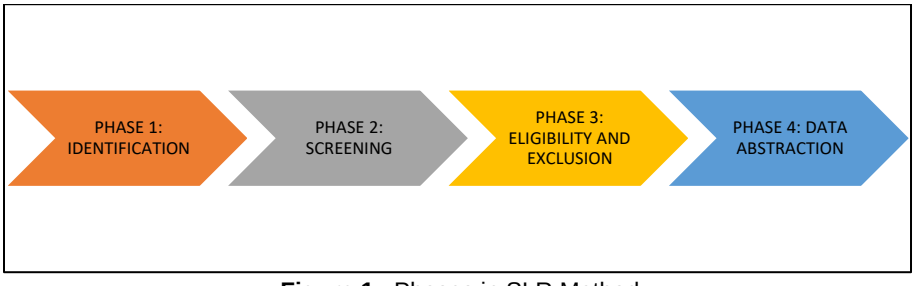

Figure 1. Phases in SLR Method

Phase 1: Identification of Literature Review

In this phase, rigorous research uses any related words, such as synonyms, related terms, and keywords. It will gain more choices of articles within the research topic. Online scientific journal publications in Building and Environment, including Scopus and Science Direct, are examples of established databases. Table 1 shows the search strings used.

Table 1. Search String

Science Direct	TITLE-ABS-KEY ("thermal comfort" AND "educational building" OR "school" AND "malaysia" OR "vietnam" OR "thailand" OR "singapore" OR "indonesia" OR "cambodia" OR "brunei" OR "timor leste" OR "myanmar" OR "laos" OR "philippines")
Scopus	TITLE-ABS-KEY ("*thermal comfort" AND "educational building" OR "school" AND "malaysia" OR "vietnam" OR "thailand" OR "singapore" OR "indonesia" OR "cambodia" OR "brunei" OR "timor leste" OR "myanmar" OR "laos" OR "philippines")*
Google Scholar	Thermal comfort, educational building, classroom, Malaysia, Thailand, Singapore, Indonesia, Brunei, Philippines, Timor Leste, Laos, Cambodia, Vietnam, Myanmar

Phase 2: Screening of Literature Review

In this phase, the articles were screened to choose those relevant and related to the educational building's thermal comfort context. Scopus database generated 23 articles, but only ten relevant articles were selected for this paper. Meanwhile, ScienceDirect generated 23 articles, but only eight relevant articles were selected. There were several same articles found on both databases. The method of "reference by reference" or "snowball" was also used to find relevant articles based on the articles reviewed earlier. Google Scholar was also used as a supporting database. In total, this paper reviewed 27 relevant articles.

Phase 3: Eligibility and Exclusion

In this phase, all articles chosen in phase 2 were analysed thoroughly to explicit the information. The data was tabulated based on the checklist of the items: publication year, country of study, educational levels, thermal comfort approach used in the study, variables used, time and period of the studies, the type of ventilation in the building, and respondents' age.

Phase 4: Data Abstraction

In this phase, a conclusion was made based on the tabulated data. Most of the research used the same thermal comfort approach with the same parameters. On the other hand, there is still a lack of research involving primary and secondary schools. Table 2 shows a summary of thermal comfort studies in the educational building for the past 20 years

Table 2. Summaries of Thermal Comfort Studies in the Educational Building in the South East Asia Region within 20 Years

Years	Authors	Country	Level	TC Approach	Variables	Operation Type	Time of Studies	Respondent
2003	Nyuk Hien Wong, Shan Shan Khoo	Singapore	Secondary	FS and SM	Environmental parameters - air temperature, relative humidity and air velocity, mean radiant temperature Personal parameters - metabolic rate and clothing insulation	MV	21st – 24th August 2001 8.00 am to 1.00 pm	506 (aged 13 – 18 y/o, aged 26 – 50 y/o)
2008	Y.H. Yau	Malaysia	University	FS and SM	Environmental parameters - air velocity, room temperature, and relative humidity	AC	N/A	N/A
2009	Ibrahim Hussein, M. Hazrin A. Rahman, and Tina Maria	Malaysia	Primary Secondary University	FS and SM	Environmental parameters - air velocity, room temperature, and relative humidity	AC & MV	15th December 2008 – 21st January 2009	141
2011	Yatim, Zain, Darus, & Ismail	Malaysia	University	FS and SM	Environmental parameters - air temperature, relative humidity and air velocity, mean radiant temperature	AC	N/A	232 (aged 18 – 27 y/o)
2012	Makaremi, Salleh, Jaafar, & GhaffarianHoseini	Malaysia	University	FS and SM	Environmental parameter - air temperature, relative humidity and air velocity, mean radiant temperature Personal parameters - metabolic rate and clothing insulation	Shaded outdoor space	March 16th – 17th & April 7th – 8th 2010 9:00 am to 5:00 pm	200
2013	Hussin, Ismail, & Ahmad	Malaysia	University	SM	The assessment was based on the occupants' vote on the thermal sensation and impressions of comfort concerning air temperature, relative humidity, and air movement	AC	N/A	238
2013	Chan, Che-Ani, & Nik Ibrahim	Malaysia	Primary	SM	The assessment of thermal comfort satisfaction levels among teachers	NV	N/A	413
2013	Kamaruzzaman & Samsul Bin Mohd Tazilan	Malaysia	Primary	FS	Environmental parameters - air temperature, relative humidity and air velocity, mean radiant temperature, noise, illuminating, and carbon dioxide concentration	NV & MV	7th – 11th May 2012	41
2015	Puangmalee, Hussaro, Boonyayothin, & Khedari	Thailand	University	FS and SM	Environmental parameters - air temperature, relative humidity and air velocity	AC	N/A	660

Table 2. Summaries of Thermal Comfort Studies in the Educational Building in the South East Asia Region within 20 Years (cont'd)

Years	Authors	Country	Level	TC Approach	Variables	Operation Type	Time of Studies	Respondent
2015	Amin, Akasah, & Razzaly	Malaysia	University	FS and SM	Environmental parameters - air temperature, relative humidity and air velocity The subjective assessment was based on the SBS among students	AC	November to December 2012	71
2016	Karyono & Delyuzir	Indonesia	Primary	FS and SM	Environmental parameters - air temperature, relative humidity and air velocity	AC & NV	September & November 2014 8.00 am and 2.00 pm	State school: 501 (aged 8 - 13 y/o) Private school: 207 (aged 9 – 13 y/o)
2016	Angeles, Ho, Le, Gillott, & Rodrigues	Vietnam	Primary	FS and SM	Environmental parameters - air temperature, relative humidity and air velocity, mean radiant temperature, noise, illuminating, and carbon dioxide concentration	NV & MV	July to September 2015	Aged 8 – 11 y/o
2017	Mao, Chen, & Sun	Philippines	Primary	FS and SM	Environmental parameters – temperature, illuminance, and sound level	MV	N/A	N/A
2017	Zaki, Damiati, Rijal, Hagishima, & Abd Razak	Malaysia (Japan)	University	FS and SM	Environmental parameters - outdoor temperature, indoor air temperature, indoor globe temperature, indoor air velocity, and indoor relative humidity	Mechanically cooling mode – AC on, Free running mode – AC off	N/A	1415 (aged 20 – 23 y/o)
2017	Mahyuddin, Wajdi Akashah, & Malina Jamaludin	Malaysia	University	FS and SM	Environmental parameters – relative humidity, temperature, particle matters, carbon dioxide and VOC concentration and light intensity, outdoor environments, such as wind speed, wind direction, and temperature	MV	Two weeks	20
2017	Kindangen	Indonesia	University	FS and SM	Environmental parameters - air temperature and air velocity	NV	morning (7.00 am to 12.00 pm), at noon (12.00 pm to 2.00 pm), and in the afternoon (2.00 pm to 6.00 pm)	182

Table 2. Summaries of Thermal Comfort Studies in the Educational Building in the South East Asia Region within 20 Years (cont'd)

Years	Authors	Country	Level	TC Approach	Variables	Operation Type	Time of Studies	Respondent
2017	Le, Gillott, & Rodrigues	Vietnam	Primary	FS and SM	Long term recording - outdoor air temperature and relative humidity, indoor temperature and humidity Spot point measurement – temperature and relative humidity	Hybrid ventilated	March 2016 – January 2017	Aged 8 – 11 y/o
2017	Mustapa, Salim, Ali, & Rijal	Malaysia	University	FS and SM	Environmental parameters - air temperature, globe temperature, relative humidity and air velocity	AC	August 2015, December 2015, and January 2016	28 (aged 24 – 26 y/o)
2017	Samad, Aziz, & Isa	Malaysia	Primary	FS and SM	Environmental parameters - air temperature, air velocity, humidity, noise, daylighting level omitting IAQ parameters - smell and visual quality	NV & MV	N/A	Aged 10 – 11 y/o
2018	Hamzah, Gou, Mulyadi, & Amin	Indonesia	Primary	FS and SM	Environmental parameters - air temperature, relative humidity and air velocity, mean radiant temperature	NV	8.00 am to 2.00 pm	1111
2019	Karyono, Heryanto, & Faridah	Indonesia	University	FS and SM	Environmental parameters - air temperature, globe temperature, relative humidity and air velocity	AC	29th April 2013, 11th September 2013, 22nd May 2013	54 (30 males, 24 females, aged 19 – 24 y/o)
2019	Puangmalee, Hussaro, & Boonyayothin	Thailand	University	FS and SM	Environmental parameters - air temperature, relative humidity and air velocity	AC	N/A	660 (424 males, 236 females, aged 21 – 23 y/o)
2019	Othman, Zaki, Ahmad, & Razak	Malaysia	University	FS and SM	Environmental parameters - air temperature, globe temperature, relative humidity and air velocity, wind direction, solar radiation	Outdoor and semi-outdoor areas	February to May 2017 9.00 am 4.00 pm	507 (age 18 – 22 y/o)
2019	Suhaila et al.	Malaysia	University	FS, SM, and computational measurement	Environmental parameters - air temperature, relative humidity and air velocity	AC	N/A	N/A

Table 2. Summaries of Thermal Comfort Studies in the Educational Building in the South East Asia Region within 20 Years (cont'd)

Years	Authors	Country	Level	TC Approach	Variables	Operation Type	Time of Studies	Respondent
2019	Lau, Zhang, & Tao	Singapore	University	FS and SM	Environmental parameters - air temperature, globe temperature, relative humidity and air velocity	AC, Hybrid, NV	February and April from 2015 to 2017	1043
2019	Ge, Xu, Poh, Ooi, & Xing	Singapore	N/A	Computational Fluid Dynamic Simulation	CFD simulations have been carried out to evaluate the natural ventilation condition of the classrooms and identify the plausible reasons causing thermal discomfort	NV	N/A	N/A
2020	Talarosha, Satwiko, & Aulia	Indonesia	Primary	Field measurement	Environmental parameters - air temperature, relative humidity, carbon dioxide concentration, and air velocity	NV	N/A	N/A

**NV – naturally ventilated, MV – mechanically ventilated, AC- air-conditioned, N/A – not available*

ANALYSIS AND DISCUSSION

Based on the reviewed articles, thermal comfort studies have mostly carried out in Malaysia with 51% (Figure 2). However, the literature review showed that the study of thermal comfort in the educational building was still minimal in the South East Asia region, where it only involved only 6 out of 11 countries. Figure 3 shows the number of researches based on education level. It can be observed that most of the studies focused on the university level compared to the secondary and primary levels.

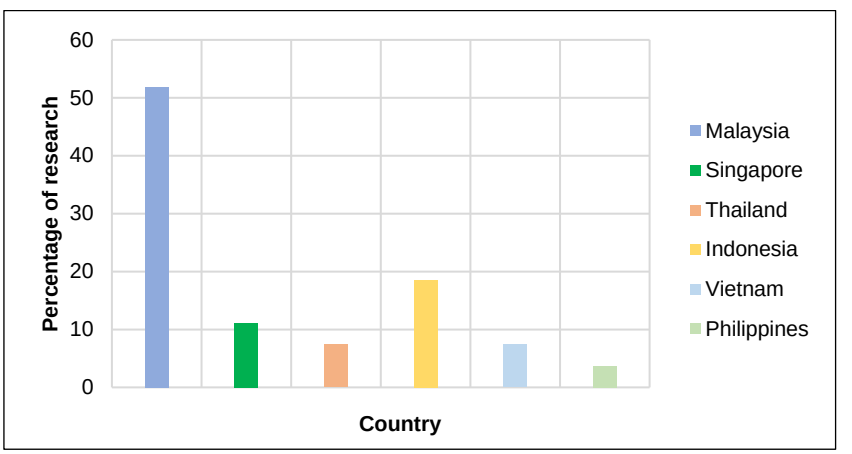

Figure 2. Percentage of Researches According to Countries

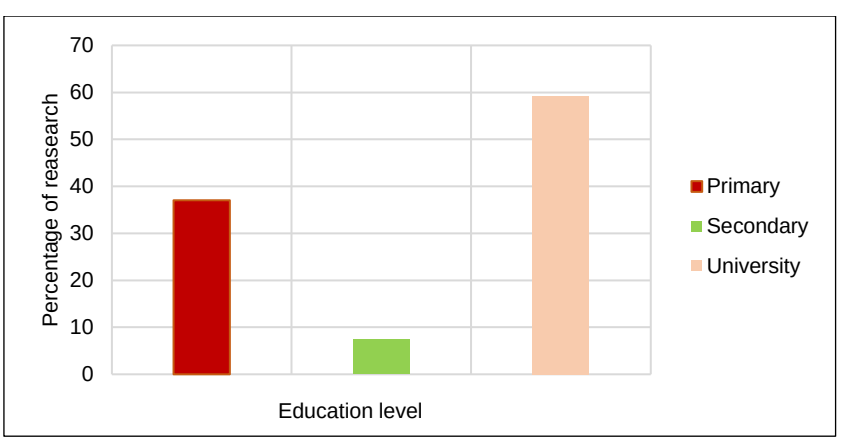

Figure 3. Number of Researches According to Education Level

As shown in Figure 4, investigations were mostly done in the air condition buildings due to number of thermal comfort investigation were high in university classroom. This is followed by naturally ventilated and mechanically ventilated. There were also investigation in a hybrid ventilation mode and outdoor environment.

Most research used the combination of field measurement and subjective measurement in which both are carried out simultaneously. Similar indoor environmental parameters were used by almost all researchers, which are the temperature, relative humidity, air velocity, and mean radiant temperature. A few researchers also included other IEQ parameters, such as noise and illuminance, and IAQ parameters, such as carbon dioxide content and VOC trace.

There were also researches that investigate the impact of students' clothing insulation and their metabolic level on thermal comfort. Furthermore, a few investigations did consider the outdoor environment by measuring the outdoor temperature, wind speed and determined the wind direction. Moreover, Computational Fluid Dynamic simulation (CFD) was also used by two studies to investigate the thermal comfort level in the classroom. A few studies at the university level reported that the thermal comfort level was accepted and satisfied. On the other hand, dissatisfaction and thermal discomfort were reported in the primary and secondary levels.

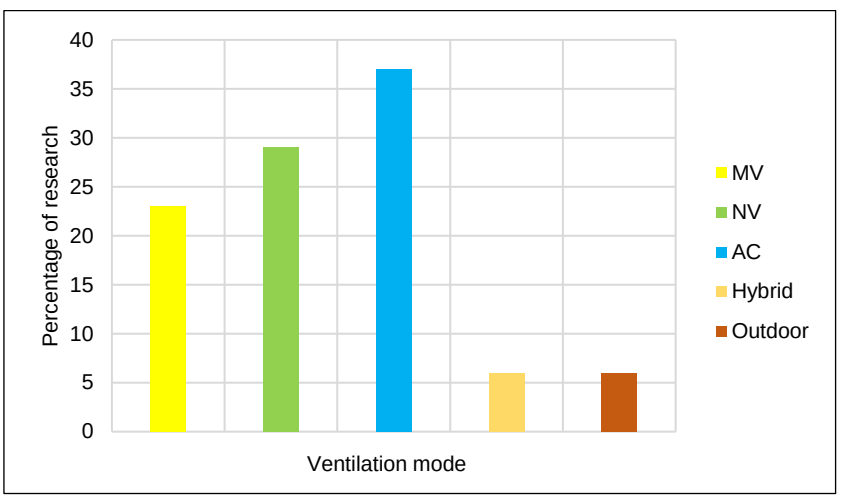

Figure 4. Number of Researches According to the Ventilation Mode

CONCLUSION

This study has led to a conclusion that more studies on thermal comfort in the educational building are needed, especially at the primary and secondary levels. The combination of field measurement and subjective measurement was used to investigate thermal comfort. The most common variables measured by researchers include air temperature, air velocity, mean radiant temperature, and relative humidity. Most studies indicate that students in classrooms at all educational level felt comfortable on the cooler side of the thermal sensation scale. Studies also showed that thermal comfort has a significant effect on students' academic performance and well-being. Nevertheless, it demands more research quantifying the students' performance and well-being in classrooms. University students are in a better position to express their thermal sensation experiences and a better position to make day-to-day adjustments because they are not regulated to wear uniforms and activities carried out are mostly listening to lectures. These adjustments play a significant role in defining thermal acceptability. Thus, in designing new classrooms and retrofitting old classrooms, it is now a priority to provide a conducive learning environment by considering the thermal comfort level.

REFERENCES

Almeida, R. M., Ramos, N. M., & De Freitas, V. P. (2016). Thermal comfort models and pupils' perception in free-running school buildings of a mild climate country. *Energy and Buildings, 111*:64-75.

Abdallah, A. S. H. (2017). Thermal monitoring and evaluation of indoor CO2 concentration in classrooms of two primary governmental schools in New Assiut City, Egypt. *Procedia Engineering*, *205*:1093-1099.

Amin, N. D. M., Akasah, Z. A., & Razzaly, W. (2015). Architectural Evaluation of Thermal Comfort: Sick Building Syndrome Symptoms in Engineering Education Laboratories. *Procedia - Social and Behavioral Sciences*, *204*:19–28. https://doi.org/10.1016/j.sbspro.2015.08.105

Angeles, L., Ho, T. H. I., Le, V. I., Gillott, M., & Rodrigues, L. (2016). *The case for hybrid ventilated primary schools in Ho Chi Minh City in Vietnam . In : . Cities , Buildings ,36th International Conference on Passive and Low Energy Architecture*.

Chan, S. C., Che-Ani, A. I., & Nik Ibrahim, N. L. (2013). Passive designs in sustaining natural ventilation in school office buildings in Seremban, Malaysia. *International Journal of Sustainable Built Environment*, *2*(2):172–182. https://doi.org/10.1016/j.ijsbe.2014.01.002

Ge, Z., Xu, G., Poh, H. J., Ooi, C. C., & Xing, X. (2019). CFD simulations of thermal comfort for naturally ventilated school buildings. *IOP Conference Series: Earth and Environmental Science*, *238*(1). https://doi.org/10.1088/1755-1315/238/1/012073

Hamzah, B., Gou, Z., Mulyadi, R., & Amin, S. (2018). Thermal comfort analyses of secondary school students in the tropics. *Buildings*, *8*(4):1–10. https://doi.org/10.3390/buildings8040056

Heracleous, C., & Michael, A. (2019). Experimental assessment of the impact of natural ventilation on indoor air quality and thermal comfort conditions of educational buildings in the Eastern Mediterranean region during the heating period. *Journal of Building Engineering*, *26*(August):100917. https://doi.org/10.1016/j.jobe.2019.100917

Hussein, I., Rahman, M. H. A., & Maria, T. (2009). Field studies on thermal comfort of air-conditioned and non air-conditioned buildings in Malaysia. *ICEE 2009 - Proceeding 2009 3rd International Conference on Energy and Environment: Advancement Towards Global Sustainability*, (December), 360–368. https://doi.org/10.1109/ICEENVIRON.2009.5398622

Hussin, M., Ismail, M. R., & Ahmad, M. S. (2013). Subjective Perception of Thermal Comfort Study in Air-conditioned University Laboratories. *Procedia - Social and Behavioral Sciences*, *91*:192–200. https://doi.org/10.1016/j.sbspro.2013.08.417

Jamaludin, N. M., Mahyuddin, N., & Akashah, F. W. (2017). Assessment on indoor environmental quality (IEQ) with the application of potted plants in the classroom: Case of university Malaya. *Journal of Design and Built Environment*, *17*(2):1–15. https://doi.org/10.22452/jdbe.vol17no2.1

Jiang, J., Wang, D., Liu, Y., Xu, Y., & Liu, J. (2018). A study on pupils' learning performance and thermal comfort of primary schools in China. *Building and Environment*, *134*:102–113. https://doi.org/10.1016/j.buildenv.2018.02.036

Kamaruzzaman, K., & Samsul Bin Mohd Tazilan, A. (2013). Thermal Comfort Assessment of a Classroom in Tropical Climate Conditions. *Recent Advances in Energy, Environment and Development*, 88–91. Retrieved from http://www.wseas.us/e-library/conferences/2013/CambridgeUSA/ENVMECH/ENVMECH-12.pdf

Karyono, T. H., & Delyuzir, R. D. (2016). *Network for Comfort and Energy Use in Buildings , Thermal comfort studies of primary school students in Tangerang , Indonesia Thermal comfort studies of primary school students in Tangerang , Indonesia*. (April).

Karyono, T. H., Heryanto, S., & Faridah, I. (2019). Thermal comfort study of university students in Jakarta, Indonesia. *Proceedings - Windsor Conference 2014: Counting the Cost of Comfort in a Changing World*, (April), 1276–1285.

Kindangen, J. I. (2017). Investigation of Thermal Environments in Humid Tropical Classroom in Indonesia. *Journal of Engineering and Architecture*, *5*(1):1–14. https://doi.org/10.15640/jea.v5n1a1

Lau, S. S. Y., Zhang, J., & Tao, Y. (2019). A comparative study of thermal comfort in learning spaces using three different ventilation strategies on a tropical university campus. *Building and Environment*, *148*:579–599. https://doi.org/10.1016/j.buildenv.2018.11.032

Le, T. H. V., Gillott, M., & Rodrigues, L. (2017). Children thermal comfort in primary schools in Ho Chi Minh City in Vietnam. *Proceedings of 33rd PLEA International Conference: Design to Thrive, PLEA 2017*, *1*(2015):1187–1194.

Makaremi, N., Salleh, E., Jaafar, M. Z., & GhaffarianHoseini, A. (2012). Thermal comfort conditions of shaded outdoor spaces in hot and humid climate of Malaysia. *Building and Environment*, *48*(1):7–14. https://doi.org/10.1016/j.buildenv.2011.07.024

Mao, C., Chen, C., & Sun, C. (2017). *Advances in Ergonomics Modeling, Usability & Special Populations*. *486*(1000):663–671. https://doi.org/10.1007/978-3-319-41685-4

Mishra, A. K., & Ramgopal, M. (2015). A thermal comfort field study of naturally ventilated classrooms in Kharagpur, India. *Building and Environment*, *92*:396–406. https://doi.org/10.1016/j.buildenv.2015.05.024

Mustapa, M. S., Salim, S. A. Z. S., Ali, M. S. M., & Rijal, H. B. (2017). Investigation of thermal comfort at different temperature settings for cooling in university building. *Journal of Mechanical Engineering*, *SI 4*(4):123–134.

Othman, N. E., Zaki, S. A., Ahmad, N. H., & Razak, A. A. (2019). Outdoor thermal comfort study of an urban university campus in Malaysia. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, *57*(2):288–296.

Puangmalee, N., Hussaro, K., & Boonyayothin, V. (2019). Thermal comfort of Thai students in university buildings under variable indoor conditions of air conditioned space. *Journal of Renewable Energy and Smart Grid Technology*, *14*(1).

Puangmalee, N., Hussaro, K., Boonyayothin, V., & Khedari, J. (2015). A Field of the Thermal Comfort in University Buildings in Thailand under Air Condition Room. In *Energy Procedia* (Vol. 79). https://doi.org/10.1016/j.egypro.2015.11.522

Samad, M. H. A., Aziz, Z. A., & Isa, M. H. M. (2017). Indoor environmental quality (IEQ) of school classrooms: Case study in Malaysia. *AIP Conference Proceedings*, *1892*. https://doi.org/10.1063/1.5005784

Šenitková, I. J. I. J. (2017). Indoor Air Quality and Thermal Comfort in School Buildings. *IOP Conference Series: Earth and Environmental Science*, *95*(4). https://doi.org/10.1088/1755-1315/95/4/042068

Suhaila, H., Suhaimi, I., Mohamed, M. A. S., Mustaffa, M. T., Kartini, A., & Atikah, A. (2019). Thermal Comfort Study of a Classroom in Northern Malaysia: A CFD Approach. *IOP Conference Series: Materials Science and Engineering*, *670*(1). https://doi.org/10.1088/1757-899X/670/1/012011

Talarosha, B., Satwiko, P., & Aulia, D. N. (2020). Air temperature and CO2 concentration in naturally ventilated classrooms in hot and humid tropical climate. *IOP Conference Series: Earth and Environmental Science*, *402*(1). https://doi.org/10.1088/1755-1315/402/1/012008

Wargocki, P., & Wyon, D. P. (2013). Providing better thermal and air quality conditions in school classrooms would be cost-effective. *Building and Environment*, *59*:581–589. https://doi.org/10.1016/j.buildenv.2012.10.007

Wong, N. H., & Khoo, S. S. (2003). Thermal comfort in classrooms in the tropics. *Energy and Buildings*, *35*(4):337–351. https://doi.org/10.1016/S0378-7788(02)00109-3

Yatim, S. R. M., Zain, M. A. M. M. M., Darus, F. M., & Ismail, Z. S. (2011). Thermal comfort in air-conditioned learning environment. *3rd ISESEE 2011 - International Symposium and Exhibition in Sustainable Energy and Environment*, (June), 194–197. https://doi.org/10.1109/ISESEE.2011.5977088

Yau, Y. H., Foo, Y. W., & Mohyi, M. H. H. (2008). A preliminary study on HVAC systems and thermal comfort in a tropical university building in Malaysia. *International Journal of Mechanical and Materials Engineering*, *3*(2):160–175.

Zaki, S. A., Damiati, S. A., Rijal, H. B., Hagishima, A., & Abd Razak, A. (2017). Adaptive thermal comfort in university classrooms in Malaysia and Japan. *Building and Environment*, *122*:294–306. https://doi.org/10.1016/j.buildenv.2017.06.016

Zomorodian, Z. S., Tahsildoost, M., & Hafezi, M. (2016). Thermal comfort in educational buildings: A review article. *Renewable and Sustainable Energy Reviews*, *59*:895–906. https://doi.org/10.1016/j.rser.2016.01.033.

THE APPLICATION OF BIOPHILIC DESIGN STRATEGIES TOWARDS OCCUPANTS' PERCEIVED PSYCHOLOGICAL PERFORMANCE IN MALAYSIAN OFFICE BUILDING

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Abstract
Biophilic design is a strategy to connect humans with nature into the built environment, such as the application of greens, natural light and ventilation, and water element. Previous studies showed that nature could help in enhancing human well-being and psychology. Nowadays, construction in Malaysia has been growing rapidly and continuously develop. It promotes the economic growth resulting in the increase of goods price, and competition for occupation. Thus, this requires occupants to work diligently, resulting in spending most of their time working indoors. Due to these circumstances, occupants are required to work longer hours to fulfil the employer's expectation, such as meeting the deadline and doing the tasks required. Focusing on their work nonstop can develop different health issues, such as stress, unstable emotions, unproductive, and well-being, thus bringing the degradation of occupants' psychology. Maintaining personal psychology is very crucial to enhance their work performance. One of the ways to do so is by being closer to nature. However, their work nature limits their interaction with the natural environment. Hence, this is where biophilic design comes to rescue. There are massive impacts of biophilic design on occupants' psychological performance, yet there is a lack of awareness and knowledge of Malaysian biophilic design. Thus, this paper will highlight the benefits of the application of biophilic design strategies towards occupants' perceived psychological performance using a Systematic Literature Review (SLR). It is hoped that the paper's outcome will contribute to the understanding and importance of biophilic design strategies towards occupants' psychology and well-being.

Keywords: *Application of biophilic design strategies; natural environment; occupants' perceived psychological performance; office building; Systematic Literature Review (SLR).*

INTRODUCTION

For years globally, buildings play an essential role in human society, serving as a shelter or a place to make a living. In recent years, there is much rapid urbanisation that has a powerful impact on the environment. This massive urbanisation can lead to climate change, global warming, biodiversity threats, and decreased access to the environment. Eventually, the current lifestyle and urban living make people distance themselves from the natural world (Yin, Yuan, Arfaei, Catalano, Alen et al., 2018). Hence, biophilic design strategies come to rescue. It serves to fill the gaps between modern design, urbanisation, and human needs. Humans are drawn by nature; hence, the biophilic design strategies function to connect and improve the relationship between nature, built environment, and humans.

According to Kellert (2008), the reconnection of people with nature is considered the primary purpose of applying the biophilic design. It incorporates strategies to connect those two elements. The biophilic design connects outdoor and indoor environments, such as natural

lights, natural ventilation, landscaping, water features, plants, and interior design elements, resembling shapes and forms found in nature, such as painting and sculpture (Gray & Birrell, 2014). Work environment is fundamental to occupants' work life as they spend significant hours at the office as it can indirectly affect occupants' behaviour, health and well-being. Factors such as noise, colour, temperature, use of indoor plants, as well as office design and layout can influence occupants' work performance. Hafeez, Hafeez, Mansoor and Cheema, 2019 reported that a good office environment is essential to ensure occupants' performance.

According to Spector (1997), in his previous observation, he stated that most employers fail to realise the benefits of good working environment hence they often overlook this issue. This problem has caused the unfortunate advance on the performance of the occupants (Raziq & Bakhsh, 2014).Occupants cannot fully utilise their skills and enhance their productivity due to certain reasons; health issue, and unconducive working environment. Malaysian occupants spend most of their time in office building resulted to less connection with natural environment as in the modern era, the built environments are lacking with the integration of nature (Totaforti, 2018). The interaction with nature can reflect people's emotions, thought, and health because naturally, humans derive in close relation with nature. Natural environment is vital in enhancing occupants' moods as it can rejuvenate human wellbeing; psychology, physiology, and cognitive known as Biophilic Design resulting to higher productivity and greater performance (Gillis & Gatersleblen, 2015).

Hence, this paper reviews the documentations of strategies in biophilic design. There are many benefits of biophilic design, however, this paper will only focus on occupants perceived psychological performance in these selected areas; productivity, emotions, cognitive function, reduce stress and well-being. In addition to that, this paper will also stress on the importance of applying biophilic design strategies inside the office building in Malaysia as it will give impacts on occupants' behaviour and psychology to maintain a good performance in the organisation.

LITERATURE REVIEW

Biophilic Design Strategies and Its Design Elements

"Biophilia" is a term derived from the Greek word, meaning 'love of life' (Ramzy, 2015). Enrich Fromm was the first man using the biophilia term in the 1960s. He used the biophilia term to describe that humans tend and are attracted to everything alive (Totaforti, 2018). Later in 1980, Edward O. Wilson, a sociobiologist, defined biophilia as "the innate tendency to focus on life and lifelike processes". During his exploration in the natural world, he exploited the term to describe his real feeling of connection to nature (Sonderlund & Newman, 2015; Totaforti, 2018). The connection with nature, such as plants, can boost and improve human health and well-being, especially in the modern built environment (Gray & Birrell, 2014). Nature should be a component of the building's design (Gautam, 2017). However, in today's architecture, designers or architects often overlook integrating the building with the natural environment. The connection is always blocked by the forms of the building (Totaforti, 2018).

The biophilic design can also be defined as healing architecture design as it is usually applied to hospitals, schools, and workplaces to enhance the recovery times, improve the learning process, and increase productivity. The biophilic design practice and application is

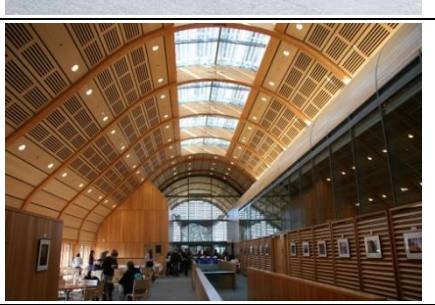
associated with various design strategies, referring to attributes and experiences. There are three types of biophilic design strategies framework: the direct experience of nature, the indirect experience of nature, and the experience of space and place. The direct experience is the actual connection with the natural environmental features in the built environment. In contrast, the indirect experience refers to the contact with the imitation of nature images from its original condition. Finally, the experience of space and place refers to spatial features characteristic of the natural environment (Kellert & Calabrese, 2015).

Table 1. The Attributes and Experiences of Biophilic Design Strategies

Direct Experience of Nature	Indirect Experience of Nature	Experience of Space and Place
Light	Nature images	Prospect and refuge
Air	Natural materials	Organised complexity
Water	Natural colours	Integration of parts to a whole
Plants	Simulating of natural light and air	Transitional space
Animals	Naturalistic shapes and forms	Mobility and wayfinding
Weather	Evoking nature	Cultural and ecological attachment to place
Natural landscape and ecosystem	Information richness	
Fire	Age, change and patina of time	
	Natural geometries	
	Biomimicry	

(Source: Kellert & Calabrese, 2015)

Table 2. Description of Biophilic Designs

Picture	Description
	Direct Experience of Nature Refers to actual interaction with environmental features in built environment such as plants, water and lights.
	Indirect Experience of Nature Interaction with the portrayal or images of nature world from it original condition such as artworks, furniture and colours.
	Experience of Space and Place Indicate on spatial features characteristic of natural environment that have advanced on human health and well-being.

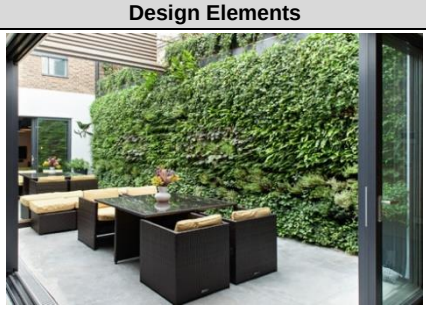
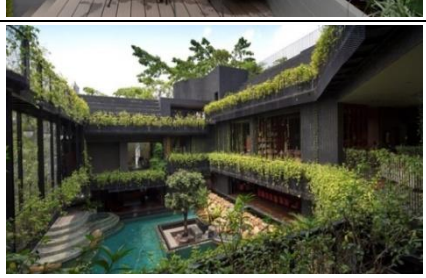
(Source: Kellert & Calabrese, 2015)

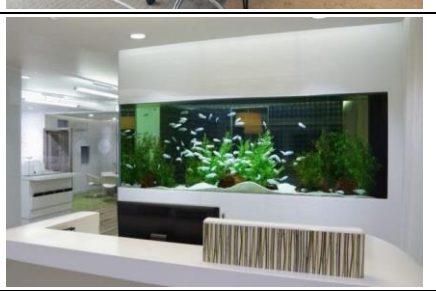
According to Dowton, Jones, Zeunert, and Roos (2017), there are five fundamental conditions of the biophilic design identified by Kellert and Calabrese (2015), which are:

1. The building space requires repetition and continuity of the connection with nature;
2. Able to highlight human setting to the natural world that over transformative time has advanced on people's health, fitness and well-being;
3. Able to develop an emotional connection to specific settings and places;
4. Able to advocate positive interaction between humans and nature; thus, encouraging the relationship between humans and communities; and
5. Able to encourage mutual reinforcing, interconnected, and integrated architectural idea and solution.

There is evidence of biophilic design from three decades of research on the impact of nature on human psychology. It can be claimed that biophilic design is indeed able to be beneficial to human psychology. However, the literature on biophilic design is still relatively rare (Gillis & Gatersleben, 2015). Hence this paper aims to discover more details on the application of biophilic design strategies and the impact on occupants' perceived psychological performance. Many design elements can be used as ideas in designing spaces or building for biophilic design. Table 3 summarises the design elements in biophilic design strategies.

Table 3. Design Elements in Biophilic Design Strategies

Design Elements	Description
	Green Wall / Vertical Greening It is a combination of vegetation into a built environment. Benefits of the green wall are to improve ecological and environmental efficiency. It can positively influence the aesthetical value of the built environment and the well-being of the building. Green wall technology is using a modular panel. Each panel holds its soil (Rakhshandehroo & Mohd Yusof, 2015).
	Rooftop Garden A rooftop garden is located on the higher floor of the building. The roof is an abandoned space that the owner tends to ignore the functionality. Green building can upgrade the quality of life for the human. Thus, it is one of the most effective ways to improve the city's urban environment (Cotthem, 2005).
	Courtyard Garden The application of the courtyard started in the arid region thousands of years ago. It is designated at the enclosed area, usually at the centre of the building surrounded by walls, glass windows, and open to the sky. The courtyard can be fully utilised for gardening, cooking, playing, sleeping, and sometimes keeping animals. A courtyard garden typically consists of various plants, water feature element, pavement, and landscapes (Almhafdy, Ahmad, & Ibrahim, 2013).

Design Elements	Description
	Daylight Opening Window Nowadays, people spend most of their time indoors and in confined office spaces. Hence, the opening window's application to utilise daylighting's full capacity is crucial in the built environment. It is because daylight can improve occupants' emotions, performance, and avoid visual discomfort. Furthermore, daylight can create a dynamic space while reducing buildings' energy needs (Kaya, Yucedag, & Asikkutlu, 2018).
	Indoor Plotting Plants Indoor potting plants can increase the comfort and attractiveness of the built environment. Plants are the basic natural elements representing the natural world. Plants can solve environmental and health problems (Sun & Zhou, 2013).
	Water Features Water features can increase someone's experience of the spaces. Water features can help the indoor environment to be more enjoyable and persuasive because it can create sensory interfaces. Furthermore, the water features could persuade sustainable behaviours and give aesthetical pleasing towards the space (Arroyo, Valkanove & Bonani, 2012).

Biophilic Design Strategies in Office Building

The average working hours for Malaysian occupants are around 15 hours per day. Truthfully, these working hours beat Singapore, Hong Kong, and other Asian countries. As a result, the majority of the occupants are troubled with the current working culture. The occupants' psychology is much worse than in past generations (Hui & Bahauddin, 2018). Recently, AIA Vitality conducted a survey among the occupants, and the result showed that 53% of the employees are overworked, negatively emotional, stressed, and less productive.

The relationship with work has changed, and the working space has been transforming according to the needs (Aboobaker, 2015). Working space and office building are more confined compared to the past. Fortunately, employers quickly realised this issue. The modern workspace is not only high concept but also encourages the sense towards the community, collaborative problem solving, and well-being. Undoubtedly, biophilic design strategies can complement all of these ideas. Indeed, the workplaces are being designed with nature concepts and approaches in mind as nature can impact our health and performance.

Previous studies showed that a comfortable and practical work environment could reduce complaints and absenteeism and increase the occupants' productivity. The satisfaction of the workplace environment can be associated with job satisfaction and perception. Hence, the quality of the workplace environment has a powerful impact on occupants' psychology (Sun

& Zhou, 2013). The application of biophilic design strategies in an office environment can increase productivity and creativity and contribute to occupant's well-being.

Perceived Psychological Performance

According to Oxford (2012), psychology can be defined as the science of mind and how it influences someone's behaviour. Many types and disciplines of psychology can counter and solve various problems faced by humans. In this research, the researchers will highlight performance psychology. Performance psychology is a sub-discipline of psychology. Performance psychology can be defined as examining psychological factors influencing human performance and improving and maintaining various psychology perspectives, such as emotions, productivity, cognitive, action, and perception (Raab, Hoffman, Loinger, & Pizzera, 2015). Thus, the factors influencing occupants' performance are motivation, personality, leadership, and work environment (Singh, 2017).

Nowadays, many psychologists are interested in human's reaction towards the environmental factors influencing the business outcomes. Specifically, they are interested in the synergy between individuals and their work environments. These factors may be crucial elements of both employees' success and happiness in their organisation (Kalantzis, 2016). The office environment plays an important factor in occupants' performance to produce either positive or negative outcomes. An excellent office environment significantly impacts occupants' performance as it can reduce the number of absenteeism and directly lead to increased productivity at the workplace. Moreover, a good office environment can impact the occupants' lifestyle, work-life balance, and health fitness (Naharuddin & Sadegi, 2013).

Other factors that can lead to the occupants' discomfort are lightings, ventilation, and noise. Occupants who always complain about their dissatisfaction and discomfort are the ones who have slow performance. Employers re responsible for giving their occupants comfort to support their work performance (Naharuddin & Sadegi, 2013). According to Lerner and Stopka (2016), a way to improve and restore occupants' cognitive function is to expose them with natural elements, which can automatically increase productivity. Previously, Rachel and Stephen Kaplan, the environmental psychologists, have developed a module called "Attention Restoration Theory (ART)". The module indicates that direct contact with the natural environment can improve the occupant's ability to focus their mental capacity after working hard for some time. Furthermore, occupants viewing nature images have faster reaction times and better memory recall than those viewing urban setting images.

Self-perceived psychological performance has been used to measure the occupants' perception of how they perceived their workplace's psychological performance. They will act according to their thinking while being influenced by their surroundings. Based on the previous research on literature review, the researcher has concluded that the items that must be included in perceived psychological performance are productivity, emotions, reduce stress, cognitive function, and well-being. All things considered; all of these items are needed to improve occupants' performance.

Table 4. Description of Perceived Psychological Performance

Perceived Psychological Performance	Description
Productivity	Productivity is a source of economic growth. Productivity can be defined as ratio between the output volume inputs. It is to measure the efficiency of production inputs such as labours and capitals that have been used in the economy to produce a given level of output. Good productivity can enhance economic growth. Hence, the rise of capacity in productivity improvement is very important (Linna, Ukko, Pekkola & Melkas, 2010).
Emotions	Emotions play with human's feelings. The factors that can trigger someone's emotion are through action, people, physical objects and the environment whether it is in the past, present, or future (Ekkekakis, n.d.). Emotions can be defined as "sudden trouble" that can cause by an experience such as fear, surprise, happiness, and sadness (Cabanac, 2002).
Cognitive Function	Refers to the mental abilities of processes that acquire knowledge and understanding through thought, experience, and senses. Cognitive function can be conscious, unconscious, concrete, abstract, or intuitive. There are many aspects of cognitive such as memory, the formation of knowledge, judgement and evaluation, attention, problem solving, creativity and decision making (Zhang, 2019).
Reduce Stress	All humans will encounter the stress issue during their lifespan. It is a widespread phenomenon that has been dubbed as "Health Epidemic of the 21st Century" by the World Health Organisation (WHO) (Fink, 2010). In the psychological term, stress occurs because of mental press and tension. The factors of the stress are because the complexity of human social, personal issue, ecological environment and interaction of humans with it surrounding (Shahsavarani, Abadi & Kalkhoran, 2015).
Well-being	Well-being is closely related to the ways of human experience and evaluate their lives positively. How people interpret the concept of well-being might differ from one person to other person as it can be understood in countless way (Tov, 2018).

SYSTEMATIC LITERATURE REVIEW METHODOLOGY

Systematic Literature Review (SLR) is a literature review using a systematic method to collect secondary data. It is one of the approaches to collecting, analysing, evaluating, and synthesising the data to answer a specific research question (Piper, 2013). SLR was employed to gather the literature on the benefits of biophilic design strategies towards occupants' perceived psychological performance. There are four phases in the SLR method.

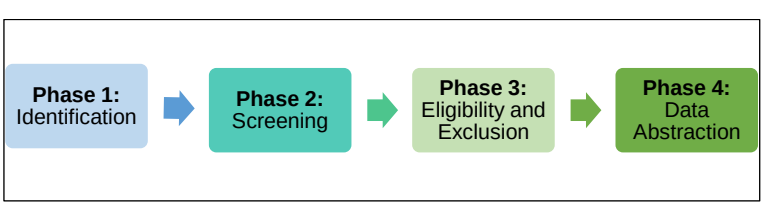


Figure 1. Phases in SLR Method

Phase 1: Literature Identification

A rigorous search was conducted searching for topics related to biophilic design strategies on occupants' perceived psychological performance. It was a process to search any related words, such as synonym, related terms, and main keywords variation. The literature identification served to gather more articles on the topic related to the review in the established publication databases. The primary databases used were Scopus, Research Gate, Mendeley, and Google Scholar. Each of the databases has its advantages.

Table 5. Results of the Identification Process

Title	Main Keyword	Enriched Keywords
The application of biophilic design strategies occupants' perceived psychological performance (Benefits)	Application	Application = utilisation, function, operation
	Biophilic design strategies	Biophilic design strategies = biophilic design attributes, biophilic design approaches, biophilic design patterns, biophilic architecture
	Perceived psychological performance	Perceived psychological performance = Occupants' achievements, workers' perceived psychological performance, workers' achievement
	Benefits	Benefits = impact, effect, influence

Table 6. SLR Research String

Databases	Keywords
Scopus	TITLE-ABS_KEY ((“Application* OR utilisation* OR Operation*) AND (“biophilic design strategy*” OR “biophilic design attribute*” OR “biophilic design pattern*” OR “Biophilic architecture”) AND (“benefit* OR impact* OR effect* OR influence*) AND (“Occupant* perceived psychological performance” OR “occupant* achievement* OR “worker* perceived psychological performance” OR “worker* achievement*))
Google Scholar	TITLE-ABS_KEY ((“Application* OR utilisation* OR Operation*) AND (“biophilic design strategy*” OR “biophilic design attribute*” OR “biophilic design pattern*” OR “Biophilic architecture”) AND (“benefit* OR impact* OR effect* OR influence*) AND (“Occupant* perceived psychological performance” OR “occupant* achievement* OR “worker* perceived psychological performance” OR “worker* achievement*))

Phase 2: Screening of the Identified Literature

In this phase, the identified literature was screened according to the suitable biophilic design strategies context towards occupants' perceived performance in the office building from 36 literature to 15 literature that suited this paper's topic. The screening process was to sort out the article duplicates, non-relevant articles, and non-English publications.

Phase 3: Eligibility and Exclusion

The next phase was eligibility and exclusion. The screened literatures were analysed thoroughly. From the remaining 15 literature, only eight literature were selected for the SLR. The articles without the required information for biophilic design strategies' benefits towards the occupants' perceived psychological performance were removed. The data gathered were extracted and analysed, and subsequently tabulated using the Item Checklist according to Author(s), Title of Publication, Year of Publication, Country of the Study, Types of the Biophilic Design Strategies, and Benefits towards Occupants' Perceived Psychological Performance.

Phase 4: Data Abstraction

The final phase was the data abstraction. To conclude, there are many benefits of biophilic design strategies towards the occupants' perceived psychological performance. Each of the strategies has its benefits. Many previous studies covered the benefits of direct experience of nature only as it is the main element in the biophilic design.

ANALYSIS, DISCUSSION AND FINDINGS

Table 7 shows the SLR analysis of biophilic design strategies and its benefits towards the occupants' perceived psychological performance.This SLR has covered from eight articles and journal from previous researchers. The timeline for this SLR was from year 2014 to year 2019.

Table 7. Application of Biophilic Design Strategies towards Occupants' Perceived Psychological Performance

	Authors	**Terrapin Bright Green LLC**	**Kellert, S. R. & Calabrese, E. F.**	**Gilis, K. & Gatersleben, B.**	**Soderlund, J. & Newman, P.**	**Sharifi, M. & Sabernejad, J.**	**Lerner, A. & Stopka, M.**	**Totaforti, S.**	**Topgul, S.**	**Frequency**
	Year	**2014**	**2015**	**2015**	**2015**	**2016**	**2016**	**2018**	**2019**	
Biophilic Design Strategies	**Benefits**	**Checklist**								
Plants	Calming		√	√			√		√	4
	Reduce Stress	√	√	√	√				√	5
	Positive Emotion	√		√						2
	Improve Productivity		√				√		√	3
	Improve Health		√	√	√		√	√		5
	Improve Concentration	√			√		√		√	4
	Improve Well-being			√					√	2
Light	Positive Emotion		√	√		√			√	4
	Improve Concentration			√		√	√		√	4
	Better Communication			√						1
	Improve Health	√	√			√	√			4
	Improve Well-being		√							1
	Improve Productivity			√			√		√	3
Air	Calming	√	√			√		√		4
	Improve Well-being	√						√		2
	Improve Concentration	√						√		2
	Positive Emotion				√					1
	Improve Productivity	√	√							2
Water	Reduce Stress	√	√			√		√		4
	Calming	√	√	√		√		√		5
	Improve Health		√			√				2
	Improve Concentration	√				√				2

Based on Table 7, many of the researchers highlighted the direct experience of nature as it is the main elements in biophilic design strategies. It is also one of the ways for occupants to have direct contact with nature and natural process. Furthermore, the direct experience of nature is also the basic elements in the built environment.

There are multitude of factors that contribute to the dominant of perceived psychological performance which one of them is by having a direct experience of nature. Previous research stated that people can reduce stress, increase positivity and productivity, and improve health and cognitive function by involving themselves in natural environment. Cognitive function is the ability to have a higher concentration, be more creative, flexible, and have higher memory (Sonderlund & Newman, 2015). Based on Table 4, it can be concluded that there are many benefits highlighted by the researchers.

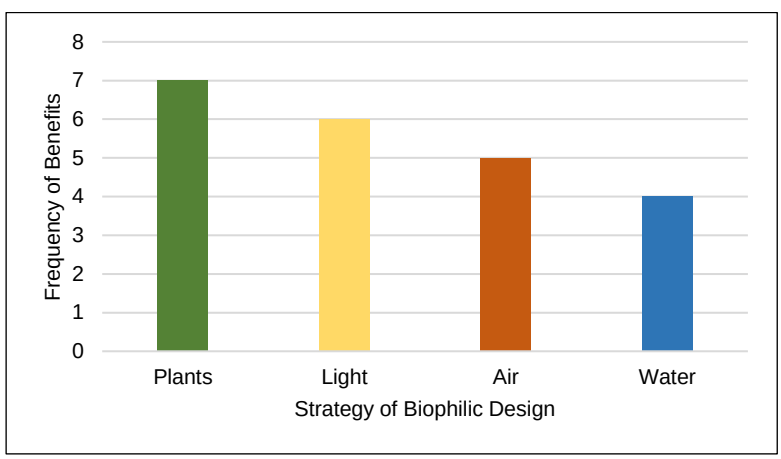


Figure 2. Frequency of Benefits of Each Strategy

From all the strategies, the plant provides more benefits compared to other strategies. Among its benefits are calming, reduce stress, positive emotion, improve productivity, improve health, improve concentration, and improve well-being.

Table 8. Frequency of Each Benefit

Benefits	Frequency
Calming	13
Improve Concentration	12
Improve Health	11
Reduce Stress	9
Improve Productivity	8
Positive Emotion	7
Improve Well-being	5
Better Communication	1

Table 8 highlights the frequency of each impact on the application of biophilic design strategies. Therefore, all of these benefits can increase the occupants' perceived psychological performance. Besides, it is found that many researchers highlight calming (f=13), improve concentration (f=12), improve health (f=11), reduce stress (f=9), and improve productivity (f=8) as benefits of biophilic design strategies. These benefits play a crucial role in occupants' psychological performance to ensure the organisation's production flows smoothly.

From the observation, the application of biophilic design in the office building positively contributes to the organisation, especially in occupants' psychological and health. Therefore, the bare minimum effort for someone to apply the biophilic design strategies is by planting plants on their individual's desk. Thus, the biophilic design can bring the office to life. Some plants that can be planted indoor are cactus and succulents, gardenia, english ivy, lily flowers and spider plants. All of these plants required a small amount of direct light and they do not need to be watered often and only a little amount of care is required.

Table 9. Types of Plants

Catus and Secculent	Gardenia	English Ivy	Lily Flowers	Spider Plants
				

Houseplants or indoor potting plants have grown in popularity for the past twenty years. Significantly, they offer various sizes, shapes, colours, and textures. Plants help the built environment to look more softer and calm the environment. Hui and Bahauddin (2019), emphasised that plants could bring a positive impact on human health. Besides, plants can also give benefits to mental health, stress reduction, and cognitive function. It was supported by Topgul (2019), stating that indoor plants could reduce occupants' stress, resulting in increasing work efficiency. Furthermore, the plants' colour can straight bring green and living nature into the indoor environment. A psychology study stated that someone could get health and well-being benefits by putting plants inside the built environment (Gillis & Gatersleben, 2015). According to Lohr (2010), occupants have higher productivity when plants are present.

Besides, human spend 80% to 90% of their time indoors because of job demand. Consequently, having a pleasant indoor air quality is crucial to avoid a syndrome called sick building syndrome. To counter this issue, the human must have exposure to nature. It is the reason why human should grow plants indoor to boost air quality. It can remove the pollutants from the air that we breathe and indeed plants can give a lot of benefits and positive effects on human's mental health, physical health, and well-being (Han & Ruan, 2019).

Now, our attention turns to the application of light. Light is a dominant identity in the architecture space. In the architectural context, natural light's practice has a significant dimension to act as an architectural design element. Light can act as a stimulus to render it visible and perceivable. Furthermore, light and architecture have a strong relationship as light can give shade and shadow, creating aesthetical and functional aspects (Ozorhon & Uraz, 2014). Natural light can be achieved by opening window, using glass dome and roof light.

Daylight is the main important element for office occupants. Natural light has proved that it can give benefits to occupants' wellness, including psychology. From a view of biophilic design, occupants emerge under natural, diurnal light. Natural light can improve occupants' communication, concentration, and moods (Gillis & Gatersleben, 2015). Moreover, natural light can also give occupants' eyes comfort and provide the mental and visual stimulation necessary to regulate the human circadian system (Wymelenberg, 2014). Daylighting can also

cooperate in energy savings. The overall concept of energy-saving is to enhance the lighting system by combining natural light and artificial light. Hence, the building's energy can be optimised and reduced when natural light distribution can maximise it (Jamala, Rahim & Mulyadi, 2019).

In addition, air is a crucial element in built environment. Air inside the building can exist through a natural ventilation. Air or ventilation can provide fresh air throughout the buildings by providing forces of wind and buoyancy and able to remove heat and air pollution. Good air quality can achieve a healthy and comfortable environment for people who live inside the building. As a result, it can increase occupants' productivity and reduce absenteeism (Khalil & Kamaruzzaman,2018). Ventilation can ensure to supply an adequate of breathing air while avoid contaminants (Yang & Croome, 2012). Furthermore, natural air allows to reduce the energy usage by cutting the unnecessary use of electrical appliances . Other than that, sick building syndrome can ovoid if the building has competent of air ventilation (Khalil & Kamaruzzaman, 2018).

Air ventilation can be achieved by implementing passive cooling strategies such as thermal mass, external shading, cross ventilation, open spaces, building orientation, window and installation of wall and roof insulations. all of these elements can secure air quality, ultra-low energy building and comfort (Hoo, Lau & Hung, 2016). According to this finding, window is an important element in built environment. Window can be your source of information about weather and about what is happening at the outside world. Furthermore, it can provide sufficient source of light and sunshine. In the same way, windows allow people to rest for a while by taking a break and observe outside world from their office thus enhance their contact with natural world while working (Kaplan, 1993).

On top of that, water elements also play an important role in biophilic design strategies as they can benefit occupants. Water can increase the space experience through seeing, touching, and hearing. Water can also improve the visual connection leading to positive emotional responses and creativity. Among the benefits obtained from the water presence are reduced stress, relaxing, improved concentration, and memory (Sharifi & Sabernejad, 2016). Implementation of water inside the building can be done by putting indoor small waterscapes. Waterscape can be classified as a small landscape which consist of rocks, small plants, water device and other suitable materials. Besides, the function of waterscape is to create a miniature garden inside the building. Afterall, the miniature garden is easy to maintain. Examples of waterscapes that can be applied inside the building are water fountain, water walls, fishpond, and fish tank (Sun, 2015).

Employers should see a bigger picture of the relationship between occupants and the office building environment. Many of these strategies can affect the psychological issues that are associated with the work performance. The integration of natural elements into the office or workplace can lead to occupants' psychological and provide major benefits to occupants. Furthermore, nature elements could bring aesthetically pleasing to the office environment. The office environment can be bright, positive, and comfortable, making the occupants more energised.

CONCLUSION

The application of biophilic design strategies can provide many benefits, such as the environment, economy, social, and psychology. However, the SLR of biophilic design strategies only focuses on the benefits of the psychological scope. There is a rationalisation to connect human and nature towards human psychology. Each of the strategies may provide the same or different benefits. Based on the SLR, the top five benefits highlighted by the researchers are calming (*f*=13), improve concentration (*f*=12), improve health (*f*=11), reduce stress (*f*=9), and improve productivity (*f*=8). Moreover, the biophilic design strategies can be used as a ground-rule to design office spaces in future to increase occupants' psychological performance as it can create a liveable and aesthetic office. It is also one way for the occupants to feel relaxed, calm, and energised from hectic tasks. Besides, the key to a good life balance is to have sanity towards our psychology. Indeed, establishing a nature connection can positively contribute to this issue. All things considered; this is why applying biophilic design strategies into a built environment is important.

To conclude this paper, currently it can be seen that biophilic design strategies has its own place on the international scale. There are growing interest among designers, and architects regarding these strategies and people start to show their interest. More people are now aware of the importance of biophilic design strategies application into the building or home. Based on the research above, international buildings have integrated this strategy towards the workings space. Malaysia should take this as consideration to apply this strategy to the building. This paper is useful as reference for architects and designers for their future planning.

REFERENCES

Almhafdy, A., Ahmad, S. S. H., and Ibrahim, N. (2013). Analysis of The Courtyard Functions and its Design Variants in the Malaysian Hospital. *Asia Pacific International Conference on Environment-Behaviour Studies, 105 (2013) 171-181.* https://doi:10.1016/j.sbspro.2013.11.018

Arroyo, E., Valkanova, N., and Bonanni, L. A. (2012). Embedded Interaction In a Water Fountain for Motivating Behaviour Change in Public Space. *Session: Sustainability & Behaviour Change. CHI 2912, May 5-10, 2012, Austin, Texas USA.* https://doi.10.1145/2207676.2207773

Cabanac, M. (2002). What is Emotion? *Behavioural Process, 2002, 60: 69-84.*

Cottham, W. V. (2005). Rooftop Gardening, a Big Step to The Future. First International Summit for Afforestation Roof Gardens in China. April 2005.

Downton, P., Jones, D., Zeunert, J., and Roos, P. (2017). Biophilic Design Application: Putting Theory and Pattern into Built Environment. *DesTech Conference Proceedings. The International Conference on Design and Technology (2017).* https://doi.org/10.18502/keg.v2i2.596

Fink, G. (2010). Stress: Defination and History. *Reference Module in Neuroscience and Behavioural Psychology, pp 1-9.* https://doi.org/10.1016/B978-008045046-9.00076-0

Gillis, K. and Gatersleben, B. (2015). A Review of Psychological Literature on the Health and Wellbeing Benefits of Biophilic Design. *Journal of Buildings*, 2015, 5, 948-963.

Gray, T. and Birrell, C. (2014). Are Biophilic-Designed Site Office Buildings Linked to Health Benefits and High Performing Occupants? *International Journal of Environmental Research and Public Health. 11, 12204-12222.*

Hafeez, I., Hafeez, S., Mansoor, R., and Cheema, K. R. (2019). Impact of workplace environment on employee performance: mediating role of employee health. *Business, Management and Education. 2019 Volume 17, Issue 2:173-193*. Retrieved from https://www.researchgate.net/publication/337553791

Han, K. T. and Ruan, L. W. (2019). Effect of Indoor Plants on Self- Reported Perceptions: A Systematic Review. *Sustainability, 2019, 11, 4506, pp 81-88.* Retrieved from https://doi:10.3390/su11164506

Hoo, L. K., Lau, B., and Hung, F. C. (2016). The Adoptation of Passive Cooling Strategy in Designing Public Assembly Building- A Design Typology for the Taoist Academic Centre in Tropical Climate. *Malaysian Construction Research Journal; Vol. 20, No.3, pp 63-84.*

Hui, O. M. D. and Bahauddin, A. (2018). Biophilic Design in Heritage Indoor Co-Working Space in Georgetown, Penang, Malaysia. *Malaysian Journal on Sustainable Environment, 6(2), 1*, pp 1-19 https://doi.org/10.24191/myse.v6i.8683

Jamala, N., Rahim, R., and Mulyadi, R. (2019). Analysis of Natural Light Distribution in the Building. IOP Conference Series: Materials Science and Engineering 619 012024. https://doi.10.1088/1757-899X/619/1/012024

Kaplan, R. (1993). The role of nature in the context of workplace. Landscape and Urban Planning, 26, 193-201.

Kaya, L. G., Yucedag, C., and Asikkutlu, H. S. (2018). Usage and Importance of Natural Light in Spatial Design. *European Conference on Science, Art and Culture, April 19-22, pp 429-436.*

Kellert, S. R. (2018). Nature by design: The practice of biophilic design: The Practice of Biophilic Design. *Yale University Press, pp 1-214*

Khalil, N. and Kamaruzzaman, N. S. (2018). Impact of Building Performance Failures to The Occupants' Health and Safety Risk: A Literature Review. *Malaysian Construction Research Journal; Vol. 25, No. 2, pp.* 43-60

Linna, P., Ukko, J., Pekkola, S., and Melkas, H. (2010). Definning and measuring productivity in the public sector: Managerial perception. *International of Public Sector Management. Vol. 23, No. 3, 300-320.* https://doi.org/10.1108/9513551011032491

Lerner, A. and Stopka, M. (2016). The Financial Benefits of Biophilic Design in the Workplace: A Review and Summary of Current Research. *MIST Environment Limited, 2016, pp 1-23.*

Naharuddin, N. M., and Sadegi, M. (2013). Factors of Workplace Environment that Affect Employees Performance: A Case Study of Miyazu Malaysia. *International Journal of Independent Research and Studies. Vol. 2, No.2, 66-78.* http://ssrn.com/abstract=2290214

Raab, M., Hoffman, S., Lobinger, B., and Pizzera, A. (2015). Performance Psychology: Perception, Action, Cognition, and Emotion. *Frontier in Psychology. Perspective Articles, Vol 5. Article 1533, pp 1-348* https://doi.org/10.3389/fpsyg.2014.01533

Rakhshandehroo, M., and Mohd Yusof, M. J. (2015). Living Wall (Vertical Greening): Benefits and Threats. *Applied Mechanics and Materials, Vol. 747, pp. 16-19.* https://doi:10.4028/www.scientific.net/AMM.747.16

Raziq, A., and Bashsh, R. M. (2014). The Impact of Working Environment on Job Satisfaction. 2nd Global Conference on Business, Economics, Management and Tourism, 30-31 October 2014, Prague, Czech Republic.

Shahsavarani, A. M., Abadi, E. A. Z. M., and Kalkhoran, M. H. (2015). Stress: Facts and Theories Through Literature Review. *International Journal of Medical Review. Vol. 2, Issue 2, Spring 2015; 230-241.*

Sharifi, M. and Sabernejad, J. (2016). Investigation of Biophilic Architecture Patterns and Prioritizing them in Design Performance in order to Realize Sustainable Development Goals. *European Online Journal of Natural and Social Science*. *Vol.5, No 3, pp 325-337.*

Sonderlund, J. and Newman, P. (2015). Biophilic Architecture: A Review of The Rationale and Outcomes. *AIMS Environmental Science*. 2(4):950-969.

Sun, C., and Zhou, X. (2013). The Effect of Indoor Plants on Human Comfort. International Society of the Built Environment. https://doi:10.1177/1420326X13481372.

Topgul, S. (2019). The Impact of Biophilic Design on Workers Efficiency. *Journal of Social Research and Behavioral Sciences.*

Totaforti, S. (2018). Applying the Benefits of Biophilic Theory to Hospital Design. *City, Territory and Architecture*. *2018, 5:1, pp 1-9*

Yang, T., and Croome, D. J. C. (2012). Natural Ventilation in Built Environment. In book: Encyclopedia of Sustainability Science and Technology. Publisher: Springer

Yin, J., Yuan, J., Arfaei, N., Catalano, P. J., Allen, J. G., and Spengler, J. D. (2020). Effect of Biophilic Indoor Environment on Stress and Anxiety Recovery: A Between-subject Experiment in Virtual Reality. Environment International 136 (2020) 105427.

Zhang, J. (2019). Cognitive Functions of the Brain: Perception, Attention and Memeory. *IFM Lab Tutorial Series #6*

THE RELATIONSHIP BETWEEN BIOPHILIC CONSTRUCTED DESIGN EXPERIENCE IN HOME OFFICE SETTING TOWARDS PERCEIVED PERFORMANCES BY ACADEMICIANS

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Abstract
Prior research have documented that natural elements or known as biophilia and the office settings have positive effects towards personnel's performances and well-being. Yet, less emphasis has been given to the personnel who are working from home due to the sudden shift from working in the office to working from home because of Covid-19 pandemic. In view of that, this study aims to examine the relationship between biophilic home design experience and home office settings towards academicians' perceived performances. 260 questionnaire responses from academician who work from home due to Covid-19 were analysed by using Statistical Package for the Social Sciences (SPSS) version 25.0 and SMARTPLS; a partial least squares-structural equation (PLS-SEM) modeling software for hypothesis testing. The results of the hyphotheses testing show that biophilic elements in a home office setting showed perceived enhancement of the academician's performances. Subsequently, the findings will contribute in the development of a comprehensive biophilic design elements model for home office setting.

Keywords: *Biophilia; design experience; home office; perceived performance, PLS-SEM, SmartPLS.*

INTRODUCTION

As the Covid-19 was spreading, institutions shut down their physical campuses and academic personnel began to work from home to contain the dissemination of Covid-19 virus. Because of the sudden shift, all academicians have been insructed to work from home, which means to set up a home office workplace or setting for course delivery. In addition, working environment influences the performance of an organisation (Garg & Talwar, 2017). Working as an academician requires long working hours and heavy workloads (Facey et al., 2015). Workers or personnel who spend most of their time doing their work tasks in poor environment often feel stressed, with high level of anxiety and depression which may lead to low engagement at work, which later will reduce personnel performances (Ong & Azizi, 2019; Smith et al., 2015).

Recent studies have indicated that biophilic experiences have positive effects on human health and performances which has reinforced 1984 Edward O. Wilson's Biophilia hypothesis that human possesses an innate tendency to seek connections with nature. For instance, research on biophilic design found that the built environment can become restorative through the natural elements implementation (Miller, 2019).

Although few studies have managed to measure the effects of biophilic in working environment and its effects on health and working performance, post Covid-19 spread, the

associations between biophilia in a home office setting due to the sudden shift from working at office to working from home and personnel's performance is yet to be established. To contribute to the literature on biophilic on an office setting at home, this study aims to examine the association between biophilic home office setting and academicians' perceived performance.

LITERATURE REVIEW

Biophilia

Biophilia denotes to describe that human have profound bond with the nature and need to be incessantly attached to the nature (Dias, 2015). The term biophilia was introduced by Edward Osborne Wilson (1984) which explains that humans is emotionally connected to other living organism (as cited by Miller, 2019). The importance of biophilia has grown largely over the last few decaded due to the rapid urbanization in cities because some buildings are associated with poor indoor quality (Smith, Tucker, & Pitt, 2011). In addition, performances of an organisation depends on the working environment (Garg & Talwar, 2017). Poor indoor quality affects the building users in health, poor work performance and absenteeism (Smith et al., 2017).

Biophilic Design Experiences

Research on biophilic design found that the built environment can become restorative through the natural elements implementation (Miller, 2019). Further, biophilia design focuses on the relationships between nature, human biology and the design of the built environment for human to experience expedite restoration in stress and clarity of thoughts or attention (Terrapin Bright Green, Browning , Ryan, & Clancy, 2014). Human exposure to biophilic design can ensue through three experiences; namely direct experience with nature, indirect experience with nature and experience of space and place. Table 1 summarises the biophilic design experiences.

Table 1. Biophilic Design Experiences

No.	Biophilic Design Experience	Examples
1	Direct Experience of Nature	Light, Air, Water, Plants, Weather, Natural Landscapes and Ecosystems, Fire
2	Indirect Experience of Nature	Image of Nature, Natural Materials, Natural Colours, Simulating Natural Light and Air, Naturalistic Shapes and Forms, Evoking Nature, Information Richness, Age, Change and the Patina of Time, Natural Geometrics, Biomimicry
3	Experience of Space and Place	Prospect and Refuge, Organized Complexity, integration of Parts to Whole, Transitional Spaces, Mobility and Way finding, Cultural and Ecological Attachment to Place

(Source: The Kellert and Calabrese, 2015)

Direct experience brings the meaning of being physically present in the natural setting where contact of human bieng with plants and animals occur (Kellert, 2008). This design experience discourses the direct, physical and ephemeral presence of nature. Besides, Kellert and Calabrese (2015) mentioned that the direct experience of nature as the real contact with environmental features in the built environment. Among the examples of direct experience of nature are plants, water, air, natural light and landscapes. Other examples include potted

plants, flowerbeds, bird feeders, butterfly gardens, water features, fountains, aquariums, courtyard gardens and green walls or vegetated roofs.

Indirect contact with nature would be considered physical contact with representations of plants and animals or an artificial form of nature (Miller, 2019). The term indirect experience of nature refers to contact with the nature through pictures including images of artwork, natural materials such as woolen fabrics and ornamentation inspired by forms and shapes occurring in nature (Garg & Talwar, 2017). Also, it refers to the non-living and indirect recreations of nature. The examples could be found in objects, materials, colors, shapes, sequences and patterns in the nature environment, manifested as artwork, ornamentation, furniture, décor, and textiles in the built environment.

The third experience is the space and place, which refer to the living organisms and environments depicted through images or metaphorical expressions of nature (Gillis & Gatersleben, 2015). It also dwells about the spatial configurations in nature. This includes human's innate and learned desires to be able to see beyond one's immediate surroundings, the fascination with slightly dangerous or unknown and obscured views and revelatory moments. Furthermore, experience of space and place may be defined as spatial features characteristic of the natural environment that contributes to human health and wellbeing. The examples of experience of space and place are organized complexity, prospect and refuge, mobility and way finding as addressed by Terrapin Bright Green et al. (2014).

Biophilic Settings and Perceived Performance

Research conducted by Castelle (2017) has managed to define perceived performances as a self assessed form that is based on the individual's perceptions, opinions and experiences. Perceived means In lieu to that, the prevalent indicator to obtain the individual's performance results is by using questionnaires and interviews (Dias, 2015).

The elements of nature or biophilia in the work environment could affect occupant's well-being and enhance their performances (Browning & Cooper, 2015; Smith & Pitt, 2009). As Dias (2015) observed, occupants felt pleased and enthused with the presence of indoor plants in their working environments. Furthermore, there is a positive relationship between the presence of natural elements and productivy as Browning and Cooper (2015) pointed out. Equally significant, a study by Smith and Pitt (2009) confirmed that the employees who were working in an office with the presence of indoor plants felt more productive, healthier and reduce their stress level.

CONCEPTUAL FRAMEWORK AND RESEARCH HYPOTHESIS

Main hypothesis: There is a significant association between biophilic settings and academician perceived performance.

H1: There is a significant association between direct experience of nature and academician perceived performance.

H2: There is a significant association between indirect experience of nature and academician perceived performance.

H3: There is a significant association between experience of space and place and academician perceived performance.

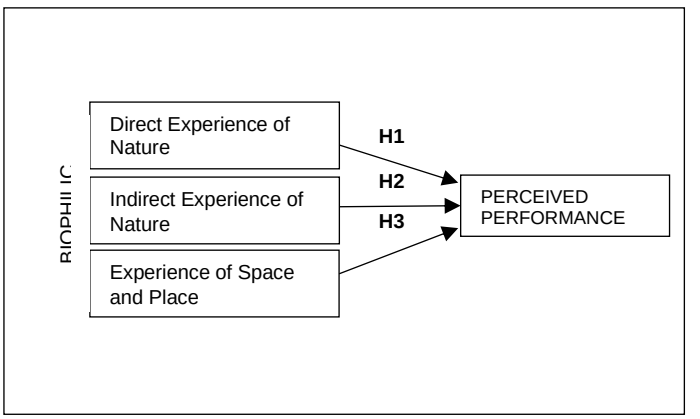

Figure 1. Conceptual Framework of Research Hypotheses

METHODOLOGY

Study Design and Data Collection

The cross-sectional method was used in this study to allow the researchers to use literature review on biophilic design experience and occupants' perceived performances, pilot study, and questionnaire as key procedures in data collection (Sekaran et al., 2014). The data collected through an online questionnaire via Google Forms obtained from a random sample of academician who were working at home during the pandemic. The online questionnaire was distributed through a website and other social media medium for the duration of one month. The researchers have cited Hair et al. (2017) as suggesting the minimum number of respondents needs to be 167 (with three constructs or independant variables) to publish the structural model with significance levels of 1% and 5%.

Data Analysis

The data collected from the online questionnaire was analysed by using Statistical Package for the Social Sciences (SPSS) version 25.0 and the hypothesis testing was analysed by using SMARTPLS. The SmartPLS method was used to evaluate the validity and reliability of the study questionnaire, subsequently testing the study hypotheses (Hair, 2017). Out of the total 260 online questionnaire responses, only 67.11 per cent (174) were fully answered by the respondents. The sample size fulfilled the requirement of data analysis using statistical inference.

RESULTS

The objectives of this study is to determine the biophilic design experience in home office setting and the relationship between biophilic design experience and academician's perceived performances. This section analyses the relationship between biophilic design experience and academician's perceived performances. Furthermore, the SmartPLS method was used to evaluate the validity and reliability of the study questionnaire, subsequently, testing the study hypotheses (Hair, 2017). The questionnaire comprised three main sections: first, section A consists of questions on demographic information of respondents such as gender, age, work experience and others. Section B focusses on the biophilic strategies in home office setting;

namely the direct experience of nature, the indirect experience of nature and the experience of space and place. The respondent was asked to rate the five-point agreement likert-scale which are 1 (Strongly Disagree), 2 (Disagree), 3 (Neutral), 4 (Agree) and 5 (Strongly Agree).

Table 2. Demographic Characteristics of the Respondents

Demographic	Items	Frequency	Percent
Gender	Male	141	54.2%
	Female	119	45.8%
Age	21 to 35 years old	125	48.1%
	36 to 50 years old	98	37.7%
	More than 50 years old	37	14.2%
Working Experience	less than 5 years	119	45.8%
	6 to 10 years	98	37.7%
	more than 10 years	43	16.5%
Do you have live plant in your home office setting?	Yes	187	71.9%
	No	73	
Do you get natural light in your home office setting?	Yes	231	89.2%
	No	29	10.8%

The above results of demography analysis shows that majority of the respondents were female 54.2 percent (141). The age of the respondents is categorized into 3 categories which are 21 to 35 years old (48.1%), 36 to 50 years old (37.7%) and more than 50 years old (14.2%). Next, most of the respondent have less than 5 years (45.8%) working experience. The analysis results also show that basically, most of the respondents (71.9%) have live plants at their workspace. Last but not least, majority of the respondents (89.2%) get natural light at their workspace while the remaining respondents (10.8%) does not get any natural light.

Table 3. Results of Item Loading Value and Construct Item Reliability

No.	Variables	No. of Items	Item Loading (≥ 0.70)	Composite Reliability (≥ 0.80)
1	Direct experience of nature	5	0.706 - 0.894	0.920
2	Indirect experience of nature	5	0.790 - 0.898	0.931
3	Experience of space and place	6	0.850 - 0.911	0.955
4	Occupants' perceived performance	3	0.780 - 0.877	0.868

Based on the measurement model analysis, Table 3 shows the item loading value for each construct is greater than 0.7, in which the value confirms that the items for each construct achieve high reliability (Fornell & Larcker, 1981). Subsequently, each construct has a composite reliability value greater than 0.80, which means that the measurement scale has a high internal consistency (Henseler, 2015).

Table 4. Construct Item Value and Discriminant Validity Test

No.	Variables	AVE (≥ 0.5)	1	2	3
1	Direct experience of nature	0.698			
2	Indirect experience of nature	0.730	0.537		
3	Experience of space and place	0.778	0.606	0.593	
4	Occupants' perceived performance	0.687	0.760	0.764	0.774

Table 4 shows that the Average Variance Extracted (AVE) for each construct is between 0.698 and 0.778, in which it exceeds the required critical value of 0.5 (Hair et al., 2017). This indicates that the study constructs fulfil the criteria of convergent validity (Henseler et al.

2015). On the other hand, the Heterotrait-monotrait (HTMT) value for each construct is less than the required critical value of 0.85 (Hair et al., 2017). This means that the study constructs have fulfilled the criteria of discriminant validity set that is each construct in the study framework differs from one another (Henseler et al., 2015).

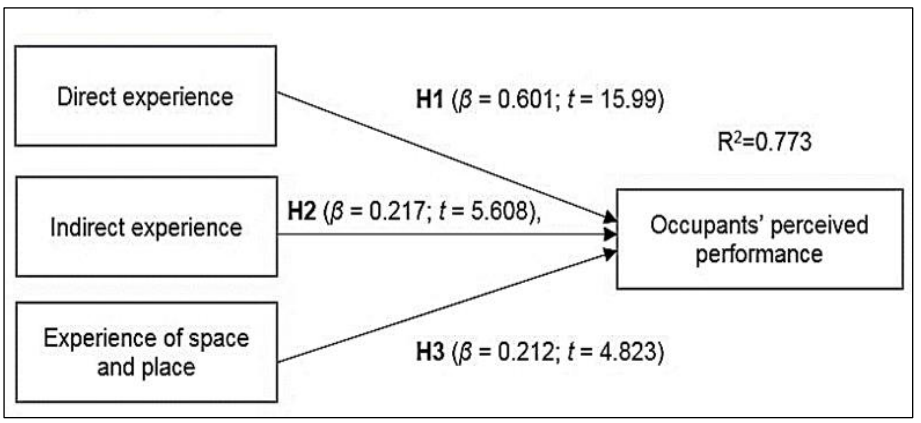

Figure 2. Results of Path Analysis

Result from Figure 2 also explain about the inclusion of independent variables (Biophilic Settings) of the path model in SmartPLS contributes 77.3 per cent to changes in the dependent variable (academicians' perceived performance). Meanwhile the other 22.7 percent of it is influenced by external factors. These values can be considered satisfactory (Cohen, 1977). Based on structural model analysis, the results of hypotheses testing using path model analysis in SmartPLS yielded several key findings: first, direct experience (β = 0.601; t = 15.99) has a strong significant relationship with academicians' perceived performances. Secondly, Indirect experience (β = 0.217; t = 5.608), experience of space and place (β = 0.212; t = 4.823) also have significant relationships with academicians' perceived performances. Therefore, all hypotheses have been supported in this study.

This study used a significant level of 1.96 (two-tailed) to determine the direction among variables as described in the study hypotheses (Henseler et al. 2015). Besides, further to the above hypothesis testing, a test of accuracy of the estimate (predictive relevance) using Stone-Geisser, the Q2 test was carried out as specified: q2 = Q2 included-Q2 excluded 1-Q2included = 0.331 (Hair et al., 2012); and it was found that the Q2 (0.516) is above the standard, which is greater than zero (Henseler et al., 2009). Therefore, these findings generally support the expected accuracy SmartPLS route model used in this study.

CONCLUSION

Overall, this study has proved that significant biophilic design experience, which are shown through direct experience of nature, indirect experience of nature and experience of space and place clearly indicates that these strategies will give positive impacts to the academicians' perceived performances. However, direct experience of nature acted as the most dominant to the implementation. Therefore, the study has shown that there is a strong relationship between biophilic design experience of nature and academicians' perceived performances. The area of research study is led based on literature review and the data analysis on questionnaire. As this is not a conclusive study, therefore, there are some points

that can be taken to improve the outcomes of the survey. For the purpose of further study, it is best to suggest researchers to conduct studies on strategies of biophilic on other groups of profession about their perception towards biophilic home office settings and academicians' perceived performances.

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REFERENCES

Browning, B. & Cary, C (2015). The Global Impact of Biophilic Design in the Workplace. 1-48 ed. Lancaster: Human Spaces.

Castelle, K. M. (2017) An Investigation into Perceived Productivity and Its Influence on the Relationship between Organizational Climate and Affective Commitment. Engineering Management and Systems Engineering, 1(1), pp.1-22

Cohen, J. (1988). Statistical power analysis for the behavioural sciences. Lawrence Erlbaum, Hillsdale, NJ.

Creswell, J.W. (2012). Educational research: Planning, conduct, and evaluating quantitative and qualitative research (4th ed.). Boston: Pearson.

Dias, B. D. (2015). Beyond Sustainability: Biophilic and Regenerative Design in Architecture. *European Scientific*, 1857-7881.

Facey, K., Henshall, C., Sampietro-Colom, L., & Thomas, S. (2015). Improving The Effectiveness and Efficiency of Evidence Production for Health Technology Assessment. *International Journal of Technology Assessment in Health Care, 31*(4), 201-206. doi:10.1017/S0266462315000355

Fornell, C., & Larcker, D.F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18*, 39-50.

Garg, P., & Talwar, D. (2017). Impact of Organisational Climate on Employee Performance: A Study with Reference to the Educational Sector or Indore. *International Journal of Research in Commerce & Management*, IV(8), 22-26.

Gillis, K., & Gatersleben, B. (2015). A Review of Psychological Literature on the Health and Wellbeing Benefits of Biophilic Design. *Buildings*, 5(3), 948-963.

Hair, J.F., Hult, G.T., Ringle, C. M., & Sarstedt, M. (2017). A primer on partial least squares structural equation modelling (PLS-SEM). California: Sage Publication, Inc. 24(3), 365-387.

Henseler, J., Ringle, C.M., & sarstrdt. M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, 43, 115-135.

Kellert, S. F., Heerwagen, M. L., & Mador Eds, M. L. (2008). *Biophilic Design: The Theory, Science & Practice of Bringing Buildings to Life.* Hoboken, NJ: John Wiley & Son.

Kellert, S. R., & Calabrese, E. F. (2015, March 1). *The Practice of Biophilic Design.* Retrieved from www.biophillic-design.com: www.biophillic-design.com/the-practice-of-biophilic-design.

Miller, E. (2019). *Implementing Biophilic Attributes in Elementary Schools.* Parkway: Proquest.

Ong, Ming Hui and Azizi, Bahauddin (2019) *Biophilic design in heritage indoor coworking space in George Town, Penang, Malaysia*. Malaysian Journal of Sustainable Environment (MySE), 6 (2). pp. 1-19. ISSN 0128-326X

Sekaran, U., & Bougie, R. (2014). Research methods for business: A skill building approach. New York: John Wiley & Sons, Inc.

Seyam, S. F. M. A. (2017) The Impact of Plants on Indoor Air Quality, Energy Use, and Psychological Status of Occupants, ProQuest Dissertations and Thesis. University of Toronto.

Smith, A. & Pitt, M (2009). Sustainable Workplaces: Improving Staff Health and Well-being using Plants. *Journal of Corporate Real Estate*, 11(1), pp. 52-63.

Terrapin Bright Green, Browning , W. D., Ryan, C. O., & Clancy, J. (2014). *14 Patterns of Biophilic Design: Improving Health and Well-being in the Built Environment.* New York: Terrapin Bright Green, LLC.

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