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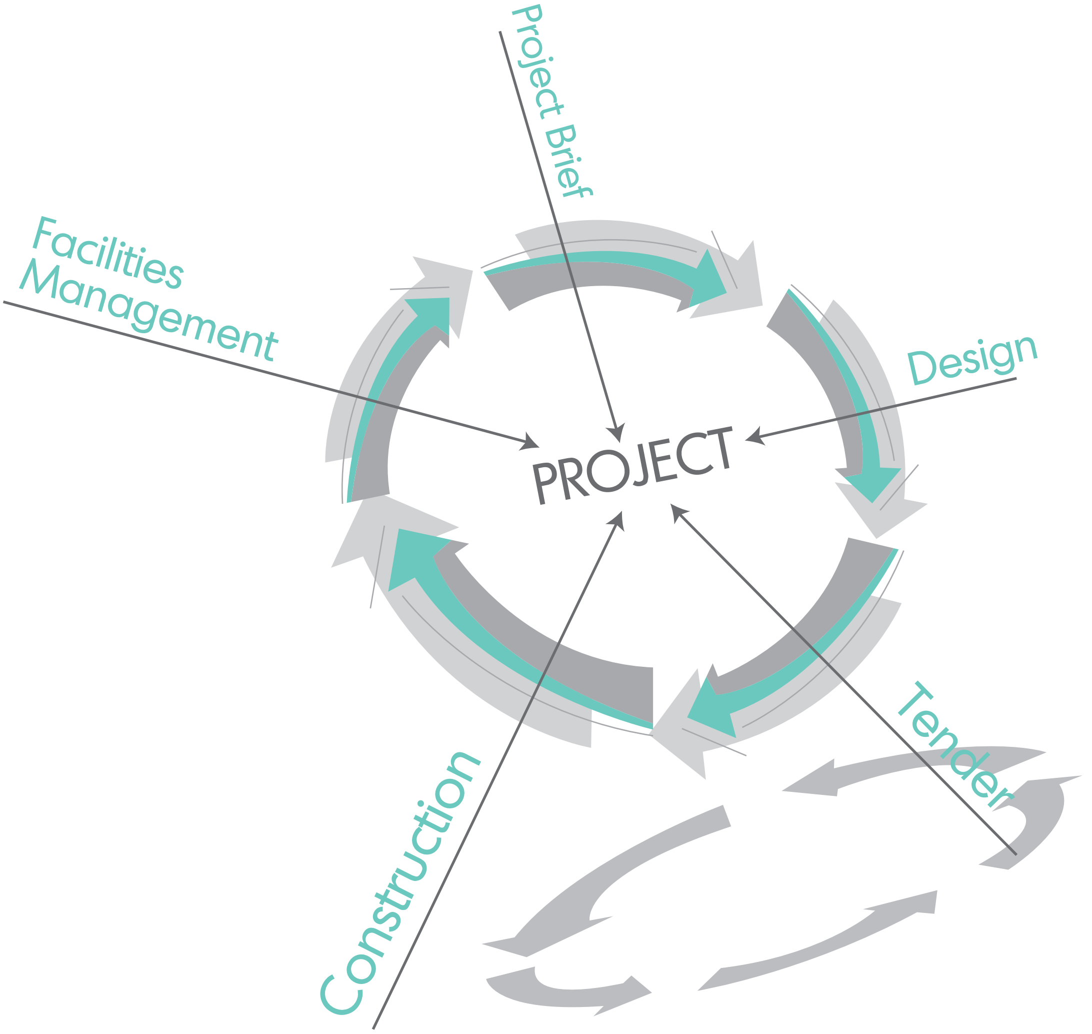

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Editorial

Welcome from the Editors

Welcome to the forty-fourth (44th) issue of Malaysian Construction Research Journal (MCRJ). In this issue, we are pleased to include eight papers that cover a wide range of research areas in the construction industry. The editorial team would like to express our sincere gratitude to all contributing authors and reviewers for their contributions, continuous support and comments.

In this issue:

Kenn Jhun Kam et al., have identified the factors and benefits of using BIM, the most influencing factors, and the solution to improve the implementation rate of BIM. This study was conducted in the whole of Malaysia to understand the issue from in Malaysian perspective. The quantitative approach was used by sending out online questionnaires through emails. The main respondents were Architects, Engineers, and Quantity Surveyors. Data analysis was carried out using mean ratio, relative important index, and ranking. The majority of the respondent's feedback was that the cost of hardware upgrades was the main hindrance to adopting BIM. And one of the main solutions to help increase the implementation rate was for the government to provide incentives for the cost of hardware as well as the training.

Razan Al Sakka et al., have reviewed BIM functionalities and their implementations in sustaining project environmental performance within AEC scope of works. A systematic review approach was adopted to analyse the literature from the two main fields; BIM and environmental performance. The findings of this study proposed four main categories of BIM functionalities which have important benefits in enhancing project environmental performance, i.e. Visualization, Analysis, Coordination and Management. The four categories of BIM functionalities and their main aspects are also reported to have important contribution in reducing the environmental impacts of eight areas namely, Air or Climate, Energy, Water, Materials, Soil, Resources and finally Environmental Performance Effectiveness. This study presents a holistic view on BIM functionalities and their contribution towards environmental benefits. It serves as a comprehensive guide for academics and practitioners, particularly AEC stakeholders to maximize the use of BIM to improve environmental performance of construction project.

Norsuzailina Mohamed Sutan et al., examine the potential of Saccharum Officinarum Bagasse Fibres (SOBF) as a sustainable reinforcement in cement composites. The study evaluates the effects of chemically treated and untreated SOBF on the mechanical properties of cement-based materials. Findings indicate that 1 wt.% SOBF optimally enhances compressive strength, with untreated fibres showing superior results due to natural lignin improving fibre-matrix bonding. Scanning Electron Microscopy (SEM) analysis reveals that SOBF mitigates surface cracking through a bridging effect. The research concludes that SOBF can significantly enhance the mechanical properties and durability of cement composites, making it a promising material for sustainable, cost-effective construction, particularly in developing regions.

Angela Ting Mee Yii et al., have proposed models of green building maintenance conceptual implementation for Malaysian higher education institutions (HEIs). The research objective it's to identify the analogies of green building maintenance for Malaysia HEIs. Therefore, to achieve the highlighted aims and objectives, a quantitative research method was adopted to gather data from 120 respondents who have been involved in building maintenance works in Higher Education Institutions. Rasch model was used to analyse the collected data and further developing the models is using the Smart PLS. The outcomes of this research may answer the highlighted objectives and increase the contribution to the building maintenance works. Additionally, it is also expected that the research findings may further broaden and enhance existing knowledge of green building maintenance which to be beneficial to the Malaysian HEIs especially with green building status to manage the maintenance activities.

Zhang Meng and Atasya Osmadi, have adopted quantitative research method and data analysis used GIS spatial statistical method. It takes the five major city clusters in China as the research area. Based on the data from the fifth and sixth national sub-county censuses and using spatial autocorrelation from ArcGIS10.7 and Geoda1.14 spatial statistics tools, empirical analysis of the spatial evolution and regional differences in the development of rental housing in 104 cities in five major city clusters in China. The results of the study show that there is a significant spatial agglomeration of the development and changes in China's housing rental market over the decade. The high-value areas of housing rental market development clustered in city clusters and ethnic minority areas. The five major city clusters show different levels of development, with the central cities having a clear radiating effect on the peripheral cities.

Mohd Suffian Ariffin et al., analyse Malaysia's Energy (DTN 2022 – 2040), focusing on strategies to enhance and accelerate renewable energy projects and attract foreign investment. The research addresses concerns about inconsistencies in the project approval process among local authorities, hindering timely implementation and reducing investment returns. The study advocates for streamlining approval processes, improving knowledge and skills in renewable energy projects, and adopting a consistent approach across local authorities. The prioritized areas for improvement include increasing the market share of electric vehicles, expanding solar energy use in residential areas through government initiatives, and implementing energy-efficient street lighting with smart monitoring systems. These measures aim to stimulate economic activity at the national level and attract investment by addressing perceived regulatory stringency in Malaysia.

Farid Wajdi Akashah et al., have identified the needs of disabled people and how occupants with disabilities at workplace responded during a fire evacuation. The analysis contains a single case study of super high-rise office building and indicators are created by distributions of questionnaires, observation of evacuation drills, and semi-structured interviews. A total of 218 questionnaires were analysed using Statistical Package for the Social Science (SPSS) statistic and presented in a form of three sections. Seven parameters highlighted the experience and knowledge of respondents on fire evacuation with still very low awareness among respondents. Based on the results, evacuation by the PWDs took significantly longer to complete in comparison to able-bodied evacuees due to lack of awareness by building management, building owners, lack of regular reviews by certified parties, lack of technology involvement, and lack of safety culture among the society and communities. Recommendations in improving the process of evacuating PWDs are highlighted. Developing a personalized evacuation plan i.e. personal emergency evacuation plan for the PWDs can be one initiative to be taken up by the Management for an improvement towards a better quality of life (QoL) particularly in regard to their well-being at the workplace.

Kai Chen Goh et al., have identified the approaches to on-site waste segregation that have been implemented and the factors that influence their implementation. The data collection method used was a case study of the MRT police quarter project in Gombak, where a literature review, site survey, and interviews were conducted. It was discovered that waste segregation had become a more integral part of routine construction activities in Malaysia. Disruption to normal site activities, management effort, and project stakeholders' attitudes are the most critical factors. In contrast, cost, site space, environmental confinement, and facility demand are no longer identified as factors to consider when implementing on-site segregation. Rather than that, education is now viewed as a new potential factor in these practices. The study's findings can be used to assess the state-of-the-art and effectiveness of current on-site segregation in Malaysia and develop benchmarking strategies and best practices for on-site segregation.

Editorial Committee

THE CONSEQUENCES ON THE ORGANIZATIONAL OPERATIONAL PERFORMANCE FROM THE BUILDING INFORMATION MODELING (BIM) IMPLEMENTATION IN THE MALAYSIAN CONSTRUCTION INDUSTRY

Kenn Jhun Kam, Tze Shwan Lim and Alfred Lee Hao Law
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Abstract
Building Information Modeling (BIM) is considered the new generation of initiating constructions. Not only it provides the necessary information for the construction project, but it is also a platform where users can edit the design of the building before actually carrying out the actual construction. Although it provides many benefits, it still has a considerably slow implementation rate in Malaysia. Therefore, a study was conducted to identify the factors and benefits of using BIM, the most influencing factors, and the solution to improve the implementation rate of BIM. This study was conducted in the whole of Malaysia to understand the issue from in Malaysian perspective. The quantitative approach was used by sending out online questionnaires through emails. The main respondents were Architects, Engineers, and Quantity Surveyors. Data analysis was carried out using mean ratio, relative important index, and ranking. The majority of the respondents' feedback was that the cost of hardware upgrades was the main hindrance to adopting BIM. And one of the main solutions to help increase the implementation rate was for the government to provide incentives for the cost of hardware as well as the training.

Keywords: *Building Information Modeling (BIM); slow implementation rate; factors; benefits; solutions.*

INTRODUCTION

The construction industry has been contributing 3 to 5 percent of the aggregates economy GDP for the past 2 decades. As we are in the modern era, there are many ways of inventing a building or having help in inventing one. Examples are the internet of things (IoT) which is one of the very important aspects not only in the construction industry but in other industries as well, Artificial Intelligence (AI), Virtual Reality or Augmented Reality, which helps a lot easier in visualizing the construction, Autonomous Equipment such as robots or drones, and 3D printing (Al-Yami & Sanni, 2019). The sole purpose of all these advancements is for our future generations to have an easier life and to have a better quality of construction. BIM intends to replace traditional 2D drawings and to be the center of communication. Many countries have already adopted the use of BIM. This research aims to identify the advantages and disadvantages of BIM and to explore the Malaysian Construction Industry perspective on this software (Almuntaser, Sanni-Anibire & Hassanain, 2018). BIM technology is an intelligent 3D modeling tool that will support architecture, engineering, and construction professionals to effectively design, plan, modify and manage their buildings and infrastructure. It begins with the creation of models and supports document management, coordination and simulation during the entire lifecycle of a project (plan, design, build, operation and maintenance). Moreover, BIM technology enables better collaboration, because each expert can add its expertise area to the same model (architecture, MEP, civil, plant, construction, and structures), enabling review of project evolution and working results in real-time.

PROBLEM STATEMENT

Although buildings were already built using BIM, the fact that there was a slow implementation in Malaysia should still be addressed. According to Chief executive Datuk Ahmad Asri Abdul Hamid (2019), he stated in the news only a few large companies were using BIM, while in the public sector, it was mandatory for them to use BIM for project costing RM100 Million and above. This states that without the obligation, the public sector would still rather not use BIM and use the traditional method. He also stated that although the use of BIM was introduced, many companies still weren't giving acceptance of using it when the idea of having mandatory use of BIM for selected private sector projects was proposed.

In Architectural firms, the adoption rate was a low 20% and only 10% of Quantity Surveying firms are involved since BIM was introduced (Mohd-Nor & Grant, 2014). Engineering firms also have a very slow rate of adopting BIM (Rogers, Chong & Preece, 2015). Since architects, engineers and surveyors are the main parties using BIM, this can be an indication of the slow uptake of BIM in the Malaysian Construction Industry (Zainon, Salleh, Mohd-Rahim, 2016).

One of the reasons this happens is because the majority of the construction players see BIM as a disruptive technology that will cause problems to the current construction industry by transforming it into a new process. According to Datuk Seri Prof Judin Abdul Karim, he said: "It is not a problem of knowledge and information on the use of ICT; it is always about the cost" (Qin, 2012). A structural engineer mentioned in PropertyGuru (2018) that although there is someone very experienced in using BIM, there will still be a risk of the project not being able to run because there might be parties not knowing how to utilize BIM. In another report, some expert states that BIM is just a process that results in a digital model; it doesn't change the responsibilities of the professionals working on a project (Decipher, 2014). In research by Hedayati, Mohandes, Preece (2015), cost, IT components, time, and readiness were ranked as the highest four barriers of BIM adoption. They have a percentage of 26.2%, 23% 16.4% and 14.8% respectively. People, the environment, and technology are critical to the implementation of BIM (Alshawi, 2008). The keys to change for improvements are People and Process while the work environment and IT infrastructures are enablers without which the first two elements cannot be sustained (Bew and Underwood, 2010).

RESEARCH OBJECTIVES

The research objectives are derived as per following: -

Objective 1: To highlight and discuss the factors and advantages of BIM adoption
Objective 2: To identify the most influencing barrier among users/respondent
Objective 3: To propose a solution/model to improve the adoption of BIM.

LITERATURE REVIEW

Definition of BIM

BIM is an abbreviation that stands for Building Information Modeling. BIM which is also known as n-D Modeling or Virtual Prototyping Technology is a revolutionary development that is quickly reshaping the Architecture, Engineering, and Construction (AEC) industry (Azhar, Khalfan & Maqsood, 2012). BIM is both a process and a technology. The technology component of BIM helps project stakeholders to be able to visualize what is going to be built in a simulated environment to identify any potential design, construction, or operational issues. In another report, BIM can also be defined as a process of generating and managing building data during its life cycle using real-time, three-dimensional, dynamic building modeling software to increase productivity in building design and construction which encompasses building geometry, spatial relationships, geographic information, and quantities and properties of building components (Enegbuma, Aliagha & Ali, 2015).

Application of BIM

BIM is also known as n-D modeling. It refers to the different levels of data and information entered into a 3D model using BIM software (3D Repo, 2019). There are four different levels of n-D modeling which are 3D, 4D, 5D, and 6D respectively. Not all BIM software have the respective n-D modeling. The first level of n-D modeling is the 3D model where it involves the process of gathering non-graphical and graphical information to create 3D models and provide the ability to share this information in a Common Data Environment (CDE) (3D Repo, 2019). The 4D model is the representation of **time**. Any source of time such as the time until operational, curation of materials, installation time, and more falls under this level.

The information is directly entered into the model where it can aid project planners to shape and create proposals at a much earlier stage. 5D BIM is any information that represents a **cost.** This is usually used by a cost estimator or Quantity Surveyor. This enables them to participate in data exchange from the start rather than just doing cost advice or taking off quantities in isolation. 6D BIM represents **project lifecycle information**. 6D BIM involves information to support facilities management and operation to provide better business products (NBS, n.d.). Its purpose is to have a smooth function for a building and measures for renovation and maintenance work over the entire lifetime of a building. It allows facility managers to plan maintenance activity years and develop spending profiles over the lifetime of a built asset, working out when repairs become uneconomical, or the existing system is inefficient.

Factors Affecting Adoption Rate of BIM in Malaysia

BIM Experience

Awareness of BIM

A barrier of BIM which can be seen within a business is their lack of knowledge and awareness of BIM. According to John & Lee (2011), they did a study for an architectural firm in Korea which resulted in not many designers have ever used BIM, and BIM was only used in projects that are mandated. The lack of awareness of BIM can also be affected by the strong failure of BIM adoption in the construction industry (Ahmed, 2018). A study by Al-Ashmori (2020) revealed that one reason for the low adoption and implementation rate in Malaysia is the major lack of awareness for BIM. Without any knowledge of awareness of BIM, each party in the construction industry will be reluctant to implement BIM.

Lack of Studies of BIM Financial Benefits

Even though construction professionals are aware of BIM advantages in the AEC (i.e., construction) industry, there is still a lack of knowledge of the economic effects and outcomes of BIM, and there is no comprehensive list of BIM advantages and associated cost savings (Mehran, 2016). In an interview with Walters, who is a project manager, he mentioned that measuring the exact benefits and savings is very challenging. Many of them are anecdotal and there were only some points where you can quantify those savings. In addition, many of them are confidential which makes it harder to report (Cousins, 2016).

Time Constraint for Training

Since BIM is relatively new software, it is no doubt that training is needed for staff to maximize its potential. As said earlier, not only will it cost a lot to the company but it will be of time constraint too. There are two types of training provided; Online training and hiring a professional. Online training is good as its benefits cost-wise but the downside is that there may be some things that are not taught online. Hiring a professional is a good choice depending on the firm as it will cost money as well as it will take up most of the personnel time. The average time for training varies depending on your role (Pena, 2011).

Software Matter

Interoperability Issues

Interoperability can be defined as the ability to make use of various systems, individuals, and/or organizations to work together, using the parts of each other, to achieve a common goal regardless of their differences (Djuedja et al., 2019). The need for interoperability is to face typical obstacles/barriers namely: technological, conceptual, and organizational barriers. Technological are barriers concerning those related to Information Technology (IT) such as computers. Conceptual are those barriers relating to information problems such as their representation at a high level of programming or a high level of abstraction (Djuedja et al., 2019). Organizational are those concerning humans such as authority, organizational structure, management, and responsibility.

Compatibility Issues

With the rise of demand and use of BIM modeling, the number of competitors increases as well. Since every BIM provider has their function and format, there are no standard platforms. Therefore, compatibility issues arise when projects are transferred to each other. There are a few causes of the incompatibility of BIM. A few examples are: BIM is still not widely used or popularized in the industry. This tool is not yet familiar to cost estimators/cost controllers (Xu, 2019). Take for example where the company has already applied for BIM. BIM software is geared primarily to design. The bill of quantity or material take off from BIM software can be generated but there is no readiness to use the cost estimation module. Main elements such as unit price, still lack manhours.

Cost Matter

Cost of Software

By implementing BIM, it necessitates the organization to purchase the pertinent software. The high front-end cost of implementing BIM has been seen to act as a significant barrier to uptake within the construction industry (Eadie et al., 2014). To top it off, each subscription only provides access per user. Because of this, not only this imposes as a factor to Small Medium Enterprises (SMEs) but also on large companies where they have more than 250 employees. Although there is a high initial cost of the BIM software, there will often be a profitable result in the long run.

Cost of Training

Once the BIM licenses have been acquired, the next step is to go into training. Training is important as it allows you to know the full and extent potential of using BIM. BIM education can be considered as a solution to accelerate the BIM learning curve thus companies can hire ready-made BIM talent when the student graduates (Wu & Issa, 2013). But for those with no BIM education, they can also go to training once they are working. According to Burger (2014), Autodesk, an American multinational software corporation that produce software services for the AEC (Architecture, Engineer & Construction) Industry (n.d.), offers training session which ranges from RM1,000 – RM7,000, a fee that is roughly cost around RM3,000 for an eight-week long program.

Cost of Hardware

Hardware components needed for BIM software are somewhat similar to those needed for CAD software. But due to the advanced feature of BIM software, additional hard disk storage, upgraded graphic cards, additional RAM and a stronger bandwidth internet connection might be needed (Hardin, 2009). Both hardware and software can be considered as major barrier for small medium enterprises (SMEs) (Stanley & Thurnell, 2014). On the other hand, after upgrading hardware components, it is also a good thing long-term wise because the processing speed would be faster and smoother which allows them to do work more efficiently.

Legal Matters

License Issue

Although there come many benefits with the implementation of BIM, there is no surprise that there is a risk. One of the first issues is to decide the ownership of the BIM data and how to safeguard it through copyright and other laws. In a report by Thomson and Miner (2010), an example of some issues that would develop from the electronic communication of construction designs would be where if the Owner paid for the design, he would feel entitled to own it, whereas if a team member is providing proprietary information to use for the project, that information needs to be kept as well. This is also known as Licensing Issue, where a project team member contributes data that is integrated into BIM.

Control of Data

The next issue would be determining who will be responsible for the entry of data into the model and any inaccuracies in it. The two jobs that involve a great amount of risk are ensuring that there are no inaccurate data integrated and having the responsibility to make sure the BIM data is updated (Thomson & Miner, 2010). Request for complex indemnities by BIM handlers and the offers of limited warranties and disclaimer of liability by designers will be essential negotiation points that need to be settled before BIM innovation is used.

Services

Services are a factor that falls under both Cost and Legal issues. Cost determinants such as hardware and software components are driven by access to continuous technical support, internet access, and energy. These will involve different cost factors and could partly depend on the contract agreement between vendors, end-users and software developers (Olatunji, 2011). Olatunji (2011) also states to limit uncertainties, another cost risk in indemnification were depending on specific needs, there are various insurance products under which construction business operates and will affect the cost of implementing new advancements.

Benefits of Using BIM

Improved Collaboration

One of the most common advantages of BIM is the increase of collaboration among parties in a project, which is achieved through the use of a centralized model (Thurairajah, 2013). Since communication and information access will be improved through this, it will reduce the work carried out in isolation as well. Eisenmann and Park (2012) found in their research that it is important to note the team level in BIM experience to fully maximize its benefits where if an individual from the team has little experience, it may be possible to receive negative results.

Reduced Cost and Mitigated Risk

BIM tools can also increase the accuracy of cost estimates by improving the availability of information (Talebi, 2014). Quantities can be extracted from the BIM models and form a Bill of Quantities which can be used in the procurement phase. This is useful since traditional methods of taking off are often insufficient and inaccurate (Talebi, 2014). Due to the historic cost information that BIM has combined with the 3D modeling tools, it can automatically generate a price list for every element that has been done before. This allows for a fast, easy, accurate, and reliable taking-off process therefore also receiving fast cost feedback in the design stage (Eastman et al., 2008). Another major benefit of BIM is that it can reduce construction rework. (Talebi, 2014). It is also stated that around 40 to 90 percentage of rework reduction was reported by using BIM before the actual start of work.

Time

Construction planning comprises of scheduling and sequencing of models to coordinate virtual construction in space and time. The utilization of scheduling introduces time as the 4th

dimension (4D) (Hergunsel, 2011). The linkage of time to 3D components makes it possible to graphically visualize the project schedule (Talebi, 2014).

There are two common types of scheduling methods which are the line of balance and the critical path method (CPM). The line of balance method uses location as its base for scheduling. This method is good for repetitive tasks to increase labor productivity. Critical Path Method (CPM) is to make sure the project stays within its timeline schedule. CPM is usually best illustrated either by computer programs that use calculations or by using a graph (Koutsogiannis, n.d.). The planning through using BIM improves site utilization, product information, and space coordination (Hergunsel, 2011).

Safety

BIM can help pinpoint hazards before they start to become a problem as well as avoid physical risks by visualizing and planning site logistics ahead of time (Hall, 2018). There are 3 ways that BIM can help provide a safer construction site.

Visual representation for construction site workers. BIM helps to provide a visual understanding of the site working conditions before construction starts. This is crucial for new workers who have not set foot on site and are unaware of the site safety measures.

Identify hazards through 4D scheduling. The 4D model helps to estimate the major construction activities which allow corporations to prepare a choreographic safety plan for the workers, eliminating potential hazards and providing a safer workplace for workers.

Prepare better for each task. Every task in the construction site has its own risk. BIM can focus on each task so workers can help to identify the risks, prepare for the work at hand and complete the task with safety.

Simulate and Visualize

BIM is also beneficial due to its increasing number of simulation tools, it allows designers to quantify the calculation of the building energy performance or to visualize things such as sunlight in different seasons of the year (Ball, 2018). BIM allows you to gather every detail of a project into one design, including 3D models and detailed floor plans (Bethany, 2017). BIM simulations also allow users to visualize their project in real-world time. Augmented reality and virtual reality also play a big role in helping you visualize your project beforehand. Improved visualization is also beneficial for the client, contractor, and design team as it gives them a better understanding of the project (Thurairajah, 2013). Cost consultants can also make fewer assumptions as the client can visualize what options do they want or what is available.

Ideas to Improve the Adoption of BIM

Target BIM Adoption for SMEs

Incentives are major drivers of new technologies, while high efficiency is not sufficient to alter business behavior. At the early stages of BIM adoption, the government needs to play a crucial role. Issues such as the high cost of schooling and insufficient spending on infrastructure need to be addressed by compulsory regulation and oversight. Specific insurance mechanisms ought to be established to alleviate apprehensions, for example, the cost of execution and upkeep outweighs the value. Aside from the costs, project managers' and engineers' curiosity and desire to use BIM still play important roles. Governments should be improving the BIM curriculum according to this principle. For starters, they should compel a small and medium sized business to set up a BIM department staff responsible for training within the companies to comment on the results of the training. In this way, they are shifting the attitude of small and medium sized businesses towards emerging technology, formulating optimistic expectations and encouraging BIM adoption in SMEs. For this strategy, the lack of BIM awareness can be addressed (Li et al., 2019).

Push-Pull Method

In another report by Walasek & Barszcz (2017), it was found that the UK government has adopted the Push-Pull method. The government will first pull every industry towards adopting BIM by implementing a rule where all public projects must be delivered using BIM, giving them access to all design, carbon, cost, and the performance of the assets throughout the project lifecycle. Next, the push method will be dependent on industries. This is because they have the primary role for adopting and utilizing BIM by providing standardization, development, training, information, and infrastructure. The study concluded that there is an enormous leap in early adoption due to the government drive. But for the adoption rate to be further improved, more needs to be done in the private sector to widespread the use of BIM.

BIM Protocols & Legal Contracts

Another critical consideration is the legal and contractual issues regarding the use of BIM models. Legal liability uncertainty is due to the large number of project participants contributing to the BIM model and/or depending on the accuracy and consistency of the knowledge found in the model. In various countries, several initiatives are being established to address this problem, but there is still a long way to go. A BIM protocol document (Conditions of Contract) has been developed by the American Institutes of Architects (AIA) to interact with BIM which is widely cited as a good legal model (Smith, 2014). This protocol provides a formal contractual framework for agreement between the parties on the main issues: protocols, software implementation level, and elements of the software.

BIM Education, Training & Research

Another innovative approach mentioned by Smith (2014) is "BIM Education, Training & Research". As mentioned earlier, these are some of the challenges to the adoption rate. IM to be applied at the tertiary level so that graduates who are entering the industry have the necessary knowledge and capabilities. It will also save the company from having to spend an extra cost and time, both are also major factors, for their employees having to learn BIM. The development of pilot projects and case studies across all market sectors and project client types is also crucial. Since many pilot projects and case studies tend to focus more on larger scale projects where the clients would have to invest in technology, there need to be more studies that cover all sectors from small to large that articulate the business benefits of investing in BIM in their projects.

Job Application

A study conducted by Wu and Issa (2014) found that rapid BIM take-up in companies would ultimately rely on professionals and experienced BIM workers who might not be ready. In a typical market transformation cycle driven by technology, intellectual preparation is usually lagging, which is the drastic reflection on the labor market off-balance between supply and demand for the labor force. As a visionary development for the industry, BIM favors more collaborative project delivery approaches, such as integrated project delivery (IPD), in which project team members' roles and duties are reconfigured, and new skill sets other than conventional positions are required. This pressing demand would probably urge the industry to rethink the skills a worker has to offer. New job titles prefixed with "BIM", e.g. "BIM Manager" and "BIM Coordinator", and the start of new organizational function units such as "BIM/VDC Department" reflects the impulse to rethink BIM-oriented workforce profiling and planning.

Developing Native Software and Application

Software is a way to realize BIM functionality, but better outcomes are only obtained when interoperability with cross-disciplinary specifications and systems is feasible. Li et al. (2019) mention that the effect of BIM implementation relies more on how an organization integrates BIM technology with its operations than on how well it is structured so that employees can respond to the innovations following their current work progress. From this point of view, a series of building-code related guidelines and applications must be established without modifying the current building construction approval process. If BIM software can automatically produce 2D sketches and associated documentation for the building approval process, BIM implementation would increase. This is also important to create a BIM based case library to meet local needs. Well-documented information allows to evaluate successes, issues, and obstacles and therefore promotes BIM implementation.

RESEARCH METHODOLOGY

Research Framework

The below Figure 1 reflects the conceptual framework of this research study. The research studies on the variables including the benefits, the barrier factors and the solution to enhance BIM adoption among Malaysian practitioners. To obtain the aim and objectives of this study, questionnaires will be sent out via email to cover large quantities of respondents. Therefore, the quantitative method was selected. The reason quantitative method was chosen was because there are 3 target population, namely Architect, Engineer and Quantity Surveyor. Since the population is huge, it would be wiser to use the quantitative method to send out to the population. Since there were also many different types of detailed questions to ask, a survey would be the better choice.

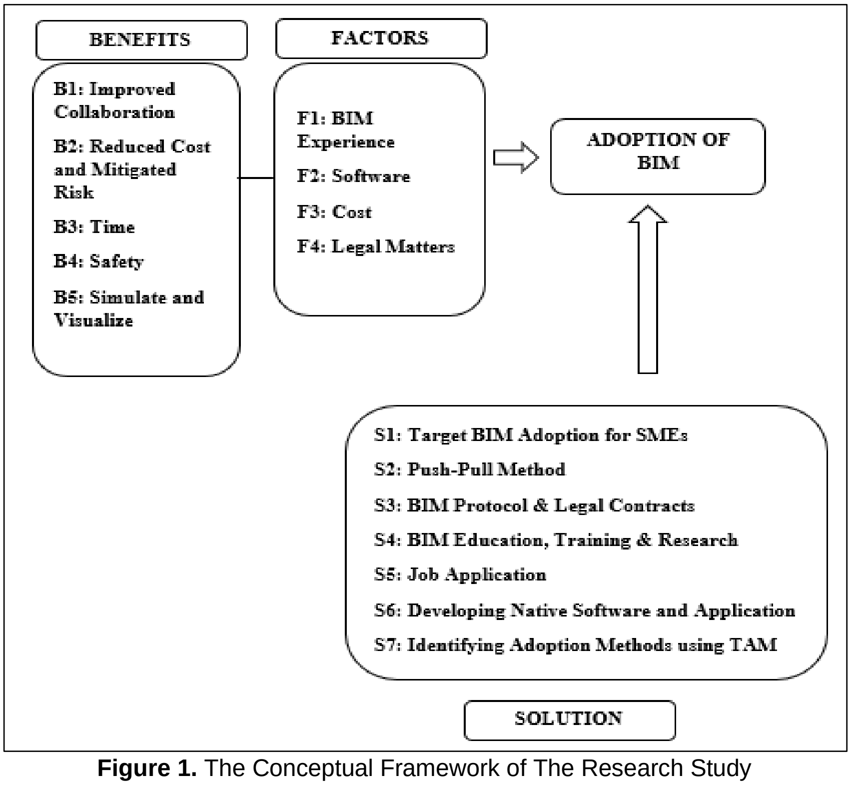

Figure 1. The Conceptual Framework of The Research Study

Sampling Method

For the sampling method, non-probability sampling will be used. This is more suitable since the questionnaires that is be sent out will be for specific occupations. The type of non-probability that will be used in this study is judgment sampling. This is because the population involved has been specifically chosen which are the Architects, Engineers, and Quantity Surveyors. Furthermore, to enhance the results obtained, both snowball and convenience sampling will be used. The Snowball sampling method, which is also sometimes referred to as "chain-referral sampling", is used when it is difficult to obtain results.

Target Population and Sampling Frame

The scope of this research will be focused on the whole of Malaysia where the target population will only be focused on people who are mainly involved in using BIM which are the Architect, Engineer, Quantity Surveyor, and Contractors. It is good to have their opinion from their point of view since they are first hand using it. The total amount of people in the sampling frame would be 12,138 people.

FINDINGS

Factors Affecting Adoption Rate Among Respondents

In this section, the first two objectives of this study will be conducted where the factors, benefits, and the most influential barrier among respondents will be answered.

BIM Experience

Table 1. BIM Experience Among the Respondents

	TR	Mean	Remark	RII	Rank
BIM Experience					
Do you think the time used for training is a waste or beneficial	31	4.13	Agree	0.83	1
Do you think it provides any financial benefits?	31	3.71	Agree	0.74	2
Your organization experienced difficulties in training your staff	31	3.06	A bit of both	0.61	3

Table 1 shows the factors that affect the adoption of BIM through BIM experiences, most respondents have understood that the time used for training is beneficial where it averages a mean of 4.13. This shows that people understand that BIM takes a while to maximize its full potential, and time is needed to learn it step by step.

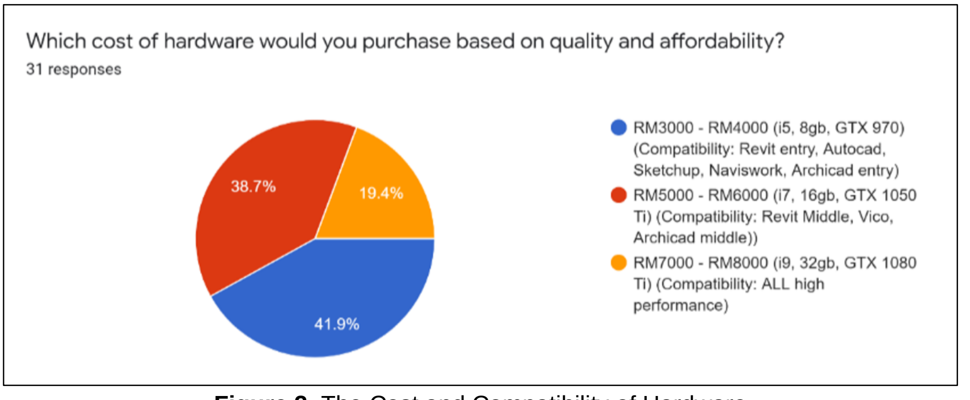

Figure 2. The Cost and Compatibility of Hardware

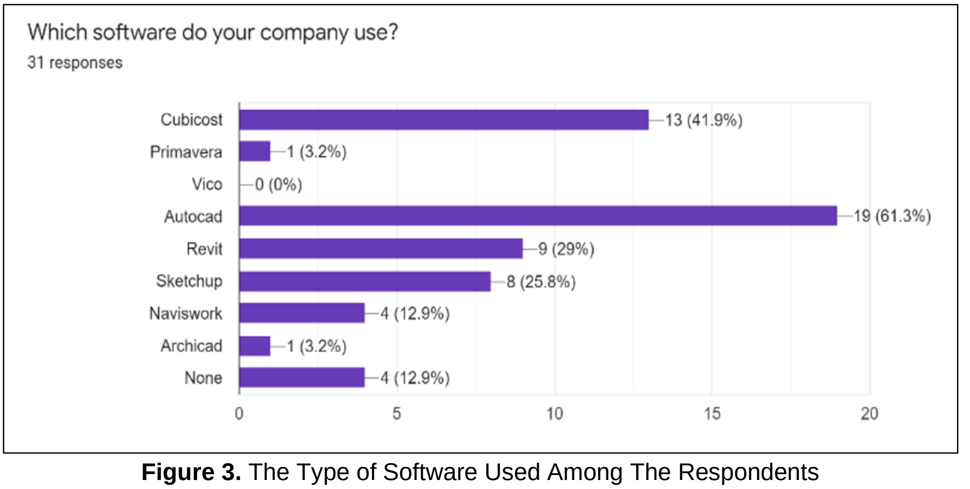

Figure 3. The Type of Software Used Among The Respondents

Compatibility

The two figures above are to better understand the compatibility issues. It can be seen from the pie chart that most respondents have chosen the cheapest cost of hardware and the specifications that it provides can support a few software which can be seen in Figure 3. The top 4 most used will be focused on. Xu (2019) has stated that each BIM provider has their functions and formats and there is no standard platform, this causes compatibility issues when projects are transferred to each other. This survey question has proven otherwise.

Cost of Hardware

The pie chart in the figure above represents the cost of hardware that the respondents are willing to purchase based on their affordability and their usage. It can be seen that 41.9% of the respondents have chosen the cheapest option which brings to the conclusion that the cheaper option was more than enough to operate BIM and are not able or not in need to afford the higher specs computer. As seen from the study of Stanley & Thurnell (2014), having a hardware upgrade may be a major issue for SMEs due to its high expenses. This finding shows that most of the respondents would prefer to purchase the lower specification because it can already support the most required software.

Table 2. The BIM License Issues Arose in Adopting BIM

Factors That Affect The Adoption of BIM	TR	Rank
License Issues		
No licensing issue	22	1
Can't log in	3	2
Not enough license	2	3
Cost increase	1	4
Subscription too expensive	1	5
License too difficult to bind/unbind	1	6
When the software became subscription instead of perpetual	1	7

Table 3. The Control of Data Matters Arose in Adopting BIM

Factors That Affect The Adoption of BIM	TR	Rank
Control of Data		
No licensing issue	24	1
The files of Cubicost can be locked and secured by password	1	2
Usually, the client and SO have the control	1	3
Some items are not able to capture in BIM software	1	4
Sometimes data is easily corrupted	1	5
Cannot track who changed the data	1	6
We have designated person and computer for BIM	1	7
The intellectual property of the data	1	8

Legal Matters

From the two tables above, 22 to 24 of the respondents have not experienced any licensing issues, which covers about 75 % of the respondents, while the remaining 25% has had encountered licensing issues. The issues they had encountered so far as they couldn't log in, there wasn't enough license, the cost of the license increased, the subscription was too expensive, files of Cubicost being locked and secured by password, items are not being able to capture in BIM software, sometimes the data is easily corrupted, can't track who changed the data, and have intellectual property of the data. To conclude this, there is not much problem with the Legal Matters where the issues are very minor.

Advantages

Improved Collaboration

Table 4. Benefit in Improving The Collaboration While Using BIM

The Benefits of Using BIM	TR	Mean	Remark	RII	Rank
Improved Collaboration					
Easier Communication	31	3.97	Agree	0.793	1
It provides a better teamwork	31	3.81	Agree	0.76	2

Most respondents have agreed that using BIM provides easier communication between teams in the project, with an average mean of 3.97. Thurairajah (2013) has stated that communication and information access can be achieved through the centralized model, which is BIM. Next is whether it provides better teamwork and there is an average mean of 3.81 which means most respondents agree it does. Also stated by Thurairajah (2013), since there is better communication between teams, it will also reduce the work carried out in isolation.

Reduce Cost and Mitigate Risk

Table 5. Benefits in Reducing Cost and Mitigating Risk While Using BIM

The Benefits of Using BIM	TR	Mean	Remark	RII	Rank
Reduce Cost and Mitigated Risk					
You received better results than using the traditional method	31	4.06	Agree	0.81	1
Provides a fast and reliable taking off process	31	3.97	Agree	0.793	2
It provides more accurate costing	31	3.94	Agree	0.787	3
Reduces the risk of construction rework	31	3.84	Agree	0.767	4

Talebi (2014) mentions that BIM can increase the accuracy of cost estimates because quantities can be extracted from BIM models and form a Bill of Quantities due to its 5D elements. This means that using the traditional method is less accurate. Next is that it provides a fast and reliable taking-off process, with an average mean of 3.97. As also found by Talebi (2014), since BIM has its 5D elements, all the object elements and price in the 3D model are linked together to the price list therefore a historic cost information is available for every element in the model. This then provides a faster and more reliable taking-off process.

Time

Table 6. Time-Saving Benefits While Using BIM

The Benefits of Using BIM	TR	Mean	Remark	RII	Rank
Time					
Saves Time	31	3.81	Agree	0.761	1
Provides a clear project timeline	31	3.65	Agree	0.729	2

Respondents gave a mean of 3.81 for the amount of time it saves. This gives a remark that most respondents agree it does save time. Next is that it provides a clear project timeline, with an average mean of 3.81, where it also gives a remark of agreement. Talebi (2014) states that since there is the linkage of time to 3D components, it makes it possible to graphically visualize the project schedule. This helps users to better understand the flow of the project.

Safety

Table 7. Safety Benefit While Using BIM

The Benefits of Using BIM	TR	Mean	Remark	RII	Rank
Safety					
Identify hazards through 4D scheduling	31	3.61	Agree	0.722	1
Provides a safe work environment	31	3.52	Agree	0.703	2
Ability to focus on each task for workers to be wary of risks	31	3.52	Agree	0.703	3

Safety is the next benefit that BIM provides, and the first choice of safety feature is that it can identify hazards through 4D scheduling, with a mean of 3.61. As mentioned by Hall (2018), BIM can pinpoint hazards before they start to become a problem. Besides that, in second place comes its ability to provide a safe work environment together with its ability to focus on each task for workers to be wary of risks. All of these can be done because BIM has the function to provide visual representation which allows them to foresee any hazards.

Simulate and Visualize

Table 8. Simulate and Visualization Benefits While Using BIM

The Benefits of Using BIM	TR	Mean	Remark	RII	Rank
Simulate and visualize					
Provides a clear visualization of the project for clients	31	4.29	Agree	0.858	1
Good simulation tools	31	4.23	Agree	0.845	2
Visualize weather in different seasons	31	3.35	A bit of both	0.67	3

There is a mean of 4.29 where it provides a clear visualization of the project for clients. Similarly, this was stated by Thurairajah (2013), from his study that, where improved visualization can help clients, contractors, and the design team have a better understanding of the project. Next is the simulation tools it provides, which ranks in second place. A good simulation tool is also agreed by Bethany (2017) in his study, he mentions that BIM allows users to gather every detail of a project into one design, which includes 3D models and detailed floor plans. It allows users to visualize their projects in real-world time. From the table, it can be seen that many users agree that it’s a good visualizing and simulating tool. Lastly, its ability to visualize weather in different seasons was not known or approved by respondents. Even though Ball (2018) mention that their simulation tool, it allows designers to quantify the calculations of the building energy performance or to visualize things such as sunlight in different seasons of the year. The reason for this could be because, in Malaysia, there is only one season throughout the year so users would not know this specific function.

Ranking of Strategies Among Respondents

This section will be answering objective 3 in figuring out which strategy to improve the adoption rate will be the best among respondents.

The idea to make public projects compulsory to use BIM has been ranked first as it seems to be the most influential strategy among respondents. Similarly, this method was implemented in the UK where researchers Walasek & Barszcz (2017) reported, these researchers found out that the government have adopted the method of Push and Pull where they will first implement a rule that every public project must be delivered using BIM. They will also be given access to all designs, carbon, cost, and assets throughout the project lifecycle.

Table 9. Strategies in Improving BIM Adoption Rate

Strategies to Improve the Adoption Rate of BIM	TR	Mean	RII	Rank
Make public projects compulsory to use BIM	31	5.38	0.359	1
Provide incentives for the cost of training and hardware	31	5.8	0.387	2
Slow down on the government push and allow companies to slowly adapt	31	6.22	0.415	3
Compel SMEs to set up a BIM department staff	31	6.35	0.423	4
Provide more awareness for BIM	31	6.67	0.445	5
Improve legal contracts	31	6.67	0.445	6
Put BIM specialty in job application	31	6.7	0.447	7
Create a BIM protocol document as a legal model	31	7.06	0.47	8
Provide a discount on government levies	31	7.16	0.477	9
Make BIM education compulsory in tertiary studies	31	7.32	0.488	10
Open a BIM library which allows improving issues and obstacles faced	31	7.35	0.49	11
Allow BIM to have interoperability between specifications and system	31	7.51	0.501	12
Solve the rights of intellectual property (IP) and data ownership	31	8	0.533	13
Get more studies on a small to large scale that covers financial benefits	31	8.06	0.537	14

Inferential Analysis

Table 10 shows the multiple regression calculation tables for coefficient. Multiple regression can be defined as the type of technique used to explore relationships between one continuous dependent variable and several independent variables or predictors. It is based on correlation, but it allows the interrelationship between several variables to be examined more sophisticatedly. Therefore, this makes it perfect for exploring more complex real-life situations rather than laboratory-based research questions.

Table 10. The Impact of BIM Benefits Towards The Users

Model	Standardized Coefficient Beta	t	Sig.
(Constant)		-3.436	0.003
D11_ Focus_each_task_for_workers_to_be_wary_of_risks	0.742	3.63	0.002
D5_fast_and_reliable_takingoff	0.581	2.991	0.009
D4_Provides_accurate_costing	-0.529	-2.919	0.01
D14_Provides_clear_visualization_of_project	0.514	2.375	0.03
D10_Identify_hazards	-0.421	-1.704	0.108
D9_Provides_a_safe_work_environament	0.354	1.965	0.067
D2_Easier_communication	0.299	1.218	0.241
D3_Better_results	0.189	0.929	0.367
D7_Saves_time	0.142	0.768	0.454
D8_Provides_a_clear_project_timeline	-0.47	-2.286	0.036
D6_Reduce_risk_of_construction_rework	0.033	0.153	0.88
D12_Good_simulation_tool	-0.028	-0.123	0.904
D13_Visualize_weatjer_in_different_seasons	-0.028	-0.157	0.877
D1_Teamwork	-0.005	-0.015	0.988

a. Dependent Variable: B1_BIM_Usage

In the table, their significant value will be focused on. It tells the researcher whether the variable is making a statistically significant unique contribution to the equation or not. The above table shows all the independent variables that have any type of relationship with the dependent variable. Out of all 14 of them, only 5 of them are accepted and the rest are rejected. This is because those that are accepted have a significant value of less than 0.05 (Pallant, n.d.).

The next thing that will be focused on is the standardized coefficient Beta value. The standardized coefficient can be defined as those that are produced by the linear regression model, using the independent variables measured in their respective scales. Table 4.10 shows that the ability to focus on each task for workers to be the way of risks is affecting the decision of using BIM software by 74.2%, which is the most influencing factor. Similarly, as seen from Hall's (2018) finding, BIM can pinpoint hazards before they start to become a problem in the ability to identify risk in Hall's (2018) study, meanwhile it is also agreed by Malaysian users from this study. There are 3 methods mentioned which are its ability to provide a visual representation for construction workers, identify hazards through 4D scheduling, and prepare for better tasks. This shows that one of the main reasons for people to use BIM software is for the safety of their workers.

CONCLUSION

The first objective will be to discuss the factors and advantages of adopting BIM. Based on the data collected for the factors, it can be seen that the main factors are the cost of adopting BIM. The majority of respondents have chosen the cheapest choice of hardware. The choice of this represents two conclusions. Since it is the cheapest, it is mostly an entry level for most software's where it might be slow at functioning. This also covers another factor which is Software, the compatibility between different software's. It is found that since the majority of the users have chosen the cheapest hardware, it supports the majority of the software that was chosen by respondents that they use.

For the benefits it provides, based on the data collected, they are relatively consistent with the advantages that were mentioned by previous researchers where all of the questions received an "Agree" remark. This means that the studies from past researchers are accurate, on the perspective of improving collaboration, reducing cost and mitigating risk, time-saving, safety benefit, and visualization benefit.

The next objective is to identify the most influencing factors among respondents. For this objective to work, the ranking for each section from the factors, benefits, and the strategies solution will be ranked accordingly. For BIM experience, the time used for training is indeed beneficial instead of a waste where it has an average mean of 4.13. For both software compatibility and the cost of hardware, the best is by choosing the cheapest specification. Not only can it run multiple software, but it is also a representation that respondents would not be able to afford higher-end specifications and will just use the entry-level.

The last objective is to propose a solution/model to improve the adoption rate of BIM. Based on the findings and data obtained from respondents, the best method to improve the adoption of BIM is to make public projects compulsory to use BIM, which comes at the first rank. This is a good push method for the companies in the industry where they will then get used to BIM and will realize the benefit it provides.

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BIM FUNCTIONALITIES IN ENHANCING CONSTRUCTION PROJECT ENVIRONMENTAL PERFORMANCE: A REVIEW

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Abstract
Building Information Modelling (BIM) technology has enormous benefits in construction project delivery. However, the functionalities of BIM and their potential in enhancing environmental performance of construction project is still much to be explored. This paper aims to review BIM functionalities and their implementations in sustaining project environmental performance within AEC scope of works. A systematic review approach was adopted to analyse the literature from the two main fields; BIM and environmental performance. The findings of this study proposed four main categories of BIM functionalities which have important benefits in enhancing project environmental performance, i.e. Visualization, Analysis, Coordination and Management. The four categories of BIM functionalities and their main aspects are also reported to have important contribution in reducing the environmental impacts of eight areas namely, Air or Climate, Energy, Water, Materials, Soil, Resources and finally Environmental Performance Effectiveness. This study presents a holistic view on BIM functionalities and their contribution towards environmental benefits. It serves as a comprehensive guide for academics and practitioners, particularly AEC stakeholders to maximize the use of BIM to improve environmental performance of construction project.

Keywords: *BIM function; Environmental Performance; Sustainable construction; Construction project*

INTRODUCTION

The construction industry is a significant contributor in the national development worldwide. However, it is criticised for causing irreversible detrimental consequences on the environment (Guo et al., 2019; Isa, Abidin, & Yahaya, 2019; Kiani Mavi et al., 2021). As the construction activities increase, the harmful effects are expected to worsen (Duan, Miller, Liu, & Tam, 2019). Thus, there is a need to reduce the environmental degradation and improve the environmental performance of construction projects (Asgari & Noorzai, 2021). Since decades ago, environmental effect has been gaining attention from worldwide. The advent of the notion of sustainable development in 1987 has prompted various industrial players to take action (Kiani Mavi et al., 2021; Saleh & Froese, 2018). The later concept of triple bottom line introduced in 1994 further emphasised the necessity to strike balance between environmental, economic and social goals in order to achieve sustainability in construction projects (Kiani Mavi et al., 2021). Following the energy crisis and rising concerns about climate change, the effort of architecture, engineering, and construction (AEC) industry's on sustainable construction and life cycle innovation have begun to thrive, with the goal of producing more environmental friendly construction projects (Crippa, Araujo, Bem, Ugaya, & Scheer, 2020; Lim, 2015; Senem Seyis, 2020).

To shift the practices toward enhancing the environmental performance of construction project, AEC industry emphasized the need for a swift transformation in technology, processes and policy making of this sector (Al Hattab, 2021). Due to the global growth of the technology, the sector has experienced significance improvements in technologies application within built environment processes. The use of technological means has also become vital solution for the sector to achieve environmental friendly outcomes (Al Hattab, 2021). One of the main tools is Building Information Modelling (BIM). BIM is a tool that that can handle diverse character of AEC industry by significantly enhancing the flow of construction information throughout its life cycle (Al Hattab, 2021; T. O. Olawumi & D. W. M. Chan, 2019). It aims to aid in the generation and management of digital information of physical and functional aspects of a construction project (S. Seyis, 2019). Through the project life cycle, it allows the stakeholders to collect, filter, manipulate and/or change a centralized and unified database. Environmental concerns are also addressed in BIM. The tool provides a detailed environmental performance analysis which assist in the elimination of hazardous environmental impact (Rezaei, Bulle, & Lesage, 2019). For example, through combining Life Cycle Assessment (LCA) with BIM software, BIM is able to analyse the environmental performance of the construction project and optimize building energy (Rezaei et al., 2019) while also assisting in decision making regarding environmental potentials and achieving sustainable standards (Abbasi & Noorzai, 2021; Potrč Obrecht, Röck, Hoxha, & Passer, 2020). BIM-based software also enables stakeholders to exchange information about environmental impacts (Signorini, Frigeni, & Spagnolo, 2019) and provide environmental information monitoring and compliance checking, both of which are critical in construction project's environmental performance (Zhong, Gan, Luo, & Xing, 2018). In today's construction process, combining environmental sustainability and BIM has substantiated to be a beneficial method (Goyal & Rai, 2020; Lim, 2015; Paskaleva, Mazak-Huemer, Wimmer, & Bednar, 2021).

The above discussion shows that there are many studies investigating BIM application in optimizing project environmental performance of construction projects. However, studying the effectual relationship between BIM and environmental performance was limited to some specific BIM functionalities in regard to specific environmental performance aspects. For example, the Analysis functionality was studied extensively with various environmental benefits in the area of energy efficiency and global warming (Huang, Xu, & Song, 2020). Whereas, Management as a BIM functionality was less studied and mainly in the area of construction wastes (Maraqa, Sacks, & Spatari, 2020). There are limited studies that comprehensively explore the capabilities of BIM functionalities and/or BIM functions in enhancing project's environmental performance looking at the whole construction phases.

To fill this gap, this study aims to provide comprehensive review on BIM functionalities and their implementations in sustaining construction project environmental performance within AEC scope of works. The objective of the study is to identify the categories of BIM functionalities and analyse their application based on project environmental performance. The findings would provide greater understanding on various environmental related BIM functionalities and provide a valuable guide for AEC players to improve project environmental sustainability through using BIM functionalities.

RESEARCH BACKGROUND

Construction industry has significant contribution to the economic growth. Its operation includes development of various types of projects, such as infrastructure, residential, industrial, commercial or public/private service buildings (Kiani Mavi et al., 2021). Multi-stakeholders from several disciplines, such as architecture, engineering, and construction, are involved in the delivery of development efforts. They serve as the backbone of the project. Their extensive collaboration in all construction project phases ensures the project success with environmental sustainability being one of the highest concern (Olawumi & Chan, 2019).

Construction Project Environmental Issues

Construction projects encompass many aspects of the natural and built environment, including building planning, design, construction, and operation. Because of the diverse range of activities, there are significant environmental implications (Jupp, 2017). As a result, construction projects have a negative impact on the environment. The activities not only pollute the environment, but they also consume a large amount of raw materials and resources. (Guo et al., 2019; Kiani Mavi et al., 2021).

The negative impact on the environment can be better described from two perspectives: consumption and production. The consumption aspect includes massive use of natural resources such as water, energy, materials and soil. In this regard, the industry has consumed 25% of all water and 40% of total energy and raw materials (Chuai, Lu, Huang, Gao, & Zhao, 2021). The production aspect, on the other hand, include the generation of wastes, emissions, and other natural resource pollutants. Construction and demolition phases are said to have generated 1.3 billion tonnes waste, which is predicted to double by 2025 (Al Hattab, 2021; Suh, Tomar, Leighton, & Kneifel, 2014; Zheng et al., 2017). Furthermore, construction-related pollution accounted for 40% of overall water contamination (Joshi, Navalgund, & Shet, 2022). Pollutant deposition at construction sites and construction dumpsites has also harmed soil ecology, and the construction sector is responsible for around 38% of greenhouse gas emissions (Senem Seyis, 2020; X. Yang, Hu, Wu, & Zhao, 2018).

Environmental aspects such as environmental planning and management, demand collaboration efforts between multi-disciplines professionals in the AEC industry. The quality of information flow is a key barrier for such procedures, causing a serious challenge in the sector (Jupp, 2017). In this regard, the use of technologies in the industry plays a vital role in decreasing the consequences on the environment and allows all stakeholders to participate in managing and mitigating the negative effects of building operations (Ajayi, Oyedele, Ceranic, Gallanagh, & Kadiri, 2015). The use of advanced technologies and innovations like BIM has been shown to be the key to improve integration and continuity in information flow (S. Zhang, Teizer, Lee, Eastman, & Venugopal, 2013). Developments in the use of scheduling and simulation for construction, workspace planning, and waste management have demonstrated that it can improve communication during the pre-construction phase. It can also facilitate shared understandings of the construction process and enable more accurate, timely, and appropriate information interchange with onsite construction employees (Feng, Liyanage, Karunathilake, Sadiq, & Hewage, 2020; Jupp, 2017).

Construction Project Environmental Performance and BIM Functionalities

In minimising the environmental issues and consequently governing project environmental performance, it is a substantial for project stakeholders to integrate environmental aspects into construction projects (Yahaya & Abidin, 2015). Environmental performance refers to consequences of specific actions aiming to make the construction processes more environmentally responsible (Awuzie & Aigbavboa, 2019; Bhattacharyya & Cummings, 2015; OSMADI, 2020). In construction project, the environmental performance embodies many aspects such as: the use of green materials, compliance with environmental regulations and standards and reducing pollution, with minimum amounts of wastes (Li, Ngniatedema, & Chen, 2017; OSMADI, 2020; Zeng et al., 2011).

Since the 1970s, traditional construction practises have shifted toward BIM-based design, which has become one of the most hotly debated topics in the industry. The AEC industry embraced BIM, and engineers began to consider its application in the management of construction projects (Abbasi & Noorzai, 2021; J.-B. Yang & Chou, 2019). BIM is a novel approach of managing design and project data as an integrated digital process throughout the life of a building. Additionally, it enables the exchange of information and collaboration among shareholders (Jafari, Sharyatpanahi, & Noorzai, 2020; J.-B. Yang & Chou, 2019).

From a three-dimensional geometric model to time and cost planning, computer simulations, energy efficiency, and facility management, the use of BIM as an n-D modelling platform has expanded (Najjar, Figueiredo, Hammad, & Haddad, 2019). Additionally, the use of BIM enables the conduct of an environmental analysis and adherence to sustainable development standards (Abbasi & Noorzai, 2021; Najjar et al., 2019). Moreover, BIM in enormous number of studies was used in assessing and analysing the environmental performance (Feng et al., 2020; Kirkegaard & Kamari, 2017) and producing environmental information (Zhong et al., 2018). BIM-LCA method was also widely used in quantifying and analyse the environmental performance and environmental aspects such as different footprints of water, materials and climate (Abbasi & Noorzai, 2021; Hollberg, Tschetwertak, Schneider, & Habert, 2018; Sameer & Bringezu, 2021). Indeed, BIM is a way forward for enhancing project environmental performance (Hollberg, Genova, & Habert, 2020; Jupp, 2017).

According to Oxford (2021), functionality is the quality of being suited to serve a purpose well; practicality. On other words the purpose that something is designed or expected to fulfil. In BIM aspect, Succar, Sher, and Williams (2013) defined BIM capability as “basic ability to perform a task or deliver a BIM service/product”, this definition is used interchangeably with the definition of BIM functionality according to Saka and Chan (2020). Accordingly, BIM functionality can be defined in this study as the multiple tools, purposes and qualifications that were designed in BIM using the fundamental requirement of parametric object modelling to serve certain tasks and missions, duties and assignments in the field of construction industry.

Nowadays, there are an expanding number of BIM software applications available that are transforming the AEC industry's working processes (Saieg, Sotelino, Nascimento, & Caiado, 2018). From the design stage to post-occupancy management, BIM is critical for cooperation among multi-discipline professionals, time and cost savings, fabrication and construction, and facility management (Ashworth, Druhmann, & Streeter, 2019). Moreover, BIM tools and software are crucial in improving the environmental performance through the diverse functionalities provided in order to mitigate the environmental impacts (Asgari & Noorzai, 2021).

A lot of researchers addressed many BIM functionalities that, according to this research, exceeded 90 detailed functionalities, and several studies tried to categorize these functionalities but no clear methodology in categorizing these functionalities has been presented so far.

RESEARCH METHODOLOGY

This study employed a systematic analysis approach to investigate the BIM functionalities classification and environmental performance of construction projects. A systematic technique is used to examine the articles' content and extract certain criteria or the frequency of use of various elements and other subjects. It is a qualitative analytical technique that enables an in-depth examination of the issues and concepts in the research field (Khan, Kunz, Kleijnen, & Antes, 2003; Siddaway, Wood, & Hedges, 2019; Tawfik et al., 2019).

Research Design Phases

In order to achieve the proposed objectives, this study went through 3 main phases namely: Data Collection, Qualitative Analysis and Thematic Discussion as shown in Figure 1. In the following sub-section, the criteria of Data Selection will be explained. While the other two phases will be introduced in detail in the Results and Discussion section.

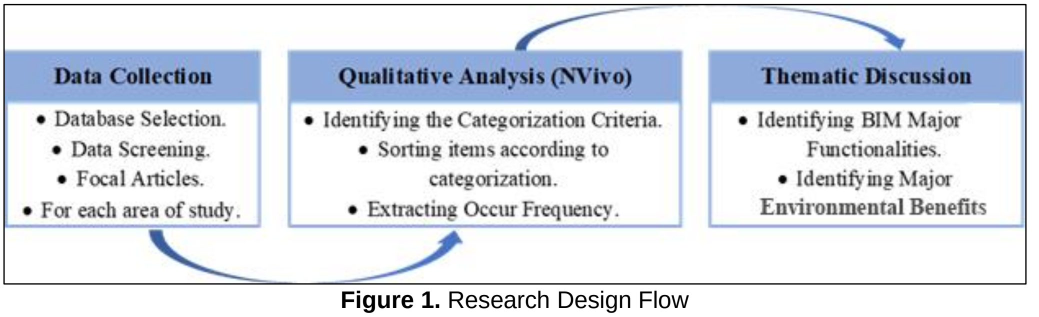

Figure 1. Research Design Flow

Data Collection

In order to collect the related data, this research went through the following steps:

Keywords Identification

The first step in collecting data is to select the correct and specific BIM terminology that is representing the scope of this study(Amrouni, Arshah, & Kadi, 2019). After a basic search the term of "BIM Function/Functionalities" was adopted as the major keywords that would be used in the process of data mining and conducting the research string.

Research Strings

After determining all appropriate keywords, research strings on SCOPUS were created in June 2021 (Refer to Table 1). A total of 43 studies related to BIM functionalities were covered from the basic search in the SCOPUS database. In addition, the research of BIM functionalities' main categories in the environmental performance has resulted in 38 articles.

Table 1. Research String & Details

	Research String (SCOPUS) / BIM Functionalities
In Title, Abstract & Keyword	(“BIM-Function*” AND “Construction”)
	Research String (SCOPUS) / Environmental Performance
In Title, Abstract & Keyword	(“Environmental-Performance”) AND (“Visualization” OR “Analysis” OR “Coordination” OR “Management”) AND (BIM) AND (construction)

Identification of the systematic review process includes selecting appropriate publications for the current analysis (Abrabba, Badarulzaman, Mohamad, & Kadi, 2021). In this study, two data sets were collected; the first is the articles related to BIM functions/functionalities, whereas the second is those related to BIM functionalities in the environmental performance.

The screening stage is aimed to remove the not related articles after screening the title and the abstract of the articles of both databases separately. The type of literature on which the researchers chose to rely exclusively on the journal (research articles), as it serves as the primary sources providing scientific evidence.

Additionally, the present work excludes publishing in the context of systematic study, meta-analysis, book show, essay, chapter of a journal (Table 2). As a result, 39 articles were included in BIM functionalities search and 32 articles in the environmental performance field.

After text mining according to this research scope, the articles of BIM functionalities retuned to 32 articles, whereas BIM functionalities categories and the environmental performance articles retuned to 27 articles as shown in Table 3.

Table 2. Screening and Text Mining Criteria

Criteria	Inclusion	Exclusion
Publication Timeline	2009 – 2021	-
Document Type	Article and Conference Proceeding	Review, chapters in book, book series, books etc.
Language	English	-

Table 3. Flow Diagram of The Study

	Records related to BIM-Functionalities (43)	(38) Records related Environmental Performance	
Identification	(n) = -4 n = 39	(n) = -6 n = 32	Full-text articles excluded (with reasons) (Excluded due to articles are not based on empirical data/articles are, hard sciences/ articles did not focus on subject did not focus on construction or related industries and Non-English).
	Sub-Total: n = 39	Sub-Total: n = 32	
Eligibility	(n) = -7 n = 32	(n) = -5 n = 27	Records excluded (excluded due to systematic review articles, review articles, meta-analysis articles, book series, book, chapter in book).
	Grand-Total: n = 32	Grand-Total: n = 27	Screening

BIM Functionalities Identification and Categorization

The primary aim of this research is to identify BIM functionalities from the literature. Therefore, after developing the research string and using SCOPUS database, 43 studies were resulted in the field of BIM functions/functionality. After scanning the results, 4 studies were omitted due to unreachability or incompatibility with the scope of this research and 7 review articles were excluded as well. The final articles count was 32. By using NVivo software, an intensive text mining method was applied to extract the mentioned BIM functionality/functionalities in each article from 32 related articles. The resulted BIM functionalities were arranged according to the articles that included them, and some of them were mentioned in many other articles while other BIM functionalities had less frequency in the literature. As a result, 4 groups of main functionalities were suggested to embrace the others according to relativeness.

BIM Main Functionalities in Project's Environmental Performance

After defining BIM functionalities main categories, their benefits in the environmental performance were investigated by conducting SCOPUS-based research of both areas. 38 studies were resulted and 6 of them were excluded due to unreachability or incompatibility with the scope of this research and another 5 review or not informative articles were also omitted. The final count of related articles is 27, which were subject to text mining using NVivio software in order to extract the mentioned benefit/benefits of BIM functionalities in enhancing the environmental performance. As a result, a list of 43 benefits were extracted as shown in Table 4.

Table 4. Research Flow Articles

Research Flow	1st Research Area	2nd Research Area
Research Keywords	BIM Functionalities	Environmental Performance + 4 BIM Main Functionalities
Data Base	SCOPUS	
Rough Results	43	38
Results After Screening	32	27
Sub-Results	92 BIM Functionalities	43 Environmental Benefits
Main Categories	4 Functionalities	8 Environmental Areas

RESULTS AND DISCUSSION

The study's findings are divided into two sections: BIM functionalities and BIM functionalities in connection to environmental performance of projects. The analysis begins with a cursory evaluation of the publications, and then moves on to a content analysis of the articles in the two primary areas. To further aid in presenting of the findings, tables and figures are used.

BIM Functionalities

This section will discuss on the importance of establishing a clear generic categorization for BIM functionalities. Following that, appropriate BIM functionality categories will be determined and discussed based on the articles found.

Based on the examination of the selected literature, a wide range of BIM functions, in fact more than ninety, are highlighted. However, only a few studies recommended categorization of these functionalities out of all the studies. BIM categorization is important as it allows the interested researchers to focus their studies and investigate the effect of adopting BIM on various aspects and issues (Saka & Chan, 2020), in addition to the significant effect on the project managers to understand and correctly select the proper BIM functionality to the suitable part or phase of the project (Volk, Stengel, & Schultmann, 2014; X. Zhang, Arayici, Wu, Abbott, & Aouad, 2009).

For instance, Abd Jamil and Fathi (2018) and Asgari and Noorzai (2021) recommended classifying BIM functionalities according to project phases. The researchers have classified BIM functionalities based on its usage in Planning, Design, Construction and Operation. Despite the positive seeming nature of this proposition, BIM functions in the two critical project phases, i.e. project initiation and closure were not clearly emphasized resulting in implausible comprehensive BIM functionalities throughout entire construction project. According to (Heldman, 2018; Srivastava, 2021) project phases should mirror the general phases as indicated in most project management studies. Despite the fact that BIM functions might occur in other project phases, identifying BIM capabilities based on time-based categorization results in single-functionality. Other research works like (Ahankoob, Manley, Hon, & Drogemuller, 2021; Evans, Farrell, Zewein, & Mashali, 2021; Schimanski, Marcher, Monizza, & Matt, 2020) also show attempts to categorise BIM functionalities. They narrowed the classification based on individual research context or case study. For example, Ahankoob et al. (2021) classified the adoption of BIM features in lean management and their interrelationships according to the scope of their research, whilst (Evans et al., 2021; Schimanski et al., 2020), define the categories based on individual case study that cannot be generalised or addressed in subsequent general investigations.

Due to the lack of particular BIM functionalities in the prior literature, it is difficult to conduct a thorough examination of BIM functionalities. As a result, the realm of BIM functionality needs to be properly classified, which is the study's goal. This may serve as a catalyst for other researchers and BIM users in the AEC sector to fully use categorization of BIM functions for different elements of building projects.

As the term function suggested, the categories for BIM function should reflect the essential concept and purpose of BIM technology. “Visualization” is one of the fundamental and primary function of BIM. Through visualization function the project can be stimulated digitally before being carried out in real life, starting with the devices for changing the data bank into visually evaluated items. This includes all functions that work on transforming the project's raw data into visual items, such as shop drawings, simulation, and reaching virtual and augmented reality (Fahmi & Safitri, 2021; Garavaglia, Anzani, Maroldi, & Vanerio, 2020).

After data has been input and visualised, it must be analysed and converted into information that enables stakeholders to make more informed decisions, conduct more accurate estimations, and achieve optimum productivity (Thakkar, Pandya, Rabadiya, Prajapati, & Thakkar, 2021; Zhao & Tang, 2021). As a result, the second category is "Analysis".

The third stage is to connect and schedule this data and information according to the project's timeline, as well as to identify the tasks and task owners, as well as all project management aspects (Mustaffa, Xiong, Mustapa, Ariffin, & Ismail, 2021; Rui, Yaik-Wah, & Siang, 2021), that would fall into the third category, which is "Management".

Finally, there is the integrated "Coordination" function, which subcategorizes all aspects of stakeholder collaboration and communication, as well as the functions of project documentation, knowledge and information management, and the system for preserving the project's knowledge heritage (Bo & Siqi, 2020; Park & Lee, 2017).

Following an investigation of related articles, this research determined that the 92 functionalities chosen to fit into four categories: first, visualization, second, analysis, third, management, and lastly, coordination. We found that the category with the most functionalities is analysis, followed by management and visualization. Coordination has the least number of functionalities.

Table 5. BIM Functionalities Categories

No.	BIM Functionality Categories	Freq.	%	No.	BIM Functionality Categories	Freq.	%
	Analysis	**77**	**100**		**Analysis**	**77**	**100**
1	Evaluation of alternatives	7	9.10%	19	Reduce rework	2	2.60%
2	Predictive analyses	7	9.10%	20	Cost planning within budget	2	2.60%
3	Material tracking and management	5	6.50%	21	Environmental analysis	1	1.30%
4	Energy assessment/analysis	4	5.20%	22	Lifecycle analysis	1	1.30%
5	Cost estimation	4	5.20%	23	Sustainability	1	1.30%
6	Analysis	3	3.90%	24	Thermal analysis	1	1.30%
7	Site Analysis, Site planning	3	3.90%	25	Solar analysis	1	1.30%
8	Performance analysis	3	3.90%	26	Acoustic analysis	1	1.30%
9	Quantity take-off	3	3.90%	27	Data evaluating	1	1.30%
10	Estimation	3	3.90%	28	Schedule of quantities	1	1.30%
11	Alternative development	2	2.60%	29	Bill of quantities preparation	1	1.30%
12	Code compliance with regulations	2	2.60%	30	Design and engineering analysis	1	1.30%
13	Risk analysis	2	2.60%	31	Quantity surveying	1	1.30%
14	Structural analysis	2	2.60%	32	Cost control	1	1.30%
15	Information management	2	2.60%	33	Productivity optimization	1	1.30%
16	Generation of reports	2	2.60%	34	Real-time evaluation of productivity	1	1.30%
17	Improving maintainability studies	2	2.60%	35	Cost alternatives evaluate	1	1.30%
18	Lifecycle environmental data	2	2.60%				
No.	**BIM Functionality Categories**	**Freq.**	**%**	**No.**	**BIM Functionality Categories**	**Freq.**	**%**
	Management	**51**	**100**		**Management**	**51**	**100**
1	Scheduling	12	23.50%	13	Project turnover and closeout	1	2.00%
2	Facility management	5	9.80%	14	Lifecycle management	1	2.00%
3	Space Management, Space planning	5	9.80%	15	Waste management	1	2.00%
4	Safety management	3	5.90%	16	Design management	1	2.00%
5	Logistics management, Logistics planning	3	5.90%	17	Procurement Management	1	2.00%
6	Planning	3	5.90%	18	Quality Management	1	2.00%
7	Monitoring construction process	2	3.90%	19	Field tracking	1	2.00%
8	Asset management	2	3.90%	20	Disaster planning	1	2.00%
9	Locating building components	2	3.90%	21	Supply chain management	1	2.00%
10	Management	1	2.00%	22	On time completion	1	2.00%
11	Management tracking	1	2.00%	23	Change management	1	2.00%
12	Workforce planning	1	2.00%				
No.	**BIM Functionality Categories**	**Freq.**	**%**	**No.**	**BIM Functionality Categories**	**Freq.**	**%**
	Visualization	**75**	**100**		**Coordination**	**64**	**100**
1	Visualization	27	36.00%	1	Collaboration	13	20.30%
2	Simulation	7	9.30%	2	Data capturing, digital documentation, document generation	11	17.20%
3	Drawings generation	6	8.00%				
4	Shop drawings	5	6.70%	3	Clash detection, constructability	9	14.10%
5	Generating as-built models	4	5.30%	4	Team communication, online communication	5	7.80%
6	Modelling existing conditions	2	2.70%	5	Object-based programming, communication	5	7.80%
7	Integrating information	2	2.70%	6	Maintenance of information integrity	5	7.80%
8	Training In Virtual Reality	2	2.70%	7	Coordination	4	6.30%
9	Simulation of alternatives	1	1.30%	8	Lifecycle cost data	3	4.70%
10	Performance simulation	1	1.30%	9	Data and information exchange	3	4.70%
11	Lightning design	1	1.30%	10	Real-time integrated building maintenance and management data	2	3.10%
12	Ventilation and air flow	1	1.30%				
13	Design authoring	1	1.30%	11	Cloud computing	1	1.60%
14	Digital fabrication	1	1.30%	12	Stakeholder engagement	1	1.60%
15	In-field construction layout	1	1.30%	13	Integrate with project partner (supply chain) databases	1	1.60%
16	Construction system design	1	1.30%				
17	Augmented reality	1	1.30%	14	Software interoperability with other applications	1	1.60%

Table 5 illustrates the primary and subcategories of BIM functionalities by categorising 92 subcategories into the four primary BIM functionalities categories, as well as the frequency of use for these subcategories using the qualitative analytic software NVivo. The frequency with which these subcategories are studied is expressed as a percentage of the overall number of subcategories studied in each of the primary categories, in order to illustrate the subcategories' relative significance.

Starting with Analysis. When it comes to the primary functionality of the subcategories, the primary criteria is analysing the data that has been submitted and delivering high-quality information. This data will help stakeholders to make more informed choices, execute more accurate predictions, create more accurate reports, and perform other critical functionalities listed in Table 5. The category of analysis has the most subcategories, with a total of 35 subcategories that have been investigated and cited 77 times during the study. As can be seen, the most major subcategories are alternative evaluation, predictive analysis, and inventory monitoring and management. The percentage of frequency spent researching these subcategories is shown in Table 5.

The second category is Management, this category has 23 subcategories, the most significant of which is scheduling. The primary criterion for this category is connecting the data and information extracted during the analysis stage to the project's time schedule, as well as identifying significant management issues such as identifying the tasks and task owners, resources and schedules, and all other items necessary to manage the project, ensuring the project's supply chain, and tracking and monitoring the progress of the project's tasks and duties.

The third category is the Visualization functionality, the primary criterion for the subcategories is converting the data associated with the items into visually examined models, charts, or figures that are easily read and understood, such as simulation, drawing generation, shop drawings, generating as-built models, and modelling existing conditions, among others mentioned in Table 5. It's worth noting that Visualization is divided into 17 subcategories.

Coordination is the last BIM functionality category. This category refers to the collaboration and communication between project stakeholders. Along with managing and maintaining project documentation and storing and distribution information, this category includes 14 critical subcategories such as collaboration, data capture, clash detection, digital documentation and constructability and many others mentioned in Table 5.

BIM Environmental Performance Benefits

In order to analyse the benefits that BIM functionalities have on construction project environmental performance, the aspects that represent the environmental performance were first identified. Despite the fact that a number of studies have attempted to categorise the environmental performance benefits of BIM, few of them clearly link the two (Asgari & Noorzai, 2021; Soust-Verdaguer, Llatas, & García-Martínez, 2017). However,–a study by Asgari and Noorzai (2021) use a categorization collected from ISO 14040, ISO 14044, and 15978EN standards. In which, 4 main environmental indicators categories were adopted namely: Air or Climate, Water, Resources, and Soil. These categories include 19 potential environmental benefits of several BIM functionalities.

By investigating other studies in the field of environmental performance in connection to BIM, many additional environmental indicators under different categorization aspects were mentioned such as: embodied energy, carbon footprint, total mass of materials, etc. (Martínez-Rocamora, Rivera-Gómez, Galán-Marín, & Marrero, 2021). In general, majority of research that has defined environmental benefits used environmental indicators to create primary groups. These studies differed, however, in that they added or limited their categories to specific indicators.

The same 4 environmental indicators mentioned by Asgari and Noorzai (2021)are included as major categories of environmental benefits in this study,–with the additional 3 categories adopted from two studies in the field of BIM as shows in Table 3. Tables 7 shows list of environmental benefits within each primary category.

Table 6. Environmental Benefits Categories References

Category	Reference	Category	Reference
Air or Climate	(Asgari & Noorzai, 2021)	Energy	(Martínez-Rocamora et al., 2021)
Water		Materials	
Resources		Wastes	(Signorini et al., 2019)
Soil		Environmental Performance Effectiveness	No reference. Extracted from the resulted articles of this research.

Table 7. Environmental Benefits Categories

No.	Environmental Performance Benefits	Freq.	Articles
1)	Air or Climate Change	18	
01	Reducing the global warming potential	3	12,13,4
02	Assess GHG emissions	2	10,12
03	Assessing CO2 emissions	2	26,32
04	Reducing ozone depletion potential	2	12,4
05	Reducing smog formation potential	2	12,4
06	Reducing acid gas emissions	2	2,4
07	Reducing fine particles generation	2	2,4
08	Demonstrate the carbon foot print	1	20
09	Reducing photochemical ozone creation potential	1	4
10	Quantifying climate footprint	1	5
2)	Energy	18	
01	Evaluate energy demand	6	1,12,18,2,4,3,2
02	Evaluate the non-renewable energy	2	12,4
03	Evaluate embodied energy	2	26,31
04	Energy analysis	2	21,25
05	Evaluate the renewable energy	1	12
06	Energy simulation	1	14
07	Daylight analysis	1	22
08	Building orientation	1	22
09	Indoor environmental performance evaluation	1	24
10	Optimize building lifecycle energy	1	3
3)	Environmental Performance Effectiveness	8	
01	Providing environmental impacts information	3	16,19,28
02	Evaluating the environmental performance/performances	2	1,29
03	Enhancing the environmental performance	1	11

No.	Environmental Performance Benefits	Freq.	Articles
04	Environmental impacts optimization	1	15
05	Prevent design errors	1	30
4)	Water	5	
01	Reducing eutrophication Potential	2	12,4
02	Reducing freshwater aquatic Eco toxicity potential	1	4
03	Reducing marine aquatic Eco toxicity potential	1	4
04	Quantifying water footprint	1	5
5)	Materials	4	
01	Materials' quantity estimation	1	25
02	Deciding the selection of environmentally friendly construction products	1	27
03	Determine the materials footprint	1	5
04	Providing material loss data	1	8
6)	Resources	4	
01	Reducing the consumption of mineral resources	1	2
02	Reducing biotic resource depletion	1	4
03	Reducing fossil fuel consumption	1	4
04	Reducing resource consumption	1	8
7)	Soil	3	
01	Land use impacts	1	4
02	Ecosystem damage potential	1	4
03	Terrestrial Eco toxicity potential	1	4
8)	Wastes	3	
01	Reducing wastes	1	13
02	Estimating hazardous, non-hazardous and radioactive waste landfilled	1	4
03	Assessing solid wastes	1	8

[Note: The numbering reference are as follows; (1) (Ansah, Chen, Yang, Lu, & Lam, 2021), (2) (Xu & Liu, 2021), (3) (Abbasi & Noorzai, 2021), (4) (Asgari & Noorzai, 2021), (5) (Sameer & Bringezu, 2021), (6) (Roberts, Allen, & Coley, 2020), (7) (Goyal & Rai, 2020), (8) (Yao et al., 2020), (9) (Potrč Obrecht et al., 2020), (10) (Feng et al., 2020), (11) (Akdag & Maqsood, 2019), (12) (Huang et al., 2020), (13) (Maraqa et al., 2020), (14) (Karunathilake, Ruparathna, Hewage, & Sadiq, 2020), (15) (Frischknecht, Birgisdottir, Chae, Lützkendorf, & Passer, 2019), (16) (Signorini et al., 2019), (17) (Lützkendorf, 2019), (18) (Amoruso, Dietrich, & Schuetze, 2018), (19) (Bueno, Pereira, & Fabricio, 2018), (20) (X. Yang et al., 2018), (21) (Krasny, Klarić, & Korjenić, 2017), (22) (Zainudin, Haron, Bachek, & Jusoh, 2016), (23) (Wong & Zhou, 2015), (24) (Lim, 2015), (25) (Ajayi et al., 2015), (26) (Abanda, Tah, & Nkeng, 2015), (27) (Adamus, 2014), (28) (Antón & Díaz, 2014), (29) (Brígitte & Ruschel, 2013), (30) (Jylhä & Junnila, 2012), (31) (Shrivastava & Chini, 2012), (32) (Raheem, Issa, & Olbina, 2011).]

BIM in enormous number of studies was used in assessing and analysing the environmental performance (Feng et al., 2020; Kirkegaard & Kamari, 2017) and producing environmental information (Zhong et al., 2018). In addition, BIM-LCA method was wildly used in quantifying and analysing the environmental performance and environmental aspects such as different footprints of water, materials and climate (Abbasi & Noorzai, 2021; Hollberg et al., 2018; Sameer & Bringezu, 2021). Indeed, BIM is a way forward for enhancing project environmental performance (Hollberg et al., 2020; Jupp, 2017).

BIM Functionality in Relation to Projects Environmental Performance

In order to inspect the extent of which BIM functionality is affecting the environmental performance of the construction project, the selected 27 articles were coded and analysed via NVivo software. The occurrence of the BIM functionality categories and the environmental performance categories were coded and counted. A general matrix coding query was performed to identify the number of the articles that combined BIM functionalities and environmental performance categories. As well as to estimate the relative significance relationship in between the various categories of both aspects studied as shown in Table 8.

Table 8. BIM Main Functionalities in Environmental Benefits Categories

	Matrix Analysis	BIM Functionality Categories							
		Analysis		Coordination		Management		Visualization	
Environmental Performance Categories	Air or Climate	10	37.0%	4	14.8%	3	11.1%	10	37.0%
	Energy	14	51.9%	4	14.8%	3	11.1%	14	51.9%
	EP. Effectiveness	7	25.9%	3	11.1%	3	11.1%	8	29.6%
	Materials	4	14.8%	0	0.0%	1	3.7%	4	14.8%
	Resources	3	11.1%	1	3.7%	2	7.4%	3	11.1%
	Soil	1	3.7%	1	3.7%	1	3.7%	1	3.7%
	Wastes	3	11.1%	2	7.4%	3	11.1%	3	11.1%
	Water	3	11.1%	2	7.4%	2	7.4%	3	11.1%

The number of articles that incorporate and discuss environmental performance in respect to BIM functionalities categories with a percentage for each usage is shown in Table 8. Many studies have recognised the usefulness of BIM functions in achieving environmental performance gains. In the majority of research, BIM is used in analysis, coordination, management, and visualisation. The result has shown that BIM is a valuable tool for enhancing project environmental performance. The proposed categories allow for a more thorough approach in dealing with environmental issues and improving environmental performance.

CONCLUSION

Nowadays, the AEC industry is moving towards achieving sustainable aspects in construction and meeting the environmental requirements and guidelines. And due to the ability to handle the complex and multi-disciplinary nature of the construction projects, innovation technologies, such as BIM, are encouraged to be adopted in the industry. In this context, BIM provides and manages multi-disciplinary information along the project's life cycle, which might be modified, exchanged, or developed any time in any stage by the projects' stakeholders.

This study investigated BIM functionalities in detail and categorised them into 4 major categorizations. Furthermore, the study inspected the effect of these functionalities' categorizations on the environmental performance of the construction project. Visualization, Analysis, Coordination, and Management are the four capabilities of BIM in aiding the improvement of 8 key environmental performance areas, namely: Air or Climate, Energy, Environmental Performance Effectiveness, Materials, Resources, Soil, Wastes, and Water. The findings highlighted the role of BIM main functionalities in sustaining the environmental performance.

This study investigated the BIM functionalities in environmental projects using two primary keywords. Comparable keywords, such as "capability, use", can be employed to expand the findings on applications of BIM functions in environmental projects that align with the proposed BIM functionalities categories. As this research explored articles published in journals indexed by SCOPUS, expanding the search to other databases (including

International Scientific Indexing (ISI) database or other data bases) in future studies would further establish the link between BIM and environmental performance. Other studies can be also conducted to analyse the main enablers and challenges of BIM environmental function using the four categories proposed.

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SURFACE MORPHOLOGY AND STRENGTH OF CHEMICALLY TREATED SACCHARUM OFFICINARUM BAGASSE FIBRES CEMENT COMPOSITES OF LOW CARBON CONCRETE

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Abstract
This study explores the potential of Saccharum Officinarum Bagasse Fibres (SOBF) as a sustainable reinforcement in cement-based composites for affordable construction in developing countries. Focusing on locally sourced SOBF, known for its sustainability and low cost, this research aims to enhance the mechanical properties of cement composites. The study examines the impact of SOBF on compressive strength, comparing 1%, 2%, and 3% fibre content at 7 and 28 days, both treated and untreated. Scanning Electron Microscopy (SEM) analysis revealed that SOBF inclusion mitigates surface cracking through a bridging effect within the hardened cement. Results indicate that compressive strength increases up to an optimal fibre content, with 1 wt.% providing the best outcomes for both treated and untreated samples. Interestingly, untreated composites displayed higher compressive strength than their treated counterparts, likely due to the natural lignin enhancing fibre-matrix bonding. The findings demonstrate that SOBF significantly improves the mechanical properties and durability of cement composites, ideal for sustainable construction in regions prioritizing cost-effectiveness and local resource utilization. This study not only highlights the benefits of integrating natural fibres like SOBF in cementitious applications but also emphasizes the importance of optimizing fibre content and treatment to enhance composite performance.

Keywords: *Saccharum officinarum bagasse; natural fibre waste; cement composites; chemical treatment; construction materials; fibre-reinforced concrete.*

INTRODUCTION

Concrete is extensively utilized in the construction industry as a fundamental material (Dhivya, Manikandan, Kavitha & Krishnakumar, 2021). There has been a growing emphasis on integrating sustainable materials into construction practices in order to enhance environmental preservation (Misnon *et al.*, 2017). Typically, concrete comprises cement, aggregate, water, and various chemical admixtures (Adnan *et al.*, 2018; Dhivya *et al.*, 2021). A significant advantage of using cement is the ability to adjust its strength to meet specific project requirements by modifying the ratios of its constituent elements (Basnet *et al.*, 2022). Introducing agricultural waste like Saccharum Officinarum Bagasse Fibres (SOBF) into concrete has been shown to impact its compressive and splitting tensile strength (Dhivya *et al.*, 2021). SOBF, a substantial by-product derived from sugarcane ash, is noteworthy for causing considerable residue deformation following combustion (Dhivya *et al.*, 2021). Its rich silica content has facilitated the synthesis of silica nanoparticles (Basnet *et al.*, 2022). Furthermore, bagasse fibre, which is a natural by-product of sugarcane, decomposes within 25-65 days, with its properties varying based on the sugarcane's maturity, type, harvesting method, and efficiency of the crushing process (Adnan *et al.*, 2018; Yadav *et al.*, 2023). Enhancing concrete with natural fibres like bagasse has been found to bolster its compressive strength (Thamara *et al.*, 2018).

Additionally, sugarcane bagasse ash (SCBA), a residual from sugar production processes post-burning, has exhibited promising pozzolanic properties that improve the compressive strength of both mortar and concrete (Idris & Yassin, 2015). SCBA may contain elevated levels of SiO_2 and Al_2O_3, qualifying it as a viable supplementary cementitious material (SCM) for blended cements, contingent on the conditions of incineration (Idris & Yassin, 2015). SOBF, harvested from sugarcane stalks, is a renewable, low-cost resource abundantly available in tropical areas (Onuaguluchi & Banthia, 2016). Construction practices significantly contribute to environmental pollution, and the incorporation of natural fibres into composite materials represents a modern approach aimed at enhancing both durability and sustainability. The extensive adoption of plant-based natural fibres in cement and soil composites confers considerable environmental, energy, and resource conservation advantages (Onuaguluchi & Banthia, 2016). Despite these benefits, agricultural waste from lesser-known sectors still poses environmental challenges. Bagasse comprises both a hard-outer rind and a softer inner pith, containing cellulose, hemicellulose, lignin, ash, and trace components (Lee & Mariatti, 2008; Reddy & Yang, 2015). Although traditionally underutilized, bagasse has recognized potential in broader construction applications like panel boards and cementitious composites, performing comparably to hardwood fibres in composite board materials. Studies have indicated that bagasse, when combined with glass fibres and reinforced with epoxy resin, significantly enhances the modulus of elasticity (Tewari *et al.*, 2012). Composites made from 50 wt.% glass fibres and 30 wt.% bagasse have demonstrated hardness comparable to commercially available bagasse boards, albeit with high water absorption and swelling issues (Magzoub *et al.*, 2015).

Phenol formaldehyde (PF), widely used in natural fibre composites, provides excellent dimensional stability and mechanical properties. PF is also prevalent in hybrid technologies, producing thermal materials for the construction and automotive sectors, thereby improving tensile, flexural, and impact properties through robust fibre/matrix bonding (Asim *et al.*, 2018). Studies on oil palm fibre-reinforced PF composites have shown exceptional mechanical performance and decreased water absorption (Sreekala *et al.*, 2000). Refined SOBF used at substitution levels of 6-20% in concrete has demonstrated improvements in both compressive and splitting tensile strength relative to 100% cement use (Dhivya *et al.*, 2021). Thamara *et al.* (2018) also observed increased compressive strength in composite resins with bagasse fibre additions, with group averages reaching 353 MPa, 364 MPa, and 348 MPa. Replacing ordinary Portland cement with natural pozzolan and bagasse ash in a ternary binder not only reduced heat conduction but also enhanced strength after 90 days, particularly with untreated bagasse fibres (Arsène *et al.*, 2016). In studies conducted by Idris

& Yassin (2015), replacing 5-10% of Portland clinker with bagasse ash resulted in an optimal compressive strength of 45.5 N/mm² at 28 days for mortars with 10% bagasse ash replacement. As the demand for sustainable materials increases, research into plant-based natural fibre composites has expanded, driven by their affordability, low density, strength, and availability. Nonetheless, the susceptibility of some natural fibres to high-pH cement environments limits their application, and their water absorption tendencies adversely impact the mechanical and durability characteristics of cement composites. This ongoing research focuses on the effects of chemical treatments on SOBF surface morphology to further enhance its mechanical properties and improve the performance of cement composites.

MATERIALS AND METHODS

Materials

The experimental procedure began by sourcing Saccharum Officinarum Bagasse Fibres (SOBF) from a vendor in Batu Kawah, Kuching, Sarawak, who specializes in sugarcane juice. The selected sugarcane was mature and ready for processing. It was subjected to a quintuple milling process using specialized machinery to extract the bagasse. Following extraction, the SOBF was exposed to sunlight for three days to eliminate any remaining sugarcane juice, and then laid out on a waterproof sheet to ensure any residual moisture was also removed. Subsequently, the fibres were meticulously separated and snipped into segments approximately 10 mm in length, suitable for use as untreated fibre. This raw SOBF is illustrated in Figure 1. Meanwhile, Table 1 tabulated the composition of the SOBF. The cement utilized in this study was Ordinary Portland Cement (OPC) provided by Cahya Mata Sarawak Cement Sdn. Bhd. (CMS). This OPC conforms to ASTM C150 standards and fulfils or surpasses the stipulations set forth in the Malaysian Standard MS 522: Part 1: 1989 Specifications for OPC. The chemical makeup of this OPC is itemized in Table 2.

Figure 1. Raw Material of Saccharum Officinarum Bagasse Fibres (SOBF)

Table 1. Saccharum Officinarum Bagasse Fibres (SOBF) Composition

Items	Percentage (%)
Moisture	49.0
Soluble solids	2.3
Fibre	48.7
Cellulose	41.8
Hemicellulose	28.0
Lignin	21.8

Table 2. Chemical Composition of Ordinary Portland Cement (OPC)

Component %	CaO	SiO_2	Al_2O_3	Fe_2O_3	SO_3	MgO	Na_2O	K_2O	Others	LOI
OPC	63.0	21.69	5.75	3.25	2.35	1.97	0.50	0.28	0.11	1.00

The preparation of the treatment solutions involved creating a 5% concentration by dissolving 50g of Sodium Hydroxide (NaOH) in 1000ml of distilled water for the alkaline solution and mixing 40ml of Hydrochloric Acid (HCl) with 960ml of distilled water for the acid solution. Each solution was thoroughly mixed to achieve a homogeneous mixture.

Experimental Program

The experimental program was organized into three primary stages aimed at thoroughly evaluating the performance of both chemically treated and untreated Saccharum Officinarum Bagasse Fibres (SOBF) in cement composites with various fibre additions. The first stage entailed the sampling and extraction of fibres, which set a consistent and high-quality standard for subsequent tests. In the second stage, fibre pre-treatment, the fibres were chemically processed to improve their integration and effectiveness within the cement mixture. The third and final stage focused on the creation of cement composites, incorporating these fibres in different proportions to study their impact on the properties of the final composites. Figure 2 provides a visual representation of the entire experimental sequence.

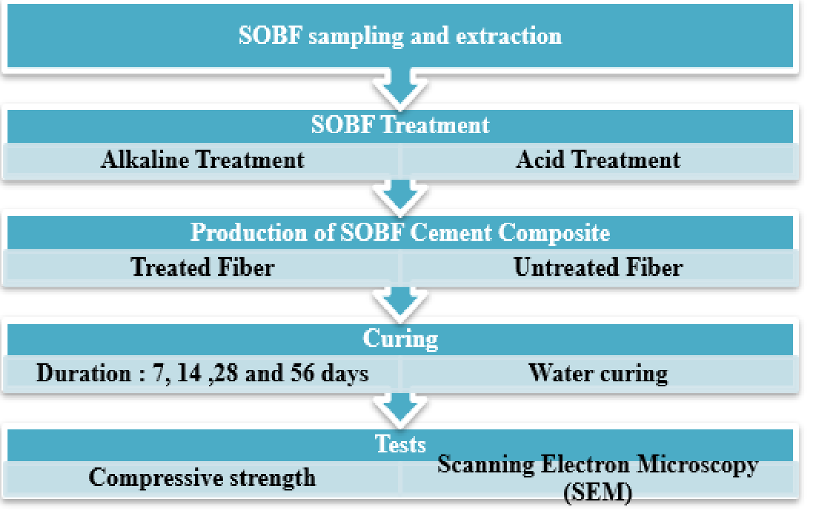

Figure 2. Experimental Program of Saccharum Officinarum Bagasse Fibres (SOBF)

Chemical Treatment of SOBF

The Saccharum Officinarum Bagasse Fibres (SOBF) underwent a treatment process beginning with an hour-long immersion in 5% by mass NaOH and HCL solutions. Following this, the fibres were washed with purified water to stabilize the pH at a neutral level of 7. After washing, the fibres were left to air dry at ambient room temperature for 48 hours and subsequently baked at 100°C for six hours to ensure thorough dryness. To protect against moisture absorption, the treated SOBF were then stored in tightly sealed plastic bags. Figure 3 illustrates the SOBF in both the alkaline and acid solutions.

Figure 3. SOBF Soaked Into (1) Alkaline and (2) Acid Solution for 1 Hour

Production of SOBF Cement Composite (SOBFCC)

The concentration of Saccharum Officinarum Bagasse Fibres (SOBF) incorporated was a key factor in this research. The composition of the SOBF Cement Composite is outlined in Table 3. To ensure an even distribution and prevent any segregation during the mixing process, the SOBF was evenly spread throughout the mixture. The newly mixed SOBF cement composite was then poured into cylindrical moulds with dimensions of 25 mm in diameter and 40 mm in height, as illustrated in Figure 4.

Table 3. Saccharum Officinarum Bagasse Fibres (SOBF) – Concrete Mix Designs

Sample		Cement (g)	Water (g)	Fibre (g)	w/c	Descriptions
Control	C	400	168	0	0.42	Non-fibre sample
Untreated	U1	400	168	4	0.42	1% untreated bagasse fibre
	U2	400	168	8	0.42	2% untreated bagasse fibre
	U3	400	168	12	0.42	3% untreated bagasse fibre
Alkali Treated	A1	400	168	4	0.42	1% alkali bagasse fibre
	A2	400	168	8	0.42	2% alkali bagasse fibre
	A3	400	168	12	0.42	3% alkali bagasse fibre
Acid Treated	B1	400	168	4	0.42	1% acid bagasse fibre
	B2	400	168	8	0.42	2% acid bagasse fibre
	B3	400	168	12	0.42	3% acid bagasse fibre

Figure 4. Casting of The Saccharum Officinarum Bagasse Fibres (SOBF) Cement Composite

Before the cement mixture was introduced, the inner surfaces of the moulds were greased to guarantee that the hardened composites could be easily extracted without damaging the specimens. After pouring, the samples were kept in the moulds at a consistent room temperature of 25°C for a 24-hour setting period. Subsequently, the samples were removed from the moulds, weighed, and placed in a curing tank at 25°C within the Concrete Laboratory, Universiti Malaysia Sarawak. They remained in the tank for curing durations of 7, 14, 28, and 56 days before being subjected to testing.

Surface Morphology of SOBF

Saccharum Officinarum Bagasse Fibres (SOBF) were initially immersed in a 5% NaOH and HCL solution by mass for an hour. Subsequently, the fibres were washed with filtered water to adjust the pH level to 7. Following the wash, the SOBF were air-dried at room temperature for 48 hours and then heated in an oven at 100°C for 6 hours. Afterward, for microscopic examination, the fibres were placed in a vacuum desiccator and coated with a fine layer of gold, as illustrated in Figures 5 and 6. The samples were then securely stored in sealed plastic bags prior to their analysis with a Scanning Electron Microscope (SEM). This SEM, capable of a 15,000V electron beam, allows for magnifications up to 30,000×. It was used to closely examine the microstructural characteristics of the samples, which were magnified up to 500 times to reveal detailed submicron features.

Figure 5. Fibre Treated and Untreated After Coated with Gold

Figure 6. Electrically Conductive Material (Sample Coating)

Compressive Strength Test

The compressive strength of cementitious materials is a critical factor in determining their effectiveness for structural or material use, as it is strongly linked to other mechanical properties and overall performance. The compressive strength test was conducted using a

Universal Testing Machine (UTM). Four different sample types were tested: untreated SOBFCC, alkali-treated SOBFCC, acid-treated SOBFCC, and 100% OPC, which was used as the control sample. These tests followed the BS 1881-116 (1983) standard to identify the maximum compressive load each sample could withstand. Figure 7 shows (a) the Universal Testing Machine setup and (b) a sample after testing.

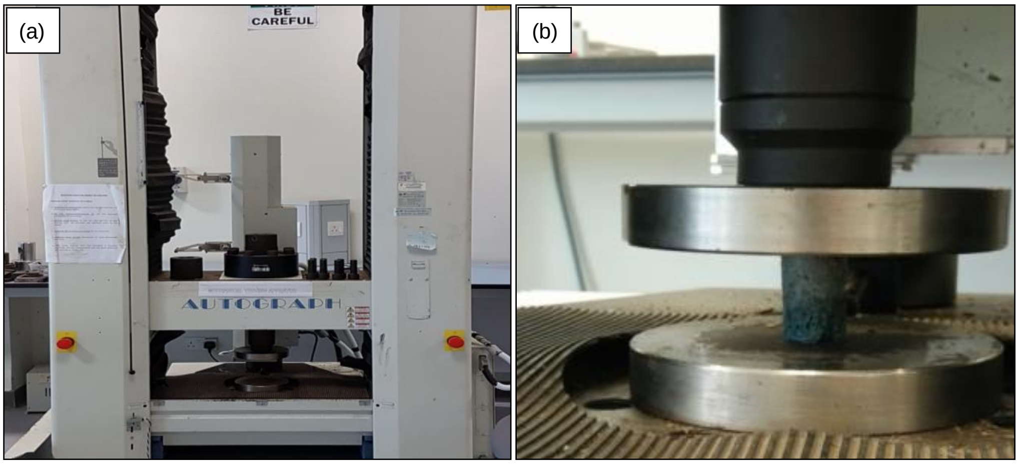

Figure 7. (a) Universal Testing Machine; (b) Sample Tested Under Compressive Load

RESULTS AND DISCUSSIONS

Surface Morphology of Untreated SOBF, Alkali Treated SOBF and Acid Treated SOBF

Figure 8 revealed significant changes in the surface morphology of SOBF after undergoing chemical treatment. Observations with an SEM showed the fractured surfaces of fibres both before and after the pre-treatment (Savastano, Warden & Coutts, 2001). The SEM images illustrated that the untreated SOBF lignocelluloses had a rough surface, indicative of lignin remnants. A one-hour alkali treatment removed this lignin, disintegrating fibre bundles and expanding the surface area effectively (Suradi *et al.*, 2009). As depicted in Figure 8, the fibre strands became thinner, and the efficacy of lignin removal improved. Additionally, increasing the duration of the treatment enhanced the porosity and pore size of the fibres, which improved physical locking and strengthened the interface bonding between the fibre and the matrix. The surface morphology of untreated sugarcane bagasse fibre was initially smooth and multicellular, but post-alkali treatment, it became rough, with visible fragments and increased fibril separation. Bagasse fibres, produced from the leftover fibrous material after processing sugarcane, could show a rough surface due to wax leakage, surface impurities, non-cellulosic substances, or synthetic materials, potentially improving the adhesion between the fibre and the polymer (Mazlan & Awal, 2012).

SEM was used to analyse both the fibre surface morphology and the extent of bonding at the fibre-matrix interface. Typical SEM micrographs of cement paste from various mixes, cured for up to 56 days. These graphs indicate a consistent rise in the presence of fibre bundles within the mixes. Notably, the treated fibres remained embedded within the cement matrix. The solidified cement paste contained a calcium silicate hydrate (C-S-H) gel. Despite various chemical treatments, the dense morphology of the C-S-H gel, which arises from full hydration, was observed. This suggested that hydration occurred as it would in ordinary concrete. The study then shifted focus to SEM-based observations of different failure models influenced by the fibre content. This study showed that higher fibre loading alters the bonding within the fibre matrix. With low fibre content (1%), the bonding was strong enough to cause fibre breakage, reinforcing the idea that compressive strength improves with reduced fibre content, which is consistent with other previous studies (Ardanuy *et al.*, 2015). The bonding strength was comparable between treated and untreated fibres. However, when fibre content increased to between 2-3%, the bonding weakened. Earlier studies have shown that this weakening is due to the interference from adjacent fibres and the fracture mechanism by pull-out (Ardanuy *et al.*, 2015). Evidence also suggests that higher fibre contents (>3%) may negate the reinforcement benefits, diminishing the functional role between the fibre and matrix (Ardanuy *et al.*, 2015).

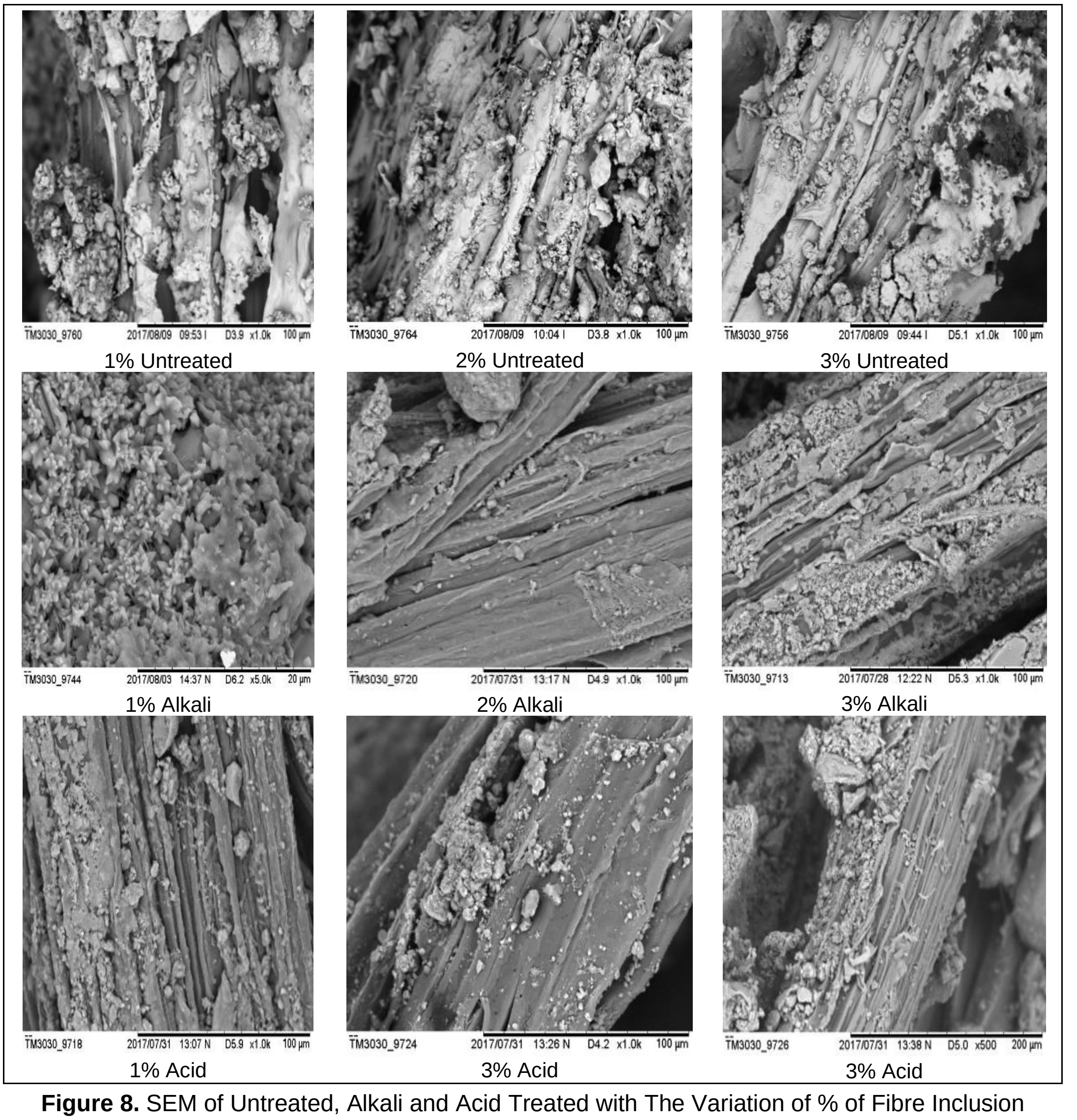

Figure 8. SEM of Untreated, Alkali and Acid Treated with The Variation of % of Fibre Inclusion

Strength Development of SOBFCC

Figure 9 showcases a comparative analysis of the strength development in fibre cement composites, with variations in treatment and fibre content ranging from 0% to 3% bagasse fibre, over different curing periods. Table 4 meanwhile, displays the average compressive strength derived from three cube samples. The strength of these composites or concrete is a crucial engineering characteristic in construction.

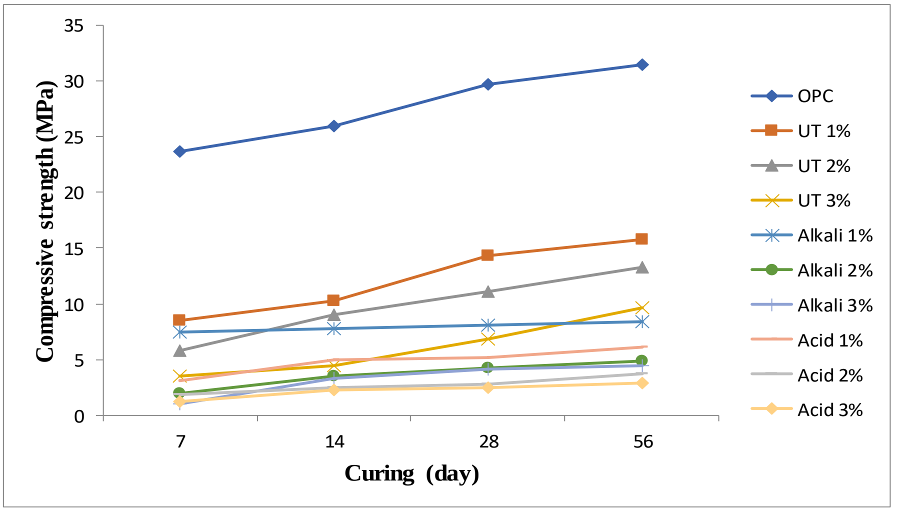

Figure 9. Strength Development of SOBF Cement Composite at Different Days

Table 4. Compressive Strength of Control and Fibre Cement Composite

Sample	Fibre (%)	Compressive Strength, MPa (Days)			
		7	14	28	56
Control	0	23.65	25.91	29.73	31.42
Untreated	1	8.55	10.32	14.29	15.80
	2	5.84	9.06	11.06	13.30
	3	3.49	4.42	6.88	9.69
Alkali Treated	1	7.45	7.73	8.14	8.42
	2	1.99	3.52	4.25	4.83
	3	1.04	3.29	4.14	4.41
Acid Treated	1	3.10	5.00	5.14	6.08
	2	1.90	2.50	2.75	3.75
	3	1.24	2.26	2.50	2.86

The curing process significantly influences strength development and durability, similar to its impact on traditional concrete through hydration of the cement. Overall, the findings suggest that incorporating fibres enhances the concrete mixture, boosting the compressive strength. It is well-established that adequate curing reduces porosity and refines the microstructure within the hydrated cement paste, highlighting the importance of proper curing to foster the formation of hydration products. This study utilized water curing to preserve moisture within the body of the fibre cement composite during initial and later stages to improve strength and durability. According to results depicted in Figure 9, the compressive strength of bagasse fibre cement composites, regardless of chemical treatment, increases with the number of curing days. Basnet *et al.* (2022) observed a similar enhancement in the compressive strength of cement/silica nanocomposites due to the silica nanoparticles' packing effect, consistent with earlier studies involving various natural fibres (Mazlan & Awal, 2012). The data reveal that curing duration markedly affects the compressive strength of all tested samples. Initially, pastes with different fibre percentages exhibit lower strength levels. Specifically, at 7-day curing period, the composite with 3% alkali-treated fibre shows the lowest compressive strength at 1.04 MPa. This decreasing trend continues for composites reinforced with 3% acid-treated fibre, where compressive strengths do not surpass 3 MPa at 14, 28, and 56 days. Such inconsistencies may relate to the chemical treatments' impact on the mechanical properties and fibre content.

Figure 10. Voids in Hardened Fibre Cement Paste

Furthermore, visible holes or pores are observed in hardened cement paste with both low and high fibre contents, as illustrated in Figure 10. These voids are likely due to air bubbles formed during processing, noticeable when the specimen is submerged in the water curing tank. The presence of these voids, considered material defects, adversely affects strength. Clarification is necessary here: "voids" refer to larger pores, whereas "porosity" pertains to smaller ones (Sobuz *et al.*, 2022), though these terms are often used interchangeably in the industry. Generally, a more porous structure is associated with weaker material properties. Notably, samples incorporating fibre as an additive to the cement paste generally exhibit lower compressive strength compared to plain concrete. Further examination shows that plain concrete with 0% fibre volume achieves the highest compressive strength, reaching 23.65 MPa at 7 days and increasing to 31.42 MPa by 56 days, indicating significant effects of porosity on strength and durability.

Effect of Fibre Content on the Strength of SOBFCC

Compression tests are essential for assessing how fibre cement composites withstand compressive forces. Figure 9 delineates the impact of varying fibre contents on the compressive strength of these materials, with Figure 11 illustrating that even a modest addition of fibre can enhance strength relative to a control mix that contains no fibre. Notably, the most substantial increase in compressive strength occurs when the fibre content is precisely 1%, for both treated and untreated samples, outperforming mixes containing 2% and 3% fibre. This enhancement in strength with a minimal fibre inclusion can be attributed primarily to the reduction in air voids and a decrease in surface porosity, which are more pronounced in composites with higher fibre content. These voids and pores act as stress concentrators, which can initiate cracks under compressive loads, thus weakening the material. Moreover, proper compaction plays a pivotal role in the structural integrity and optimal strength attainment of these composites. A mix with 1% fibre content demonstrates superior compaction, which contributes to a more uniform distribution of the fibre within the cement matrix. This uniformity ensures that the stress under compression is more evenly distributed across the composite, reducing the likelihood of failure points and enhancing the overall structural cohesion. This results in a higher compressive strength as the composite can better resist breaking under pressure. These observations underscore the critical relationship between a well-compacted, homogeneous structure and the effective interaction between fibres and the cement matrix. Such synergy is instrumental in boosting the compressive strength of fibre cement composites, confirming that meticulous material preparation and fibre distribution are crucial for optimizing the mechanical properties of these construction materials.

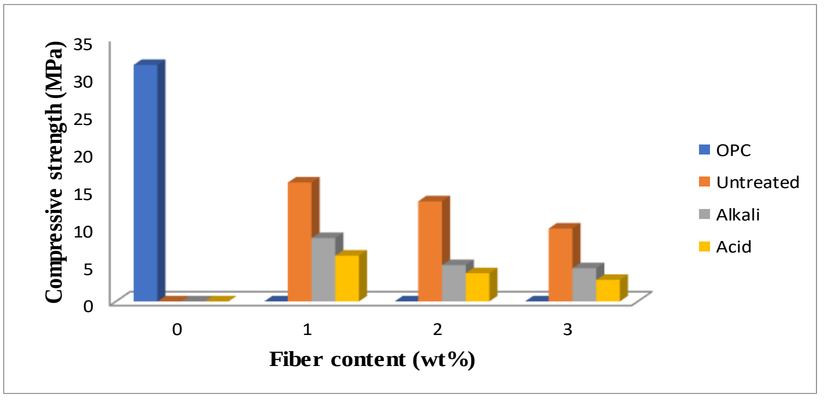

Figure 11. Effect of SOBF Content on Compressive Strength

Conversely, the strength of cement composites enhanced with bagasse fibre continues to escalate until a critical fibre content is achieved. This observation underscores the hypothesis that compressive strength increases up to a definitive fibre content threshold. The research identifies 1wt% as the optimal bagasse fibre content, marking the peak compressive strength observed. These findings are consistent with previous studies, which noted modest enhancements in compressive strength and bulk density with fibre content in the range of 0.3-1.5%. However, any increase in fibre content beyond this threshold tends to deteriorate the mechanical properties of the composites. Additionally, the cement paste displays superior integration and uniformity with the fibre at this optimal concentration. Such improvements in material compatibility and workability at this specific fibre content corroborate with existing literature that advocates for efficient mixing and curing processes at these levels (Mazlan & Awal, 2012).

Subsequent research indicated that increments in the volume of sugarcane bagasse fibre in concrete slightly impact its compressive strength (Ardanuy *et al.*, 2015), paralleling the findings with bagasse fibre cement composites. Notably, Figure 11 illustrates a marked reduction in compressive strength at fibre content between 2% and 3%, attributed to increased void formation within the composite, a phenomenon more prevalent at higher fibre concentrations, as evidenced by recent research (Nath *et al.*, 2021; Rajamane *et al.*, 2007).

These studies also examined the repercussions of having high void content – over twenty percent by volume – highlighting its adverse effects on fatigue resistance, increased water diffusion, and the variability of mechanical properties. Such negative outcomes often occur when the resin undergoes rapid curing and cooling, leading to void formation (Rehsi, 1988). Additionally, micro voids may develop along interfaces post-curing, affecting the spacing between laminate and resin-rich regions, thereby negatively influencing the mechanical properties of the composites.

Excessive fibre inclusion can significantly reduce bonding strength due to fibre congestion and clustering (Abdullah *et al.*, 2011). This issue aligns with observations from composites with a 3% fibre inclusion, which showed the lowest compressive strength. Notably, acid-treated fibres exhibited the weakest strength among untreated and alkali-treated fibres, registering 2.86 MPa at 56 days, indicative of poor bonding. Moreover, composites with higher fibre content exhibited strength loss at later stages, likely because the absorbed water was unavailable for further hydration, leading to void formation within the composite (Nath *et al.*, 2021; Rajamane *et al.*, 2007). Additionally, fibre inclusion disrupts the matrix, potentially causing fibre blockage and further void formation, with these gaps potentially serving as initiation points for microcracking.

Furthermore, high fibre content complicates the mixing process, affecting the workability and uniformity of the mix. This study emphasizes that maintaining workability and proper compaction becomes increasingly challenging with fibre contents of 2 wt.% and 3 wt.%. Observations revealed that as fibre content increased, the workability of the cement paste decreased, resulting in a mix that was too dry and lacked sufficient water for proper blending. This inadequate blending process compromised mechanical properties. Previous research noted that adding chopped fibres to a fresh mortar mix could cause stiffening and reduce workability (Rehsi, 1988). Additional studies, particularly those involving coconut fibre, have highlighted the difficulties associated with high fibre content, focusing on the fibre's characteristics and condition. These investigations demonstrated that if the fibre is stiff and rigid due to a lack of water in the mix, it can complicate fibre packing, leading to significant void formation and adding complexities to the mixing process (Abdullah *et al.*, 2011).

Despite previous conflicting results, the benefits of incorporating natural fibres into a cement matrix are clearly demonstrated in terms of enhanced structural stability. Compression tests revealed that specimens without fibre (control group) showed highly unstable and erratic failure modes. In contrast, cement composites reinforced with natural fibres exhibited considerably more stable and consistent behaviour under pressure. This stability is evident in the significant deformations observed in the hardened fibre cement composites, which experienced a gradual reduction in applied load rather than abrupt failure. Such behaviour suggests an increased capacity for deformation, attributable to the improved interfacial bonding between the fibres and the cement mortar mix, thereby enhancing the overall structural integrity of the composite (Pereira *et al.*, 2015).

Additionally, the inclusion of fibres significantly altered the failure mode of the composites, transitioning from brittle to more ductile behaviour. This ductility is largely due to the fibres' bridging effect, as shown in Figures 12 and 13, which prevents the rod specimens from breaking apart completely. Instead, the fibres help maintain the structural cohesion of the composite throughout the testing process, effectively holding the material together even as cracks begin to develop (Mazlan & Awal, 2012). Bagasse fibres are particularly crucial in transferring stress across cracked regions and play an essential role in preventing crack propagation within the matrix. Further research has indicated that fibres in cement or concrete act as crack arrestors, facilitating slow crack propagation and a gradual failure process, thus enhancing the material's ability to endure prolonged stress without sudden failure (Mondol *et al.*, 2022). It is also noteworthy that isolating the broken specimens after testing proved challenging due to the bridging effect, which kept the hardened parts connected. Overall, the addition of fibres led to a more stable and predictable failure mode under compressive loads, as reported in the experimental findings shown in Figure 14.

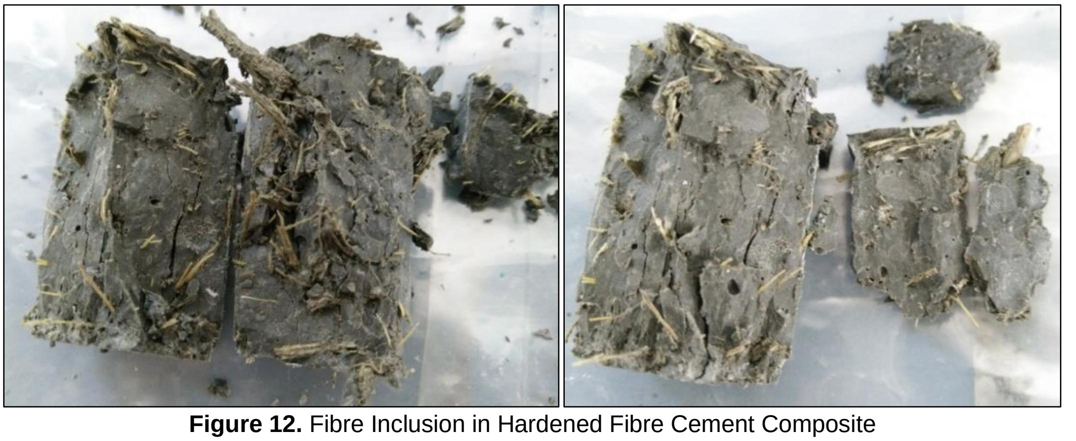

Figure 12. Fibre Inclusion in Hardened Fibre Cement Composite

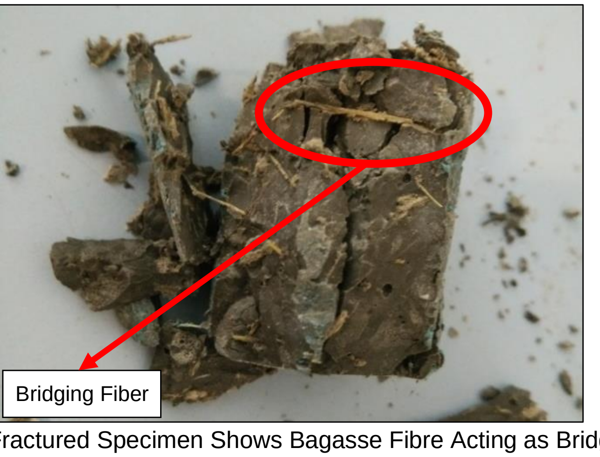

Figure 13. Fractured Specimen Shows Bagasse Fibre Acting as Bridging Agent

Figure 14. Failure Mode of Rod Specimen Under Compressive Load

CONCLUSION

This investigation confirms the essential function that Sugarcane Bagasse Fibre (SOBF) serves in bolstering the structural robustness of cement composites, particularly by reducing surface cracking in hardened SOBF Cement Composites (SOBFCC). The integration of SOBF introduces a bridging effect that is pivotal in curbing the extension of cracks and simultaneously boosting the composite's strength and ductility, particularly following the initial occurrence of cracks. These insights reinforce the theory that the bridging effect substantially elevates both the mechanical strength and the ductility of the composite material, corroborating previous studies and enriching the scholarly understanding of this phenomenon. The research also discovered that the compressive strength of the cement composites progressively increases until reaching an optimal fibre composition. Specifically, a 1 wt.% inclusion of bagasse fibre was found to produce the highest compressive strength for both chemically treated and untreated specimens. This optimal percentage underscores the delicate balance between fibre content and the mechanical properties of the composite, indicating that exceeding this threshold could potentially reduce the composite's structural integrity. Further analysis on the effect of chemical treatment on compressive strength showed that untreated fibres, across varying inclusions from 1-3 wt.%, consistently exhibited higher compressive strengths compared to those subjected to alkali or acid treatments. This difference is largely attributed to the lignin present in untreated fibres, which naturally boosts the compressive strength of the cement paste. Conversely, chemical treatments, which eliminate lignin, lead to a notable decrease in strength, regardless of the chemical used. Additionally, Scanning Electron Microscopy (SEM) analysis affirmed that the integrity of both treated and untreated fibres was maintained within the cement matrix after treatment, without hindering the hydration processes of the cement. Notably, fibres treated with a 5% NaOH solution displayed greater surface roughness compared to those treated with 5% HCL or those that were untreated. Microstructural examination revealed that this enhanced surface roughness aids in better energy absorption during loading, thereby improving the composite's mechanical properties. The increased roughness from the NaOH treatment improves load distribution and strengthens fibre-matrix bonding, facilitating enhanced energy dissipation under mechanical stress. Therefore, while chemical treatments reduce lignin content, they improve fibre-matrix interactions and result in fibres with smaller and more uniform diameters, optimizing the mechanical performance of the composite.

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MODELS OF GREEN BUILDING MAINTENANCE CONCEPTUAL IMPLEMENTATION FOR MALAYSIA HIGHER EDUCATION INSTITUTIONS (HEIs)

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Abstract
All buildings require maintenance to allow them to continue to operate, keep their values and extend their lives. The purpose of having building maintenance is to provide a safe and better working environment and to maintain the aesthetic value of a building to the building user especially to the students. This research aims to propose models of green building maintenance conceptual implementation for Malaysian higher education institutions (HEIs). The research objective it's to identify the analogies of green building maintenance for Malaysia HEIs. Therefore, to achieve the highlighted aims and objectives, a quantitative research method was adopted to gather data from 120 respondents who have been involved in building maintenance works in Higher Education Institutions. Rasch model was used to analyse the collected data and further developing the models is using the Smart PLS. The outcomes of this research may answer the highlighted objectives and increase the contribution to the building maintenance works. Additionally, it is also expected that the research findings may further broaden and enhance existing knowledge of green building maintenance which to be beneficial to the Malaysian HEIs especially with green building status to manage the maintenance activities.

Keywords: *Green building; Maintenance; Higher education institution, CSF, barriers, model*

INTRODUCTION

Every building element requires care to restrict the deterioration and exposure of the elements which eventually thirsts. According to Shirley Jin Lin Chua et al. (2018) buildings need to have the activity of building maintenance to keep them in good condition of working. Green building maintenance is defined conclusively from the different definitions as a combination of technical and related administrations actions to ensure that all building items and elements are working and work in satisfactory and acceptable standards (Shirley Jin Lin Chua et al., 2018; Ali et al., 2010).

As a fact that Building Maintenance can be used for facilities, services, elements, facades, and structures and each maintenance activity is different in their classification while; all buildings require maintenance to allow buildings to continue to operate, keeping their value as high as possible and extending their lives (Shirley Jin Lin Chua et al., 2018). According to the same scholar, to get good maintenance practices in the building, it is important to take into account the whole maintenance management aspect, which is standard maintenance, maintenance planning, statutory control, maintenance information, cost management, maintenance organization, service delivery, maintenance document, and sustainability. Everything must be well designed to provide a good application for building maintenance. To strategies on maintenance process, the important elements to be carefully selected are building size, user standard, budget, and functionality of the building itself.

To achieve Malaysia's Advanced Economy by 2025, the gazette is an important milestone in the twelve Malaysia Plan 2021–2025 (Nadzirah et al., 2021; R. Saian et al., 2017). Where in twelve Malaysia Plan 2021–2025 has developed six core strategies which one of them focuses on continuing green growth for sustainability and endurance. This is where the place in the country will begin green growth particularly in the development of the new project. Besides, it will also be a lifeway for Malaysians. They are not only either the public or government sector who has put their effort to take the initiative in developing green environment and culture, but also NGOs and private companies. But then, the spark of the green building concept should start from Higher Education Institutions (HEIs) where the institution appearance should reflect first the concept and start implementing. Where there has the existing building, the maintenance may come in and the building maintenance strategy that is generally applied in Malaysian buildings is reactive or unplanned based, and sometimes the strategy even the criteria not based on the application of the building itself. The strategy is claimed as ineffective if it causes frequent breakdown or downtime and requires high maintenance costs for also repairing replacement work (Shirley Jin Lin Chua et al., 2018; Au-Yong et al., 2014). Shirley Jin Lin Chua et al. (2018) and Au-Yong et al. (2014) highlighted the causes of no specific building maintenance measures leading to poor performance performing building maintenance to existing buildings even to the green building in fact to the HEIs green building too.

Therefore, this study is to seek a clear understanding of Green Building Maintenance Conceptual Implementation for Malaysia Higher Education Institutions (HEIs) via presenting in model form to be beneficial to all parties involved directly and indirectly from designing, constructing, and maintaining the building.

THE IDEOLOGIES

Nowadays, Green building plays an important role observe that many countries and adopting this concept towards theirs. In 199. the concept of “green building” was proposed at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro formally (Nadzirah et al., 2021: Nik Elyna Myeda et al., 2011). Thus, each of the countries' systems out from other countries to provide practical guide the development of green building (Zuo and Zhao, 2014; B. Mattonia et al., 2018). There are numerous definitions found where based on Yongtao Tan et al. (2014), green building can further be designed and built by applying ecological impact to human health. The Environmental Protection Agency (EPA) defines green building as “the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation, and deconstruction.” In the course of design and construction, green buildings use recycled materials, less water, less energy, and resource-efficient techniques, thereby minimizing adverse impact on the environment (Latif Onur Uğur et al., 2018). Green buildings consume fewer resources and provide good indoor air quality. It has 4 pillars and 6 main criteria of green building which the pillars are environmental sustainability, life cycle perspective, health issues, and impacts on the community (Jian Zuo, Zhen Yu Zhao, 2014; Abdullah A. Alshorman et al., 2017; Zamzarina et al., 2020). There are six main criteria for the assessment tools which are material and resources, water efficiency, energy efficiency, indoor environmental quality, sustainable site planning, and management and innovation (Abdullah A. Alshorman et al., 2017; Zamzarina et al., 2020). Table 1 shows the clear definition of building maintenance quoted from seven different scholars. From the table, building maintenance can be defined as work undertaken to improve the existing function of the building and to meet occupant satisfaction.

Table 1. Definition of Building Maintenance

No	Definition of Building Maintenance	Author
1.	Works undertake to keep, restore or improve every part of a building, its services and surrounds, to a currently accepted standard, and to sustain the utility and value of the building	Olanrewaju Ashola Abdul Lateef et al. (2011)
2.	The combination of all technical and associated administrative actions to ensure all the items and elements in the building are abandoned perform into acceptable and satisfactory standard	Shirley Jin Lin Chua et al. (2018); Ali et al. (2010)
3.	Keeping up or restoring an existing function, and investment, where there is some kind of improvement of the object	Hans Lind and Henry Muyingo (2012)
4.	A combination of technical and administrative actions contributing to the protection and satisfactory operation of asset maintenance everything from regular cleaning to repairs and replacements	Yuseni Wahab et al. (2013)
5.	All practical and technical measures to keep the building or site at a standard that permits enjoyment of their cultural significance and resources without damage	Alan M. Forster and Brit Kayan (2009)
6.	A continuous fabric, contents, and setting of a place	Alan M. Forster and Brit Kayan (2009)
7.	Retain an item or restore to an acceptable standard	Emma Marinie Ahmad Zawawi et al. (2010)

According to Tan Yongtao et al. (2014) and Zamzarina et al. (2020), there are 5 objectives of building maintenance which of them are:

1. To ensure that the buildings and their associated services are in a safe condition,
2. To ensure that the buildings are fit for purpose,
3. To ensure that the condition of the building meets all statutory requirements,
4. To carry out maintenance work necessary to maintain the value of physical assets; and
5. To carry out work necessary to maintain the quality of the building

Table 2. Criteria of Green Building Maintenance

No.	Criteria of Green Building Maintenance \ Authors	Ashok Kumar et al. (2013)	Emma Marinie Ahmad Zawawi et al. (2010)	Abdul Lateef Olanrewaju et al. (2015)	Alan M. Forste et al. (2015)	Yuseni Wahab et al. (2013)	Total Referred
1.	Drainage system					√	1
2.	Waterproofing membrane					√	1
3.	Structural deck					√	1
4.	Thermal Performance	√				√	2
5.	Wall and roof	√					1
6.	Lighting	√					1
7.	Solar energy	√					1
8.	Life cycle approach			√	√		2
9.	Material and component			√			1
10.	Energy		√		√		2
11.	Resources emission		√				1
12.	Building facilities		√				1

By referring to Table 2, which is about the criteria of building maintenance on green buildings. Among the 12 factors pointed out by 5 different scholars, it shows that green building maintenance is more referred to or concerned on the criteria of thermal performance, life cycle approach, and energy. Thermal comfort refers to the response of the structure to changes in external temperature during the daily and seasonal cycles. According to Ashok Kumar et al. (2013), the importance of thermal comfort in buildings is to minimize consumption of conventional energy by the building design and selection of equipment. According to Yuseni Wahab et al. (2013), building maintenance toward a life cycle approach on the material extends the product's lifetime from the extraction of raw materials. Out of four, there is one of the pillars of green building which pointed which is about the consideration of the life cycle during the planning and development process as referred from Alan M. Forste et al. (2015).

Table 3 shows the critical success factors of green building maintenance. There are nine study focuses which are maintenance contractor, total productive maintenance, maintenance auditing, communication between client/maintenance contractor, reactive maintenance, construction projects, construction projects, key performance indicator in maintenance project, and innovation in maintenance contracts.

Table 3. Critical Success Factors of Green Building Maintenance

No.	Study Focus	Critical Project Success Factors	Authors
1.	Maintenance Contractor	Providing safety precautions, proper planning, and scheduling, subcontracting control, efficient administration, ensuring delivering material, technical competence, and providing suggestions on cost-cutting	Latif Onur Uğur et al. (2018)
2.	Total Productive Maintenance	A measure of performance, involvement of people, alignment of the company mission, an implementation plan, implementation time allocation, knowledge and beliefs, motivation management, and workforce	Chee Hung Foo, (2018)
3.	Maintenance Auditing	Organization and human resources, work planning and scheduling, material management, workload identification, work accomplishment, and performance measurement	Jian Zuo, Zhen-Yu Zhao, (2017)
4.	Communication between Client/ Maintenance Contractor	Sufficient human resources, use of appropriate visualization techniques, checking information with users, the timing of information, working experience, client feed, back and straightforward work requests	Nik Elyna Myeda et al. (2011)
5.	Reactive Maintenance	Quality of information, knowledge sharing	Mahmoud Sodangi et al. (2014)
6.	Construction Projects	Project manager's experience, contractor experience, decision making effectiveness contractor's cash flow, planning effort, site management and client's ability to make decision	Ali et al. (2010)
7.	Construction Projects	Planning monitoring analysis, role of project participants, decision make action implementation and approval	Ashok Kumar et al. (2013)
8.	Key Performance Indicator in Maintenance Project	Cost, time, quality, safety, functionality, and environmental friendliness	Au- Yong et al. (2014)
9.	Innovation in Maintenance Contracting	Maintenance design scenarios and performance measurement plans, knowledge and competencies in cost calculation, coordination skills, integrity and honesty and empathy skills	Jian Zuo et al. (2017)

There are nine CSF has been listed in Table 3. According to Latif Onur Uğur et al. (2018), the maintenance contractor should provide safety precaution, proper planning, and scheduling, subcontracting control, efficient administration, ensuring delivering material, technical competence, and providing suggestions on cost-cutting. Chee Hung Foo (2018) further said that green building should have a measurement of performance, involvement of people, alignment of the company mission, an implementation plan, implementation time allocation, knowledge and beliefs, motivation management, and workforce. Organization and human resources, work planning and scheduling, material management, workload identification, work accomplishment, and performance measurement it's for auditing the entire process (Jian Zuo, Zhen-Yu Zhao, 2017). Communication between clients and maintenance contractors is important where this may further describe on sufficient human resources, use of appropriate visualization techniques, checking information with users, the timing of information, working experience, client feed, back and straightforward work requests (Nik Elyna Myeda et al., 2011).

According to Mahmoud Sodangi et al. (2014), to reactivate the knowledge on green building maintenance should be one of the CSF as to deliver the quality of information via knowledge sharing. Project manager's experience, contractor experience, decision making effectiveness contractor's cash flow, planning effort, site management and client's ability to make decision during construction project stage are one of the factors to ensure the CSF of green building maintenance (Ali et al., 2010). Which this also been agree by Ashok Kumar et al. (2013) that the planning monitoring analysis, role of project participant's, decision make action implementation and approval one of the factors during the construction project stage. As key performance indicator in maintenance where this pillar has been considered: Cost, time, quality, safety, functionality, and environmental friendliness (Au-Yong et al., 2014). There are in need the innovation in doing maintenance whereby the maintenance design scenarios and performance measurement plans, knowledge and competencies in cost calculation, coordination skills, integrity and honesty and empathy skills (Jian Zuo et al., 2017).

RESEARCH METHODOLOGIES

The systematic study of phenomena using measurable data and empirical, mathematical, or computer methodologies is referred to as quantitative research (J. Branne, 2016). For quantitative research, sampling methods are used to collect data from participants and submit online surveys, online polling, questionnaires, and other forms of data collection that can be presented numerically. This quantitative analysis to uncover large-scale patterns and to construct casual and correlative links between variables using statistical techniques as highlighted by T. A. Christopher (2017). This research relies entirely on quantitative methods, with the questionnaire created from a comprehensive examination of the literature. A structured questionnaire was distributed to 360 respondents who involve in green building maintenance in Malaysia. Only 120 responses were obtained, which, according to T. T. R. Miller, E. Muñoz and C. L. Redman (2011), is just enough to put this study through its paces. Where the 50% respond received just appropriate to make this study undergo to the next process. Items in the questionnaire have been developed based on the input gathered through rigorous literature review, thus they are in-line with the objective of this study.

The likert scale is a psychometric measure that is often used in surveys that use questionnaires. When answering to a Likert questionnaire item, respondents describe their degree of agreement on a symmetric agree-disagree scale for a sequence of assertions using a psychometric scale. For a particular question, the range of the Likert scale depicts the concentration of their approaches (A. Barua, 2013). The scales of agreement and importance utilised in this study are five-point Likert scales, which are routinely used for scales (Likert, 1932). For this questionnaire survey, a purposive sample was utilised, in which a non-probability sample was chosen based on the characteristics of the population and the study's research aims.

Factor analysis will be used to categorise the definition, criteria of green building maintenance and critical success factors of green building maintenance. WINSTEPS version 3.69.1.16 software is used to analyse all of the data collected from the questionnaire survey using the Rasch model. The Rasch model includes five analyses: reliability and validity, organisational misfit analysis, unidimensionality analysis, item misfit analysis, and Person-Item distribution map analysis. Rasch model analysis is employed because it shifts the focus of dependability from fitting data to building a reliable measurement instrument as referred from R.F. M. Said (2016).

One of the benefits of the Rasch model, according to P. Baghaei (2008), is that it creates a hypothetical unidimensional line along which objects and people are recognised based on their difficulty and ability measures and shown in the Person Item Distribution Map (PIDM). The Rasch model, as noted in T. G. Bond and C. M. Fox (2001) is a prescriptive model in which the data fit the model rather than the more traditional statistical problem of how the model fits the data is explored. According to A. Z. Scholten (2011), went on to say that the data must fit the model, and if they don't, the elements that indicate misfits are removed until a good fit is found.

As a result, the Rasch model analysis is carried out in this study, as explained by T. G. Bond et al. (2001), who state that the Rasch model's logit value is the unit of measurement at an interval level rather than a single number. This study used summary statistics, item characteristic curve scalogram, PIDM, and person and item measure order in the Rasch model analysis. To demonstrate that the respondent is completing the survey, the analysis shows both person and item measures. At the same moment, the responder comprehends the questions asked, and the survey item is comprehended and replied.

DATA ANALYSIS AND FINDINGS

There are 360 questionnaires has been sent out to the respondents and 120 respondents responded back to the questionnaire. Figure 1 shows the output of the respondents’ years of experienced details. From Figure 1 shows that most of the respondents are having between more than 16 years of experienced. Which this makes this research output unbiases in communicating the findings.

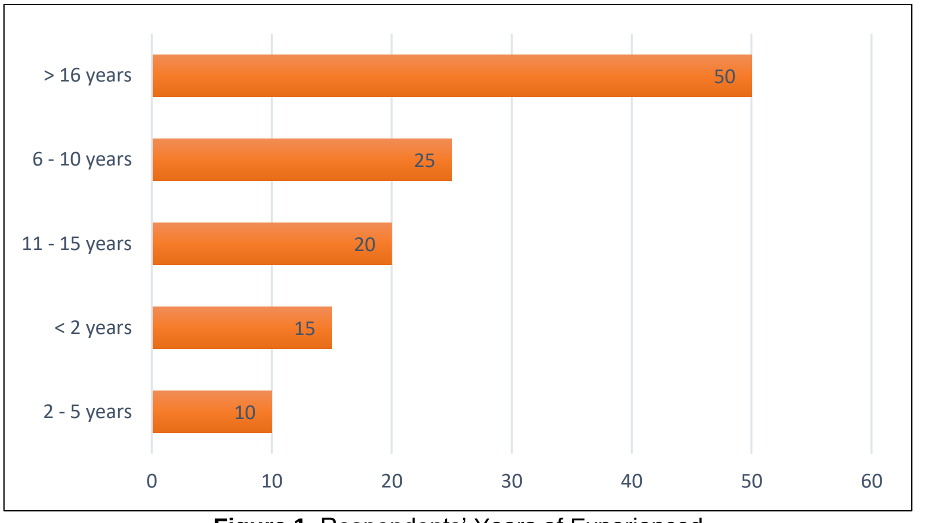

Figure 1. Respondents' Years of Experienced

Table 4 shows 12 constructs (non-extreme) are reporting the value of person reliability β = .99 with 0.20 Standard Error (SE), suggesting that the respondents were competent to answer the questionnaire survey (P. Baghaei, 2008). This indicates that the 12 constructs in investigating the criteria of green building maintenance for HEIs have an excellent range of difficulties in measuring the organisation ability. Organisation fit statistics investigation on outfit on Mean Square (OMNSQ) and z-score (OZSTD) show that the OMNSQ is 0.00 and OZSTD is –5.71, which is near to expectation 1 and 0. This reveals that 1–2 constructs are targeting the right type of respondents in measuring the latent traits and produced data is at a reasonable prediction level of the responses to the constructs. The maximum organisation ability is βmax = +97.60 logit, and the minimum measure is βmin = –27.47 logit. The organisation mean βmean = 0.00 logit reveals that most of the respondents find the important to understand criteria of green building maintenance for HEIs.

Table 4. Summary of 12 Constructs (Non-Extreme) to Investigate The Criteria of Green Building Maintenance for HEIs

	TOTAL SCORE	COUNT	MEASURE	MODEL ERROR	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	ZSTD
MEAN	349.9	75.0	.00	2.66	.03	-1.08	.00	-5.71
S.D	32.6	.0	29.39	.77	.04	.17	.00	2.74
MAX.	370.0	75.0	97.60	3.35	.14	-.73	.01	-2.86
MIN.	227.0	75.0	-27.47	1.39	.01	-1.23	.00	-9.90
Real SMSE 2.76		TRUE S.D 28.43		SEPARATION 10.30		CONSTRUCT RELIABILITY .99		
Model S.E. 2.76		TRUE S.D 28.43		SEPARATION 10.30		CONSTRUCT RELIABILITY .99		
S. E. of constructs MEAN = 6.93								

The principal component analysis (PCA) shows that the raw variance explained by measures was approximately 99.0 percent lower compared to the expected target of 99.3 percent as shown in Table 5, which shows good quality criteria of variance in data explained by measures as stated by P. Baghaei (2008). In addition, the unexplained variance in the 1 contrast is also in good quality criteria (P. Baghaei, 2008), which is 0.0 percent. This can be concluded that the 12 constructs in investigating the criteria of green building maintenance for HEIs have one single overarching dimension.

Table 5. Standardised Residual Variance (in Eigenvalue Units)

		Empirical		Modelled
Total raw variance in observation	459.5	100.0%		100.0%
Raw variance explained by measurer	459.3	99.0%		99.3%
Raw variance explained by persons	132.1	28.8%		28.6%
Raw variance explained by item	327.2	71.2%		70.7%
Raw unexplained variance (total)	1.80	0.0%	100.%	0.7%
Unexplained variance in 1st contrast	0.95	0.0%	53.2%	

Table 6 shows 9 constructs (non-extreme) are reporting the value of person reliability β = .99 with 0.20 Standard Error (SE), suggesting that the respondents were competent to answer the questionnaire survey (P. Baghaei, 2008). This indicates that the 9 constructs in investigating the critical success factors of green building maintenance for HEIs have an excellent range of difficulties in measuring the organisation ability. Organisation fit statistics investigation on outfit on Mean Square (OMNSQ) and z-score (OZSTD) show that the OMNSQ is 0.00 and OZSTD is -5.71, which is near to expectation 1 and 0. This reveals that 12 constructs are targeting the right type of respondents in measuring the latent traits and produced data is at a reasonable prediction level of the responses to the constructs. The maximum organisation ability is βmax = +97.60 logit, and the minimum measure is βmin = -27.47 logit. The organisation mean βmean = 0.00 logit reveals that most of the respondents find the important to understand critical success factors of green building maintenance for HEIs.

Table 6. Summary of 9 Constructs (Non-Extreme) to Investigate The Critical Success Factors of Green Building Maintenance for HEIs

	TOTAL SCORE	COUNT	MEASURE	MODEL ERROR	INFIT		OUTFIT	
					MNSQ	ZSTD	MNSQ	ZSTD
MEAN	349.9	75.0	.00	2.66	.03	-1.08	.00	-5.71
S.D	32.6	.0	29.39	.77	.04	.17	.00	2.74
MAX.	370.0	75.0	97.60	3.35	.14	-.73	.01	-2.86
MIN.	227.0	75.0	-27.47	1.39	.01	-1.23	.00	-9.90
Real SMSE 2.76		TRUE S.D 28.43		SEPARATION 10.30		CONSTRUCT RELIABILITY .99		
Model S.E. 2.76		TRUE S.D 28.43		SEPARATION 10.30		CONSTRUCT RELIABILITY .99		
S. E. of constructs MEAN = 6.93								

The principal component analysis (PCA) shows that the raw variance explained by measures was approximately 99.0 percent lower compared to the expected target of 99.3 percent as shown in Table 7, which shows good quality criteria of variance in data explained by measures as stated by P. Baghaei (2008). In addition, the unexplained variance in the 1 contrast is also in good quality criteria (P. Baghaei, 2008), which is 0.0 percent. This can be concluded that the 9 constructs in investigating the critical success factors of green building maintenance for HEIs have one single overarching dimension.

Table 7. Standardised Residual Variance (in Eigenvalue Units)

		Empirical		Modelled
Total raw variance in observation	459.5	100.0%		100.0%
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Raw variance explained by item	327.2	71.2%		70.7%
Raw unexplained variance (total)	1.80	0.0%	100.%	0.7%
Unexplained variance in 1st contrast	0.95	0.0%	53.2%	

Table 6. Standardised Residual Loadings for Construct (Sorted by Loading) to Investigate The Criteria of Green Building Maintenance for HEIs and Critical Success Factors of Green Building Maintenance for HEIs

Contrast		Loading	Measure	MNSQ		Construct
				Infit	Outfit	
1	1	0.93	-8.19	0.02	0.00	A_CGBM_01
1	1	0.93	-8.19	0.02	0.00	A_CGBM_02
1	1	0.93	-8.19	0.02	0.00	A_CGBM_03
1	1	0.93	-8.19	0.02	0.00	A_CGBM_04
1	1	0.93	-8.19	0.02	0.00	A_CGBM_05
1	1	0.93	-8.19	0.02	0.00	A_CGBM_06
1	1	0.93	-8.19	0.02	0.00	A_CGBM_07
1	1	0.93	-8.19	0.02	0.00	A_CGBM_08
1	1	0.86	0.43	0.01	0.00	A_CGBM_09
1	1	0.86	0.43	0.01	0.00	A_CGBM_10
1	1	0.86	0.43	0.01	0.00	A_CGBM_11
1	1	0.86	0.43	0.01	0.00	A_CGBM_12
1	1	0.86	0.43	0.01	0.00	B_CSFGBM_01
1	1	0.86	0.43	0.01	0.00	B_CSFGBM_02
1	1	0.86	0.43	0.01	0.00	B_CSFGBM_03
1	1	0.86	0.43	0.01	0.00	B_CSFGBM_04
1	1	0.86	0.43	0.01	0.00	B_CSFGBM_05
1	1	0.86	0.43	0.01	0.00	B_CSFGBM_06
1	1	0.86	0.43	0.01	0.00	B_CSFGBM_07
1	1	0.86	0.43	0.01	0.00	B_CSFGBM_08
1	1	0.86	0.43	0.01	0.00	B_CSFGBM_09

Indicator:

Code	Construct
Criteria of Green Building Maintenance	
A_CGBM_01	Drainage system
A_CGBM_02	Waterproofing membrane
A_CGBM_03	Structural deck
A_CGBM_04	Thermal Performance
A_CGBM_05	Wall and roof
A_CGBM_06	Lighting
A_CGBM_07	Solar energy
A_CGBM_08	Life cycle approach
A_CGBM_09	Material and component
A_CGBM_10	Energy
A_CGBM_11	Resources emission
A_CGBM_12	Building facilities
Critical Success Factors of Green Building Maintenance	
B_CSFGBM_01	Maintenance Contractor
B_CSFGBM_02	Total Productive Maintenance
B_CSFGBM_03	Maintenance Auditing
B_CSFGBM_04	Communication between Client/ Maintenance Contractor
B_CSFGBM_05	Reactive Maintenance
B_CSFGBM_06	Construction Projects
B_CSFGBM_07	Construction Projects
B_CSFGBM_08	Key Performance Indicator in Maintenance Project
B_CSFGBM_09	Innovation in Maintenance Contracting

Table 8 shows the measure order of 12 constructs in investigating the criteria of green building maintenance and 9 construct to in investigating the critical success factors of green building maintenance. The constructs are sorted based on their measured value, which the positive value is less aware constructs while negative value is the aware constructs, based on Construct mean μmean = 0.00 *logit* as the cut-off point.

Table 5 shows the matrix categorisation based on respondents responded to the rating. There are 41.92% score on very true scale follow by 26.95% somewhat true and 25% neither true. The output shows that the respondents responded the most on the construct on the very true scale and its shows that the construct are reliable to relates with the criteria of green building maintenance and critical success factors of green building maintenance.

Table 8. Measure Order of The Constructs to Investigate The Criteria of Green Building Maintenance for HEIs and Critical Success Factors of Green Building Maintenance for HEIs

Construct	Measure	Model SE	Remarks
A_CGBM_01	10.67	2.35	Somewhat true
A_CGBM_02	10.67	2.35	Somewhat true
A_CGBM_03	10.67	2.35	Somewhat true
A_CGBM_04	10.67	2.35	Somewhat true
A_CGBM_05	10.67	2.35	Somewhat true
A_CGBM_06	0.43	3.31	Somewhat true
A_CGBM_07	0.43	3.31	Somewhat true
A_CGBM_08	0.43	3.31	Somewhat true
A_CGBM_09	0.43	3.31	Somewhat true
A_CGBM_10	0.43	3.31	Somewhat true
A_CGBM_11	0.43	3.31	Somewhat true
A_CGBM_12	0.43	3.31	Somewhat true
B_CSFGBM_01	-8.19	2.89	Very true
B_CSFGBM_02	-8.19	2.89	Very true
B_CSFGBM_03	-8.19	2.89	Very true
B_CSFGBM_04	-8.19	2.89	Very true
B_CSFGBM_05	-8.19	2.89	Very true
B_CSFGBM_06	-8.19	2.89	Very true
B_CSFGBM_07	-8.19	2.89	Very true
B_CSFGBM_08	-8.19	2.89	Very true
B_CSFGBM_09	-8.19	2.89	Very true

Table 9. Matrix of Categorisation to Investigate the Criteria of Green Building Maintenance for HEIs and Critical Success Factors of Green Building Maintenance for HEIs

Categories	Logit	n	%
Very true	0.00 logit to ∞	70	58.33
Somewhat true	-8.19 logit to 0.00 logit	50	41.67

CONCLUSION

From the research outputs, there are 12 constructs for criteria of green building maintenance and 9 construct for critical success factors of green building maintenance who contributing to the highest rating which can be categories as very true statements. There are 12 constructs for criteria of green building maintenance: drainage system, waterproofing membrane, structural deck, thermal performance, wall and roof, lighting, solar energy, life cycle approach, material and component, energy, resources emission, and building facilities. Follows by 9 constructs for critical success factors of green building maintenance: maintenance contractor, total productive maintenance, maintenance auditing, communication, between client/ maintenance contractor, reactive maintenance, construction projects, construction projects, key performance indicator in maintenance project, and innovation in maintenance contracting.

Figure 2 shows the proposed Models of Green Building Maintenance Conceptual Implementation for Malaysia Higher Education Institutions (HEIs) according to the data analysis and finding from the study.

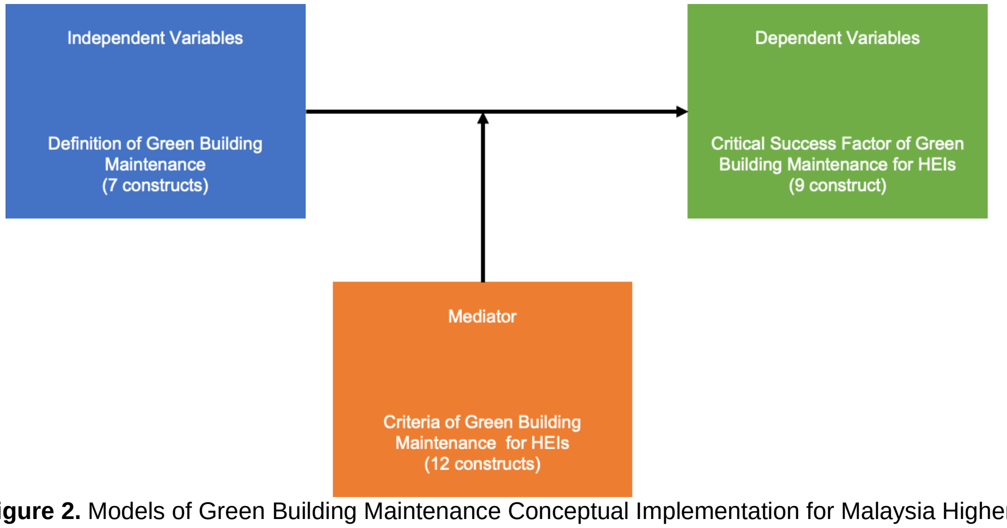

Figure 2. Models of Green Building Maintenance Conceptual Implementation for Malaysia Higher Education Institutions (HEIs)

From Figure 2, the independent variable is to clearly define the definition of green building maintenance which directly acting to the dependent variables which is critical success factors of green building maintenance for HEIs. The mediator who acting in between of independent variables and dependent variables it's the criteria of green building maintenance for HEIs.

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ASSESSING THE SPATIAL EVOLUTION AND REGIONAL DIFFERENCES OF RENTAL HOUSING DEVELOPMENT IN CHINA

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Abstract
The housing rental market is an important part of the national housing system and is conducive to economic growth and social stability. The form of city cluster will be the main spatial pattern for the development of China's housing market in the future, and it is crucial to promote the regional coordinated development of the housing rental market between and within city clusters. Past research has been more on housing rental behaviour and property rights differentiation from a micro perspective, and there is a lack of relevant research based on a geographic spatial perspective. This paper adopted quantitative research methods and data analysis used GIS spatial statistical method. It takes the five major city clusters in China as the research area. Based on the data from the fifth and sixth national sub-county censuses and using spatial autocorrelation from ArcGIS10.7 and Geoda1.14 spatial statistics tools, empirical analysis of the spatial evolution and regional differences in the development of rental housing in 104 cities in five major city clusters in China. The results of the study show that there is a significant spatial agglomeration of the development and changes in China's housing rental market over the decade. The high-value areas of housing rental market development clustered in city clusters and ethnic minority areas. The five major city clusters show different levels of development, with the central cities having a clear radiating effect on the peripheral cities. It is hoped that the study will contribute to understanding the current state of development of the housing rental market, anticipating future demand in the housing rental market and informing the provision of improved policies.

Keywords: *GIS; City cluster; Rental housing; Spatial evolution; Regional differences*

INTRODUCTION

The housing purchase market and the housing rental market are two inseparable pillars of China's housing market and neglecting either market will hinder the stable development of the housing market. China's rental housing market is in a lagging development situation due to its long-term neglect. The housing rental market as the last line of defence in solving the housing problem of residents, it has an irreplaceable role in the housing purchase market (Huang, 2020). According to the National Bureau of Statistics, in the past seven years, the national housing development enterprise housing rental revenue is only about 2% of the housing sales revenue (Li, 2019). According to the China Floating Population Development Report, the floating population will grow to 327 million by 2030. With the favourable environment of housing rental, the number of Chinese rental population is expected to rise significantly (Guo, 2020).The inadequate development of the rental housing market has caused many problems, such as soaring urban housing prices, wasting social housing resources and restricting the free flow of labour force, which not only seriously affects the healthy development of the housing industry, but also affects the normal operation of the whole economy, and is more likely to affect the social stability (Wu, 2009). To this end, in recent years, the country around the cultivation and development of rental housing market made a series of decision deployment, accelerating the development of the rental housing market has also gradually attracted the wide attention of the whole society (Yi, 2018).

However, China has a vast land area, a huge gap in regional development, and the development level and demand of different rental housing markets in different regions (Zhan et al., 2020). As global urbanisation enters its middle and late stages, population growth in cities of different sizes will change from the previous flush of growth to a divergence. The population migration from rural and small and medium-sized cities to city clusters, while the population growth of small and medium-sized cities faces stagnation or even net migration. From China's point of view, although the overall population flow is slowing down, the agglomeration to city cluster is more obvious. In the city clusters, the differences in the regional economic basis relied on by the eastern, central and western Chinese city clusters lead to the different development degrees of each regional city cluster. For the five major city clusters, including the Beijing-Tianjin-Hebei, the Yangtze River Delta, the Pearl River Delta, the middle reaches of the Yangtze River and the Chengdu-Chongqing, with the fastest increase in urban population, housing demand will continue to increase with rapid economic growth and industrial upgrading. The integrated development of city cluster will also have a positive impact on the rental housing market, and the development of city cluster will form a benign interaction with the rental housing market. At present, although the housing control policies for housing purchase are constantly introduced, the rental housing policies issued by various provinces and cities are similar, and the implementation effect of the policies is limited. This paper is of great theoretical and practical significance for improving the development policy formulation of the rental market in different city clusters in China, especially for clarifying the spatial focus of the development of China's rental housing market and predicting the future trend changes of China's rental housing market.

LITERATURE REVIEW

Housing rental is an important component of the choice of housing property rights, and also a long-term concern of housing research in various countries. The research methods of housing property rights differences mainly include: economics and socio-demographic methods. The economic method assumes that residents are economic rational people and maximize the benefits through property rights choice under budget constraints (Arnott, 1987). Therefore, property right choice is not only a consumption decision, but also an investment decision under the competitive housing market, believing that family income, property and housing prices are important factors affecting the transformation of housing property rights (Henderson & Ioannides, 1983). Geography, planning and sociology use social-demographic methods to match the choice of housing property rights to family socio-economic characteristics (Clark & Dieleman, 1996; Huang & Clark, 2002). Scholars have made some analysis of China's housing market, including the analysis of housing property right selection behavior from the micro aspect; and also, the analysis of housing differences in Chinese cities from the macro perspective. On the micro side, past studies have mainly analysed housing property selection behavior and differentiation characteristics (Li, 2003). In terms of housing property rights characteristics, some studies have compared the characteristics of housing property ownership rate or rental ratio of different regions and social and economic property groups (Yu and Xu, 2018; Freeman and Hamilton, 2004; Myers et al., 2005). This literature mainly reveals the micro mechanism of residents' individual housing property rights selection from the perspective of economic, social population and system, and also provides a theoretical reference for further exploring the causes of regional differentiation of housing property rights. On the macro side, a large number of scholars have analysed the housing differences in urban China by quantitative and qualitative research methods from different perspectives of supply, demand, system, economy and society. In the qualitative analysis, some scholar analysed the situation of urban residential separation in China in terms of supply, institutional factors and performance characteristics, etc. These studies have played a very important role in grasping the current situation and problems of urban living separation as a whole (Xu & Zhu, 2008; Li, 2008; Song & Wu, 2010). However, the qualitative analysis lacks depth in the detailed analysis of the status quo and characteristics, so further quantitative research is necessary. On the basis of the qualitative analysis, some studies have found that income, housing value, family size and age distribution and population change ratio are the main factors affecting the spatial difference in the US metropolitan statistical areas (Eilbott and Binkowski, 1985; Lauridsen et al., 2009). Huang & Clark (2002) used the 1995 census data, quantitatively calculated the size of the housing separation by calculating the divergence index and regression analysis. Some studies used the data of the fifth census data in 2000 and the Comprehensive Survey of China Society (CGSS) data in 2005 and 2006 to study the housing differences of different groups of different levels on a large scale and compare the differences of housing differences among cities at different levels (Bian & Liu, 2005; Liu & Hu, 2010; Liu et al., 2010). Some studies respectively took Nanjing, Beijing, Guangzhou, Shanghai and other cities as examples to conduct an in-depth study on the differences of housing property rights among groups within cities (Huang & Jiang, 2009; Liu et al., 2006; Wu, 2002; Chen & Li, 2014; Chen et al., 2016), and the difference in housing sources at the provincial level (Yi, 2006). Wei (2017) studied the difference between the rent-to-sale ratio in different regions of China. Zhan et al. (2020) used GIS spatial statistical method and spatial measurement model, the regional differences and influencing factors of rental housing development in 337 cities above the prefecture level were effectively analysed.

Compared with the rich achievements from the micro perspective, there is still a lack of housing property rights differentiation research based on the geographical spatial perspective, and there is a lack of research on housing property rights differentiation in city clusters units and the development of rental housing market. At the macro level, the existing quantitative research has been deeply discussed in different levels of cities and individual city scales. However, due to the complexity of housing problems and the particularity of cities, coupled with the limitation of data access channels, there are still some deep needs for the existing research. To make up for the lack of existing research, this paper from the perspective of social-demographic statistics, based on the fifth and sixth national census county data, using quantitative analysis, the systematic analysis of Chinese rental housing development spatial evolution and regional differences, in order to scientific guidance for reasonable development of scientific decision-making basis.

METHODOLOGY

Research Design

The present research adopted quantitative research method. The relevant data in this paper are obtained from the statistics of household housing status of the national census sub-county data, because the seventh latest census sub-county data has not yet been released (China's census is conducted every ten years, and the 2020 census is completed, but data have not been released), so this paper is based on the fifth and sixth data. There is a certain time lag in the data, which can be further improved combined with the latest national census data, but it still has a good theoretical and practical guiding significance for interpreting the regional differences and spatial evolution of China's rental housing development. The development of the housing rental market in the study unit is characterized by the "proportion of rental housing" of all households. Using the global spatial autocorrelation and local spatial autocorrelation of ArcGIS10.7 and Geoda spatial statistical tools, this paper empirically analyses the spatial evolution and regional differences of rental housing development in the five urban clusters in China.

The calculation formula is: the rental housing proportion = the number of rental households / the total number of family households.

Due to partial adjustment of China's urban administrative divisions and corresponding merging and processing of some urban data, the national number of actual spatial units applied in this study was 337, the number of actual spatial units in the five major city clusters was 104 (Table 1), and the research objects were urban units above the prefecture level, and Hong Kong, Macao and Taiwan have not been involved.

Table 1. Distribution of Prefecture-Level Cities Among The Five Major City Clusters in China

City Clusters	The Number of Prefecture-Level Cities	Prefecture-Level Cities
Beijing-Tianjin-Hebei	16	Beijing, Tianjin, Zhangjiakou, Chengde, Qinhuangdao, Tangshan, Cangzhou, Hengshui, Langfang, Baoding, Shijiazhuang, Xingtai, Handan, Dingzhou, Xinji and Anyang.
Yangtze River Delta	26	Shanghai, Nanjing, Wuxi, Changzhou, Suzhou, Nantong, Yancheng, Yangzhou, Zhenjiang, Taizhou, Hangzhou, Ningbo, Jiaxing, Huzhou, Shaoxing, Jinhua, Zhoushan, Taizhou, Hefei, Wuhu, Ma'Anshan, Tongling, Anqing, Chuzhou, Chizhou and Xuancheng.
Pearl River Delta	15	Guangzhou, Foshan, Zhaoqing, Shenzhen, Dongguan, Huizhou, Zhuhai, Zhongshan, Jiangmen, Shaoguan, Shanwei, Yangjiang, Heyuan, Qingyuan and Yunfu.
The middle reaches of the Yangtze River	31	Hubei Wuhan, Huangshi, Ezhou, Huanggang, Xiaogan, Xianning, Xiantao, Qianjiang, Tianmen, Xiangyang, Yichang, Jingzhou, Jingmen, Changsha, Zhuzhou, Xiangtan, changyang, Yueyang, Yiyang, Hengyang, Loudi, Nanchang, Jiujiang, Jingdezhen, Yingtan, Yichun, Pingxiang, Shangrao, Fuzhou and Gian.
Chengdu-Chongqing	16	Chongqing, Chengdu, Zigong, Luzhou, Deyang, Mianyang, Suining, Neijiang, Leshan, Nanchong, Meishan, Yibin, Guang 'an, Dazhou, Ya'an and Ziyang.

Research Technique

Space Statistical Method

Spatial autocorrelation analysis is one of the basic methods of theoretical geography (Chen, 2009), which is mainly used to analyse the statistical distribution law of spatial data. The spatial autoregressive model was used to analyse the proportion of rental housing at both global and local levels using the global Moran's I, the Local Indicator of Spatial Association (LISA) and the Moran scatter plot.

i) Global Spatial Autocorrelations.

Global spatial autocorrelation is a description of the spatial characteristics of geographic element attribute values across the region (Xie, 2013). The global Moran's I is commonly used as the global autocorrelation statistic. Moran's I is used to measure the interrelation of spatial elements, similar to the correlation coefficients in general statistics, with values between +1 and -1. Greater than zero indicates the existence of a spatial positive correlation, vice versa negative correlation, equal to zero indicates no spatial correlation.

The calculation formula is as follows:

$$I = \frac{N}{S_0} \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} W(i, j)(X_i - \bar{X})(X_j - \bar{X})}{\sum_{i=1}^{N} (X_i - \bar{X})_i^2}$$

N indicates the number of subjects studied, X_i is the observed value, $\bar{X}$ is the mean value of $X_i.S_0 = \sum_{i=1}^{N} \sum_{j=1}^{N} W(i,,j).W(i,,j)$ is the matrix of spatial connections between the i,j study objects. $W(i,,j) = 0$.

After calculating Moran I, a statistical test of its results is also required, generally using the z-test (Wang et al., 2019).

$$\mathrm{z(I)} = \frac{\mathrm{I-E(I)}}{\mathrm{S(I)}}, \text{In type} \mathrm{S(I)} = \sqrt{\mathrm{var(I)}}$$

ii) Local Space Autocorrelation.

Global spatial autocorrelation is a general description of the entire study space, only valid for homogeneous spatial processes (Wang & Xiu, 2011). However, for this paper, the development of rental housing is not uniform and homogeneous nationwide due to the size of spatial autocorrelation, and as the different spatial locations change, the global Moran's I cannot accurately indicate the specific spatial location where aggregation or anomaly occurs. Further analysis using local autocorrelation methods, including the spatial association of local metrics and Moran scatter plots, is required.

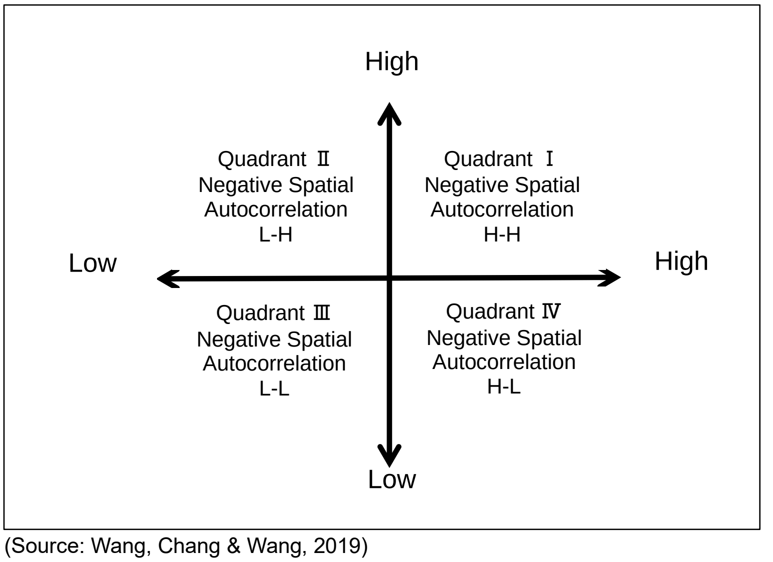
Local spatial autocorrelation reflects the spatial correlation degree of the spatial object attribute value and its adjacent regional attribute value, which is used to explore the agglomeration degree of the spatial object attribute values in the local space and can capture the heterogeneity of the spatial object distribution. The local spatial autocorrelation analysis used in this paper is using Local Moran's Ii as the statistic, which is the decomposition form of Moran's I (Global Moran's I) (Anselin, 1995) to measure the degree of spatial difference between the spatial unit i and its surrounding units and its significance. In essence, local Moran I is breaking Moran I into various regional units. Anselin calls it the LISA (Anselin, 1995), or the spatial contact local indicator (Local Indicators of Spatial Association, LISA). For a certain spatial unit i.

$$I_i = \frac{X_i - \overline{X}}{S_3} \sum_{j=1}^{N} W(i,j)\left(X_j - \overline{X}\right)$$

$N, X_i, \overline{X}, W(i,j)$ mean the same as above, $S_3 = \left(\sum_{i=1, j\neq i}^{N} X_j^2\right)/(N-1) - \overline{X^2}$

The LISA's z-test is:$z(I_i) = \frac{I_i - E(I_i)}{S(I_i)}, S(I_i) = \sqrt{var(I_i)}$

The statistical tests of LISA usually include High-High(HH), High-Low(HL), Low-High(LH), and Low-Low(LL). Among them, the HH distribution indicates higher proportion or change values of rental housing in both the observed and adjacent areas, while the LL distribution has the opposite meaning; the HL distribution indicates the high proportion of rental housing or change value in the observation area, while the proportion or change value is low in the adjacent area, and the LH distribution is the opposite. The HH and LL distribution types indicate that there is a spatial positive correlation between the proportion or change of rental housing in China, suggesting the spatial agglomeration and similarity of the proportion or change of local spatial rental housing. HL and LH indicate that there is a negative spatial correlation between the proportion or change of rental housing in China, reflecting that the proportion or change of local spatial rental housing is spatial heterogeneous.



(Source: Wang, Chang & Wang, 2019)

Figure 1. Spatial Autocorrelation of The Local Indicators of Spatial Association (LISA) Analysis

The Moran scatter plots can visualize the spatial patterns (Li et al., 2010). The Moran scatter plot is divided into four quadrants, representing four different association types. The 1 and 3 quadrants represent positive correlation types, denoted by HH and LL respectively; The 2 and 4 quadrants represent negative correlation types, denoted by HL and LH respectively.

1) Space Weight

Spatial weights are the premise and basis for the spatial autocorrelation analysis (Yang et al., 2009). Anselin proposes a method for determining spatial weights (Anselin,1995), dividing the neighbours of spatial positions into three categories: adjacency, distance, and nearest k-point relationships. Adjacency refers to giving a spatial weight value by whether the spatial units are adjacent. If adjacent, Wij=1, otherwise Wij=0; which can be subdivided into 3 classes of adjacency criteria such as Rook, Queen and Bishop.

RESULT AND DISCUSS

The Spatial Evolution of Rental Housing in China from 2000-2010

In 2000, the average proportion of rental housing in China was 9.12%, and the standard deviation was 6.82%. The proportion of rental housing in all study areas was divided into five grades according to Natural Breaks Method and the results are shown in Figure 2a. The proportion of rental housing in the highest grade areas exceeded 24.1%, mainly in big cities in Beijing, Tianjin, Shanghai, Xiamen, Shenzhen, Dongguan and Haikou, as well as regional economic center cities in Lhasa and western Urumqi, and cities in Haixi Mongolian and Tibetan Autonomous Prefecture and Nyingchi with many ethnic minorities. The proportion of rental housing is 14.2%~ 24.1%, mainly distributed in Changchun, Wuhan, Xi'an, Hefei, Hefei, Nanjing, Nanchang and Hangzhou eastern and central provincial capitals, Shenyang, Fushun and Benxi, liaxi, Lanzhou, Yinchuan, Guiyang western cities, Nanning, Guilin, Baise and Liuzhou and some cities in western Sichuan, Tibet and Xinjiang. The proportion of rental housing in the lowest level areas is less than 4.9%, mainly in Henan, Anhui and northern Jiangsu, southwest Shandong, southern Hebei, eastern Inner Mongolia and southern Gansu, as well as economically underdeveloped areas such as Guizhou, Guangxi, Guangdong and Fujian. The analysis results are basically similar to other scholars on low housing property rights in big cities (Li & Wu, 2008), mainly due to the large proportion of migrant floating population in economically developed areas and tight housing resources, directly stimulate the large demand for housing rental, large family income gap and obvious social space, aggravate the housing difficulties of socially vulnerable groups and reduce the degree of housing autonomy. Some regions of western China also have a relatively high proportion of rental housing, which is consistent with the findings of other scholars (Huang, 2004), indicating that the impact of housing market oriented reform in the transformation period on the choice of housing property rights in some regions of China is not yet obvious.

The average Chinese rental home ratio in 2010 was 9.99%, slightly above the 2000 average, with a standard deviation of 9.69%.The proportion of rental housing in China is divided into five grades according to the Natural Breaks Method, and the results are shown in Figure 2b.The high-value areas of the rental housing ratio in China (40% to 72.3%) and the sub-high-value areas (27.1% to 40.4%) are mainly distributed in the Beijing-Tianjin-Hebei region, the Yangtze River Delta and the Pearl River Delta region, as well as the cities such as Ordos, Lhasa and Nyingchi in the western region. The areas with the middle proportion of rental housing (15.2% to 27.1%) are mainly concentrated in the Yangtze River Delta city cluster and the west bank of the Taiwan Straits, as well as a few cities in the central and western regions. In most other areas, the proportion of rental housing is the lowest, with rental housing being less than 7.2 percent.

The results show that compared with 2000, the regional differences of high-value proportion of rental housing in China was more obvious in 2010 was more obvious, and its spatial distribution was further concentrated to the core cities of social and economically developed eastern regions and a few central cities in western regions, indicating that the impact of economic factors on the regional differentiation of housing property rights in China is more and more prominent. Cities in relatively economically developed areas such as the Beijing-Tianjin-Hebei, the Yangtze River Delta and the Pearl River Delta city clusters, as well as resource-based cities represented by Ordos and Yulin (Figure 2c), the proportion of rental housing increased by more than 10.9%. The added value of regions with the proportion of rental housing increased by 2.55% to 10.86%. In addition to the Yangtze River Delta, the Pearl River Delta and the west bank of the Taiwan Straits, they are also widely distributed in Shandong and western ethnic minority regions, especially the Inner Mongolia Autonomous Region. Areas where the proportion of rental housing in China has decreased significantly (-8.1%~-1.7%), mainly concentrated in some cities in the western region, northeast China and Hubei and Guangxi in the central region. The region with the largest reduction of urban rental housing in China (-18.4%~-8.1%) is mainly concentrated in northern Sichuan, southern Xinjiang, and some areas in Qinghai, Jilin and Liaoning provinces. The spatial changes in the development of rental housing in China reflect the comprehensive impact of local economic development, social culture and policy systems in the social and economic transition period on the changes of housing property rights.

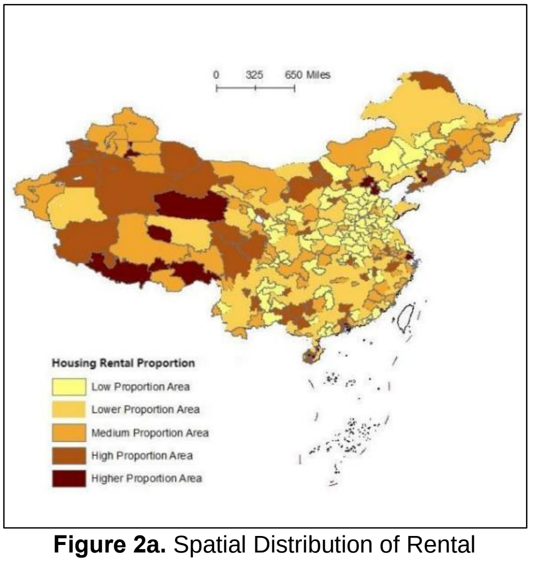


Figure 2a. Spatial Distribution of Rental Housing Development in China in 2000

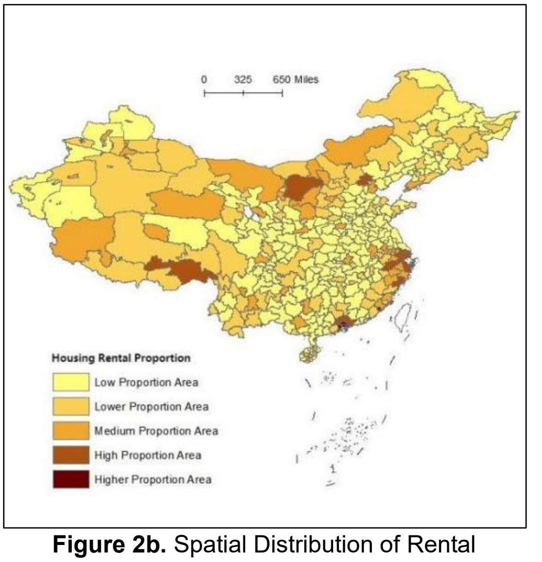


Figure 2b. Spatial Distribution of Rental Housing Development in China in 2010

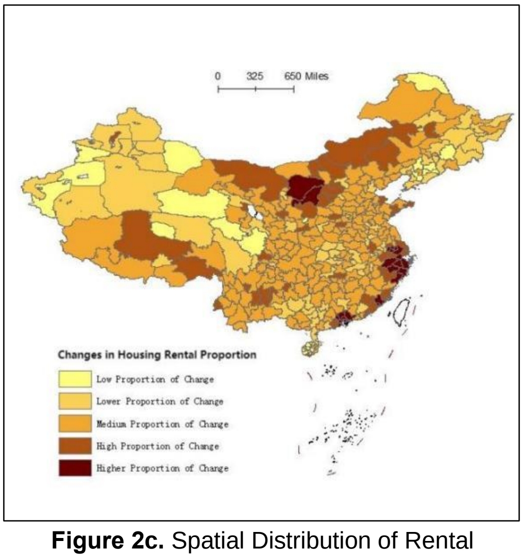


Figure 2c. Spatial Distribution of Rental Housing Development in China from 2000-2010

Spatial Statistical Analysis of Rental Housing Development in China

Global Spatial Autocorrelation Analysis

Selecting Contiguity Edges Corners by Boundary and Node, a global spatial autocorrelation analysis of the proportion and change in rental housing in China was conducted using the spatial statistics tools of ArcGIS 10.7. The results of the global spatial autocorrelation analysis show that there is a significant positive spatial correlation between the proportion of rental housing in China in 2000 and 2010 and the change between 2000 and 2010. The corresponding Moran's I index was 0.212, 0.312 and 0.388 respectively, and both passed the significance test of 0.05, indicating that the proportion and change of rental housing in China, and the spatial agglomeration trend of rental housing proportion in China is getting stronger and stronger.

Table 2. Statistics of The Global Autocorrelation Index for The Proportion of Rental Housing

	Moran's I	Expected Index	Variance	Z Score	P Price
2000	0.212	-0.0028	0.000211	14.7	0
2010	0.312	-0.0028	0.000208	21.86	0
2000-2010	0.388	-0.0028	0.00021	27.03	0

Local Spatial Autocorrelation Analysis

In order to analyse the degree of local spatial aggregation and heterogeneity in the proportion and change in rental housing in China, a local spatial autocorrelation analysis of the proportion and change in rental housing in China was conducted using cluster and outlier analysis.

Figure 3a shows a local spatial autocorrelation of the rental housing development in China in 2000. The results show that the high-high (HH) in 2000 are mainly in the Yangtze River Delta city cluster, the Pearl River Delta city cluster, Fujian, Shanxi and Inner Mongolia; Low-low clusters (LL) are mainly in southern northeast, Guangxi, Hainan, Xinjiang, Qinghai, Hunan and Hubei provinces and autonomous regions; High-low (HL) consists of three central and northeast study regions and low and high heterogeneous (LH) is mainly distributed in parts of Guangdong and Hainan.

Figure 3b shows a local spatial autocorrelation diagram of the rental housing development in China in 2010.The results show that the high-high (HH) are dominated by the Yangtze River Delta city cluster, the Pearl River Delta city cluster, and a few regions within Fujian, Tibet and Inner Mongolia; low-low (LL) are mainly concentrated in the North China Plain and parts of the Northeast region; high-low heterogeneity (HL) are also dominated by provincial capitals in the central and western regions; low-high heterogeneity (LH) are mainly found in a few cities such as Xinjiang, Qinghai, and Guangdong.

Figure 3c shows a local spatial autocorrelation diagram of the development and changes of rental housing in China from 2000 to 2010. The results show that high and high (HH) are mainly distributed in the southeast coastal areas, including the Yangtze River city cluster, Shanxi, Tibet and Inner Mongolia; Low and low (LL) are mainly concentrated in the northeast and central regions; high and low (HL) are mainly provincial capitals in the central and western regions; and low and high (LH) are distributed in a few cities of Inner Mongolia, Guangdong, Jiangxi and Anhui.

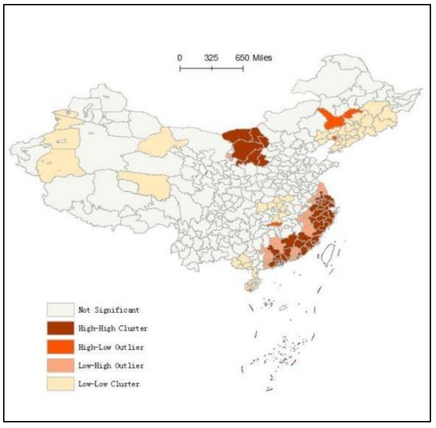


Figure 3a. Local Spatial Autocorrelation of Rental Housing Development in China in 2000

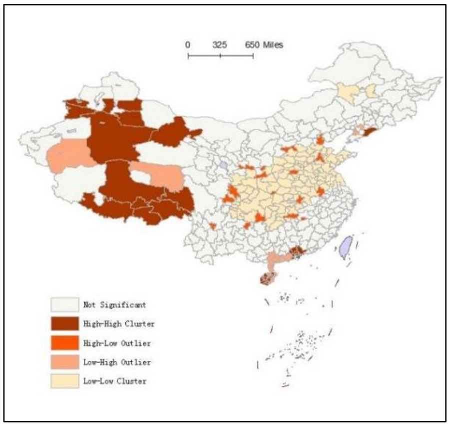


Figure 3b. Local Spatial Autocorrelation of Rental Housing Development in China in 2010

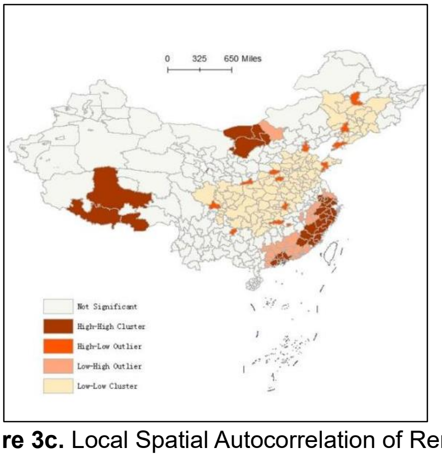


Figure 3c. Local Spatial Autocorrelation of Rental Housing Development in China from 2000-2010

The Development Space Evolution of Rental Housing in the Five Major City Clusters from 2000-2010

According to the Natural Breaks Method, the proportion of rental housing in the five major city clusters is divided into three levels. The figure below shows, the proportion of rental housing in the five major city clusters has increased in the decade. The Beijing-Tianjin-Hebei city cluster has increased in the proportion of medium rental housing over the past decade, mainly in Chengde, Langfang and Shijiazhuang in Hebei Province. The Yangtze River Delta city cluster is mainly Ma'Anshan, Tongling, Anhui Province, Changzhou, Zhejiang Province, Shaoxing, Jinhua and Taizhou, changed from a low proportion to a medium proportion, Suzhou, Jiangsu Province, Hangzhou and Ningbo, Zhejiang Province changed from a medium proportion to a high proportion, and Jiaxing, Zhejiang Province changed from a low proportion to a high proportion. The Pearl River Delta city cluster is mainly the proportion of rental housing in Guangzhou has increased. The middle reaches of the Yangtze River city cluster are mainly Jingmen, Jingzhou, Xianning in Hubei Province, Loudi, Hunan Province and Jingdezhen, Jiangxi Province from a low proportion to a medium proportion, and Changsha, Hunan Province and Xinyu in Jiangxi Province from a medium proportion to a high proportion. The Chengdu-Chongqing city cluster has seen no obvious changes.

The results show that on the basis of the obvious regional differences in the high proportion of rental housing in China from 2000-2010, the regional differences in the development level of the five major city clusters are obvious. The national spatial distribution further gathers to social and economically developed cities, indicating that the impact of economic factors on the regional differentiation of China's housing property rights is becoming more and more prominent. The city cluster is not only a central city, but also the proportion of rental housing in other neighbouring cities is also increasing, indicating that the central city within the city cluster plays an obvious radiating and driving role on the peripheral areas. The central cities and city clusters in the developed eastern coastal areas (such as the Yangtze River Delta city cluster and the Pearl River Delta city cluster) have been gradually formed. The central cities are forming the power of coordinated development with the peripheral central cities and promoting the coordinated regional development through the gradual extension of industrial spillover, population migration, infrastructure and public services. However, city cluster in underdeveloped regions (such as the Chengdu-Chongqing city cluster) has relatively limited radiation and driving effect on the peripheral areas.

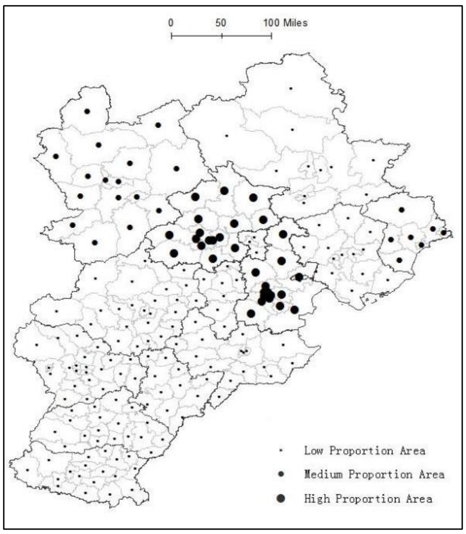


Figure 4a1. Space Distribution of Rental Housing Development in the Beijing-Tianjin-Hebei City Cluster in 2000

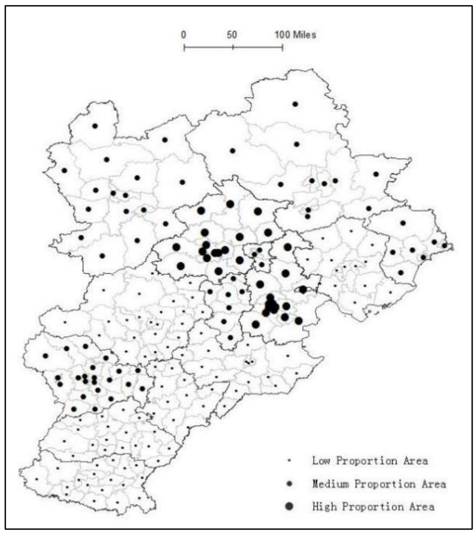


Figure 4a2. Space Distribution of Rental Housing Development in the Beijing-Tianjin-Hebei City Cluster in 2010

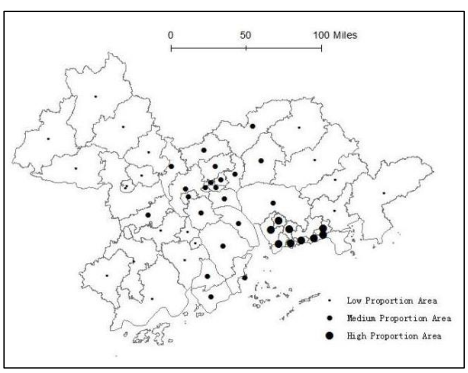


Figure 4b1. Space Distribution of Rental Housing Development in The Pearl River Delta City Cluster in 2000

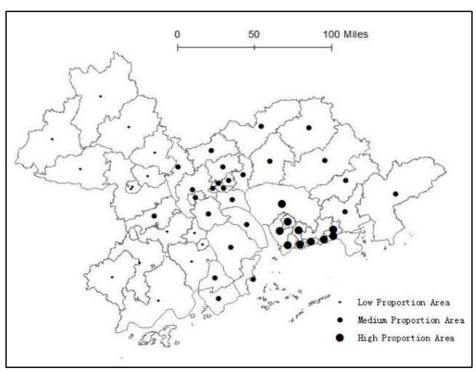


Figure 4b2. Space Distribution of Rental Housing Development in The Pearl River Delta City Cluster in 2010

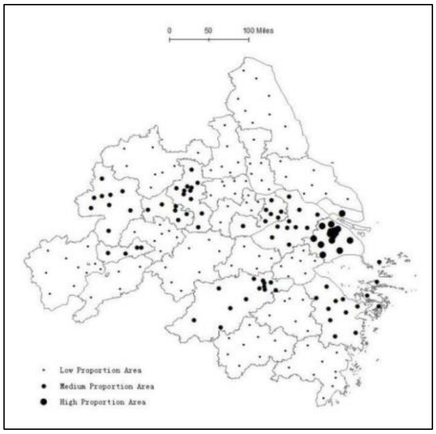


Figure 4c1. Space Distribution of Rental Housing Development in The Yangtze River Delta City Cluster in 2000

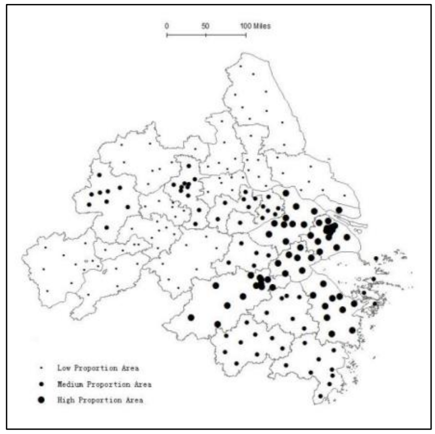


Figure 4c2. Space Distribution of Rental Housing Development in The Yangtze River Delta City Cluster in 2010

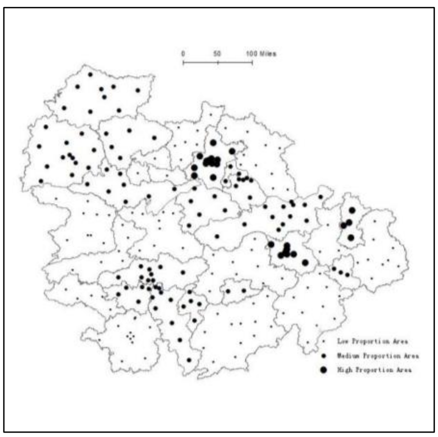


Figure 4d1. Space Distribution of Rental Housing Development in The Middle Reaches of The Yangtze River City Cluster in 2000

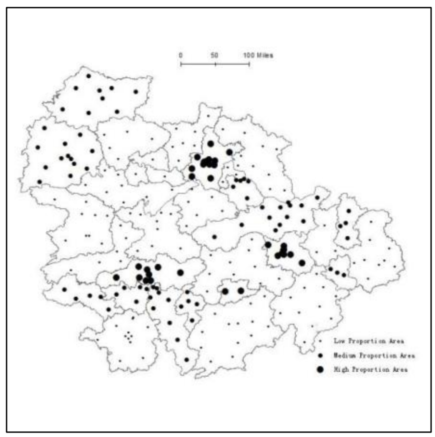


Figure 4d2. Space Distribution of Rental Housing Development in The Middle Reaches of The Yangtze River City Cluster in 2010

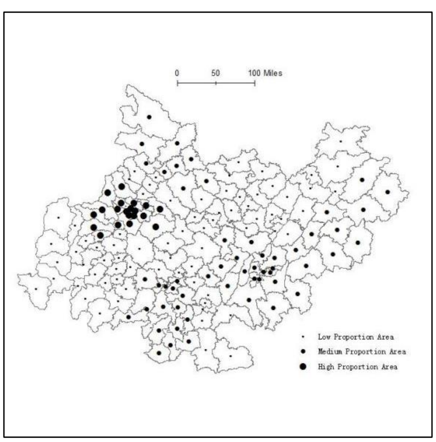


Figure 4e1. Space Distribution of Rental Housing Development in The Chengdu-Chongqing City Cluster in 2000

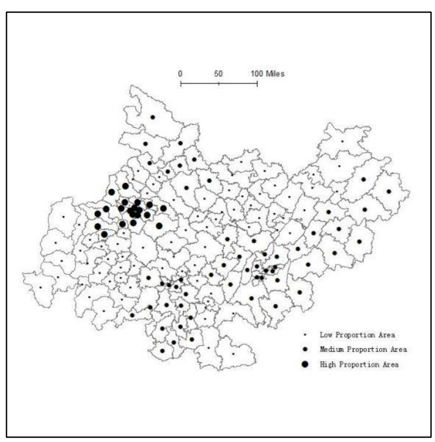


Figure 4e2. Space Distribution of Rental Housing Development in The Chengdu-Chongqing City Cluster in 2010

Spatial Statistical Analysis of Rental Housing Development in The Five Major City Clusters

The Local Spatial Autocorrelation Analysis in the Five Major City Clusters

i) Identification of the Space Weights

In the process of spatial data processing, the spatial weight frequency requirements meet the normal distribution, otherwise the proportional effect will appear to reduce the accuracy of data estimation, eventually resulting in some structural characteristics are not obvious (Sun et al., 2004). In this paper, for local spatial autocorrelation analysis of the proportion of rental housing in the five urban clusters, the spatial object adjacency provided by the topological information generated by ArcGIS software is used, constructing the spatial adjacency matrix based on Rook, Queen and Bishop neighbour principles and through first-order adjacency. By calculation contrast, the spatial adjacency frequency histogram of the Queen adjacency relationship basically complies with the normal distribution characteristics. Therefore, the Queen neighbour principle is used to determine the spatial weights.

ii) Analysis of the Moran Scatter Plot and The Moran's Ii Value

Local spatial autocorrelation analysis was performed using GeoDa1.14 software to obtain local spatial autocorrelation scatter plots of rental housing ratio in prefecture-level cities in the five major city clusters. The Moran's Ii values reflect the local spatial autocorrelation eigenvalues with prefecture-level cities as units. Moran's Ii is taken between [1,1], the closer to 1, the positive correlation is stronger; the closer to 1, the stronger the negative correlation; near 0, there is no spatial clustering.

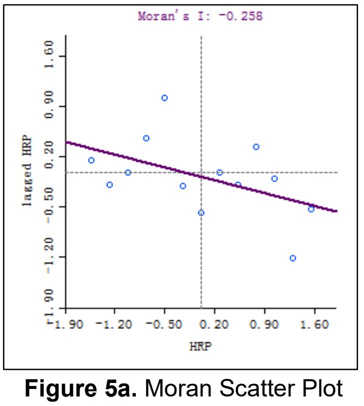


Figure 5a. Moran Scatter Plot of The Proportion of Rental Housing in The Beijing-Tianjin-Hebei City Cluster

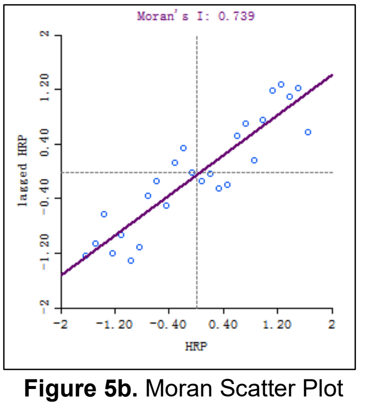


Figure 5b. Moran Scatter Plot of The Proportion of Rental Housing in The Yangtze River Delta City Cluster

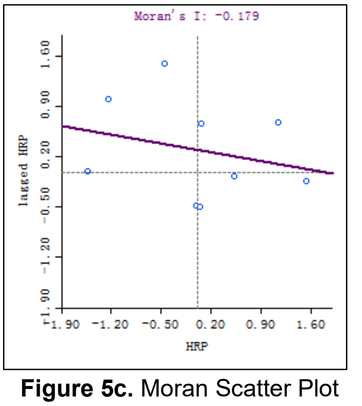


Figure 5c. Moran Scatter Plot of The Proportion of Rental Housing in The Pearl River Delta City Cluster

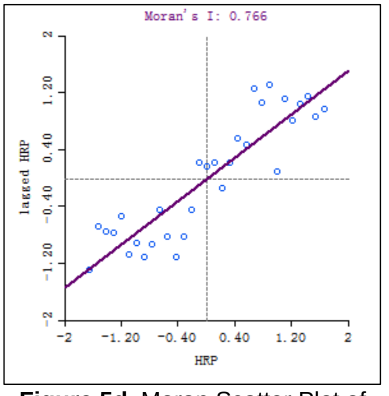


Figure 5d. Moran Scatter Plot of The Proportion of Rental Housing in The Middle Reaches of The Yangtze River City Cluster

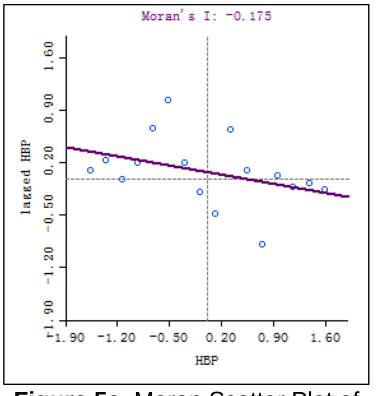


Figure 5e. Moran Scatter Plot of The Proportion of Rental Housing in The Chengdu-Chongqing City Cluster

From the perspective of Moran's Ii value size, the proportion of rental housing in the Yangtze River Delta city cluster and the middle reaches of the Yangtze River city cluster both shows a strong spatial positive correlation in space. The Beijing-Tianjin-Hebei and Pearl River Delta Chengdu-Chongqing city clusters show a weak spatial negative correlation. It reflects that the proportion of rental housing in the Beijing-Tianjin-Hebei, Pearl River Delta and Chengdu-Chongqing city cluster is relatively small spatial correlation, while the proportion of rental housing in the Yangtze River Delta and the middle reaches of the Yangtze River city cluster has relatively large spatial correlation.

Findings

Local spatial autocorrelation analysis of the proportion of rental housing in the prefecture-level cities in the five major city clusters, and a summary table of local spatial autocorrelation types was obtained. The statistical results showed that with 95% confidence, most non-level cities are non-significant in space (Table 3). The corresponding plot of local spatial association reflecting the spatial distribution of the respective correlation types (Figure 6a-e).

Table 3. Statistical Summary of Local Spatial Autocorrelation Types and The Number of Prefecture-Level Cities in The Five Major City Clusters

Autocorrelation Types	**Beijing-Tianjin-Hebei City Cluster**		**Yangtze River Delta City Cluster**		**Pearl River Delta City Cluster**		**Middle Reaches of The Yangtze River City Cluster**		**Chengdu-Chongqing City Cluster**	
	Number	**Ratio/%**	**Number**	**Ratio/%**	**Number**	**Ratio/%**	**Number**	**Ratio/%**	**Number**	**Ratio/%**
H-H	1	7.69	6	23.08	2	22.22	9	29.03	1	6.25
H-L	2	15.38	0	0	0	0	0	0	1	6.25
L-H	0	0	0	0	1	11.11	0	0	2	12.5
L-L	0	0	7	26.92	0	0	11	35.48	0	0
Non-Significance	10	76.92	13	50	6	66.66	11	35.48	12	75
Amount To	13	100	26	100	9	100	31	100	16	100

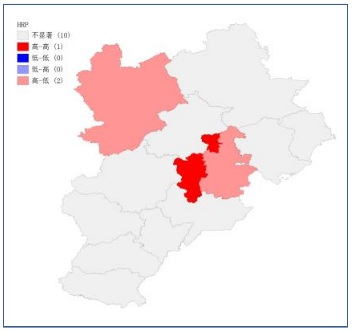


Figure 6a. Local Spatial Association and Aggregation Map of The Proportion of Rental Housing in The Beijing-Tianjin-Hebei City Cluster

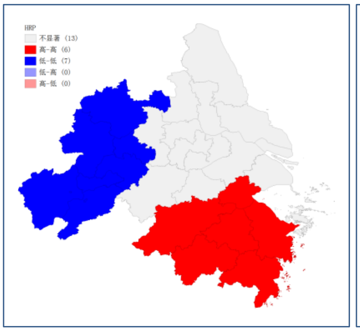


Figure 6b. Local Spatial Association and Aggregation Map of The Proportion of Rental Housing in The Yangtze River Delta City Cluster

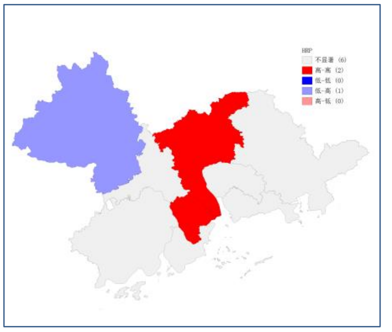


Figure 6c. Local Spatial Association and Aggregation Map of The Proportion of Rental Housing in The Pearl River Delta City Cluster

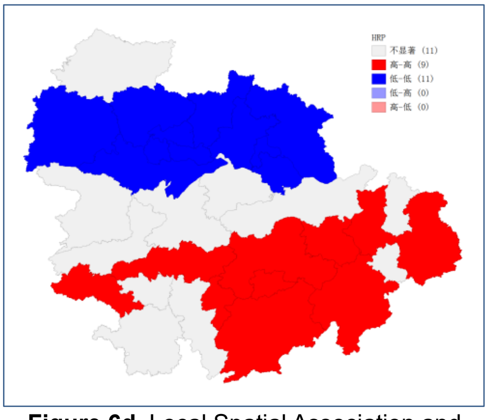


Figure 6d. Local Spatial Association and Aggregation Map of The Proportion of Rental Housing in The Middle Reaches of The Yangtze River City Cluster

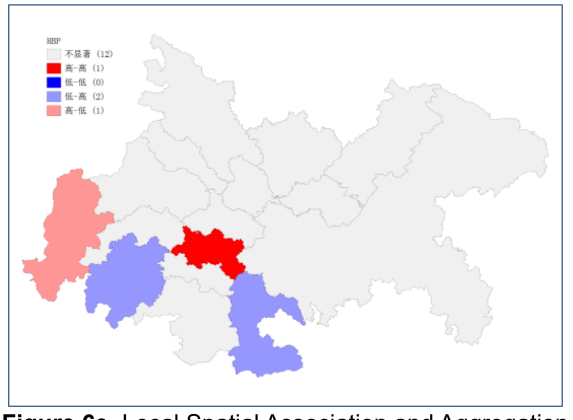


Figure 6e. Local Spatial Association and Aggregation Map of The Proportion of Rental Housing in The Chengdu-Chongqing City Cluster

i) Local spatial autocorrelation analysis of the rental housing proportion in the Beijing-Tianjin-Hebei city cluster.

Combined with Table 3 and Figure 6a, the local spatial autocorrelation analysis of rental housing ratio in Beijing-Tianjin-Hebei city cluster shows that only one HH prefecture-level city, accounting for 7.69% of the total number of prefecture-level cities, and the LL and LH types were 0. Among the positive correlated types, HL has 2 prefecture-level types, accounting for 15.38%. There are 10 non-significant prefecture-level cities, accounting for 76.92%. In terms of spatial distribution, HH is mainly Langfang; HL is mainly distributed in Zhangjiakou and Tianjin.

In practice, the housing market trend of the Beijing-Tianjin-Hebei city cluster is often the same. Langfang is the most affected by Beijing's housing market. The GDP of Beijing and Tianjin, adjacent to Langfang, accounted for 55% of the city cluster, and the migrant population accounted for nearly 30%, which effectively drives the development of the housing rental market in the surrounding cities. This overlaps spatially with the HH type. Although it is also the earliest national-level city cluster to be established, due to the unbalanced economic development in the region, Beijing and Tianjin have an obvious siphon effect on other cities in the region, and the overall economic development driving force is slightly insufficient. However, after a decade of development, Beijing and Tianjin have also driven the good development of the housing rental market in the surrounding cities.

ii) Local spatial autocorrelation analysis of the rental housing proportion in the Yangtze River Delta city cluster.

Combined with Table 3 and Figure 6b, the results of local autocorrelation analysis of rental housing in Yangtze River Delta shows that 6 HH cities, about 23.08% of the total number of prefecture-level cities. The HL and LH types were 0. There are 7 prefecture-level LL types, accounting for 26.92% and 13 non-significant cities, accounting for 50%. In terms of spatial distribution, HH are mainly Jiaxing, Hangzhou, Ningbo, Shaoxing, Jinhua and Taizhou in Zhejiang Province; LL are mainly distributed in Chuzhou, Ma'Anshan, Hefei, Wuhu, Tongling, Anqing and Chizhou in Anhui Province.

In the Yangtze River Delta city cluster, Shanghai, Jiangsu and Zhejiang provinces have developed economies. In contrast, Anhui province is less attractive to the population, with only the net population inflow of Hefei and Maanshan, and a total net inflow of less than one million people. The net inflow of population directly reflects the situation of the rental housing market. Zhejiang Province and neighbouring Shanghai and Suzhou, Jiangsu Province overlap with HH type in the spatial analysis of local spatial autocorrelation. The overall proportion of rental housing in Anhui Province is low, which matches the spatial distribution of LL type.

iii) Local spatial autocorrelation analysis of the rental housing proportion in the Pearl River Delta city cluster.

Combined with Table 3 and Figure 6c, the local spatial autocorrelation analysis of rental housing ratio in the Pearl River Delta shows that 2 HH cities account for 22.22% of them, there is 1 prefecture-level LH type, about 11.11%. The LL and HL types were 0 and 6 non-significant prefecture-level cities, accounting for 66.66%. In terms of spatial distribution, HH type is mainly Guangzhou and Zhongshan, and L H type is Zhaoqin.

The highest ratio of external population to resident population in the Pearl River Delta city cluster is in Guangzhou, Shenzhen, Dongguan and Foshan. The high inflows of the population have created a large demand for housing, where the housing markets show great potential in the context of high housing prices. Zhaoqing has the lowest proportion of migrant population and permanent resident population. Consiagreement with HH and LH types in spatial position.

iv) Local spatial autocorrelation analysis of the rental housing proportion in the middle reaches of the Yangtze River.

Combined with Table 3 and Figure 6d, the local spatial autocorrelation analysis results of the proportion of rental housing in Yangtze River Delta shows that 9 HH-level cities account for 29.03%, HL and LL types are 0. There are 11 prefecture-level LL types, accounting for 35.48%. 11 non-significant cities, 35.48%. In terms of spatial distribution, HH types are mainly Shangrao, Nanchang, Fuzhou, Yichun, Xinyu, Ji'an, Pingxiang, Loudi and Hunan

Province; LL type is mainly distributed in Yichang, Jingmen, Xiaogan, Tianmen, Qianjiang, Xiantao, Jingzhou, Wuhan, Huanggang, Ezhou and Huangshiin Hubei Province.

Although the middle reaches of the Yangtze River is the city cluster with the widest regional scope and the largest number of cities among the five major city clusters, but limited by the level of economic development, only four cities in Wuhan, Changsha, Nanchang and Yichang are cities with net population inflow, accounting for 13%.The demand for rental market in the middle reaches of the Yangtze River is roughly positively correlated to the maturity of economic development, and the provinces spread from central cities to other cities, which is basically consistent with the spatial distribution of HH and LL types.

v) Local spatial autocorrelation analysis of the rental housing proportion in the Chengdu-Chongqing city cluster.

Combined with Table 3 and Figure 6e, the local spatial autocorrelation analysis of the proportion of rental housing in Chengdu-Chongqing city cluster shows that 1 HH and HL is accounting for 6.25%, LL is 0,2 prefecture-level LH is 12.5% and 12 non-significant cities, accounting for 75%. Only Chengdu in the Chengdu-Chongqing city cluster shows a trend of net population inflow. From the overall population of Chongqing shows an outflow trend. On the whole, the rental housing market of Chengdu-Chongqing city cluster did not show an obvious correlation.

CONCLUSION

The research findings in this paper can provide important policy enlightenment for scientifically grasping the development status of China's rental housing market and predicting the future rental housing market demand. i) Under the background of rapid urban social and economic development in China, due to the rapid growth of migrant population in big cities, the transformation and upgrading of industrial structure and high urban housing prices and many other practical factors, should focus on strengthening the domestic first and second-tier central city rental housing market development, to help these urban residents to realize the basic demand of living; ii) Formulate the development strategy of differentiated rental housing market according to local conditions. Due to the differentiation and the imbalance of regional economic development pattern still exists, the eastern economic development is better, high urbanization level, city cluster development at a higher level, the focus is to promote the coordinated development of city cluster rental housing market, Midwest and northeast economic development and urbanization level is still rapidly, in the new city cluster stage, the focus is to enhance the number of rental housing market level and speed up the cultivation of city cluster; iii) From the perspective of spatial form, the population continues to gather from the periphery of the city cluster to the centre. The long-term and stable residence of the floating population and the family migration is the premise to guarantee and improve their labour participation rate and release the demographic dividend to the cities where they are located. On the one hand, the housing demand brought by the population entering the city needs to be allocated in advance, and on the other hand, the population flow shows polarization. For the cities shrinking by the population outflow, we need to pay attention to the housing risks and do a good job in ensuring people's livelihood and social policy support; iv) The development of the housing rental market in areas where ethnic minorities concentrate is special. We should appropriately increase the investment of housing construction funds and housing security, combining the actual needs of all ethnic groups, reduce the development of the housing rental market, and help to maintain social stability in the border areas and promote ethnic unity and social integration.

There are also partial limitations in this study. First of all, limited by the data source, the rental housing statistics used in this paper from 2000 and 2010 national county census, data has a certain time lag, later can be combined with the national census data in 2020 to be further improve. But to interpret the spatial evolution of rental housing development in China, still has good theoretical and practical guiding significance. Secondly, there are 19 city clusters in China. However, due to the slow development of city clusters from 2000 to 2010, the results presented with five major city clusters as research units are relatively significant. In the later stage, the data from 2020 can be used to conduct comparative research on the development of rental housing in 19 city clusters in China in different periods.

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DRIVING FOREIGN DIRECT INVESTMENT IN MALAYSIA: THE ROLE OF RENEWABLE ENERGY POLICIES AND STRATEGIC REFORMS

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Abstract
This research examines Malaysia's Energy Policy (DTN 2022 – 2040) and its strategic initiatives aimed at expediting the development of renewable energy projects to attract foreign direct investment (FDI). A mixed- method approach was employed, combining qualitative case studies with quantitative analysis of investment trends and policy impacts. Data were collected through interviews with key stakeholders, including policymakers, industry experts, and investors, as well as a review of government reports and investment data. The findings reveal significant barriers to FDI in renewable energy, including cumbersome approval processes at the local government level, lack of expertise, and limited public awareness of renewable energy benefits. Case studies demonstrated that streamlining these processes and enhancing government support could significantly boost investment. For instance, the study highlighted how the adoption of electric vehicle (EV) infrastructure and rooftop solar financing could lead to increased FDI and progress towards Malaysia's renewable energy targets. The research concludes that while Malaysia's Energy Policy provides a solid foundation for renewable energy growth, achieving the ambitious targets requires coordinated efforts to simplify regulatory frameworks, enhance public awareness, and provide targeted financial incentives. These measures are essential to positioning Malaysia as a competitive destination for renewable energy investments and ensuring long-term energy sustainability.

Keywords: *Renewable Energy; Foreign Direct Investment; Approval Process at City Council*

INTRODUCTION

The global shift towards renewable energy has emerged as a critical priority for governments and industries, driven by the urgent need to address climate change and reduce dependence on fossil fuels (IRENA, 2022). Renewable energy offers not only a sustainable alternative to conventional energy sources but also substantial economic opportunities, particularly through foreign direct investment (FDI) (World Bank, 2021; Pratiwi & Juerges, 2020). In this context, Malaysia, endowed with abundant natural resources and a strategic position in Southeast Asia, is well-positioned to lead the renewable energy transition in the region (MIDA, 2022). Malaysia's Energy Policy, known as Dasar Tenaga Negara (DTN) 2022 – 2040, outlines ambitious goals to increase the share of renewable energy in the national energy mix and reduce carbon emissions (Suruhanjaya Tenaga, 2020). The policy aims to promote the development of renewable energy projects, such as solar, wind, and biomass, while accelerating the adoption of electric vehicles (EVs). However, the successful implementation of these initiatives is crucial not only to meet environmental objectives but also to attract significant FDI, which is vital for financing large-scale renewable energy projects (Lau et al., 2022).

Despite Malaysia's supportive policy framework, the country faces several challenges in realizing its renewable energy potential (Chachuli et al., 2021). These challenges include complex regulatory hurdles that delay project approvals, financial barriers that discourage investors and consumers, and a general lack of public awareness and acceptance of renewable technologies (IRENA, 2022). These issues have contributed to Malaysia's slower progress in renewable energy adoption compared to neighbouring Southeast Asian countries (World Bank, 2021). To address these challenges, this study adopts a qualitative research approach, using case studies to examine the implementation of renewable energy initiatives in Malaysia and their potential to boost FDI. The research focuses on three key areas: the deployment of EV charging infrastructure along expressways, the adoption of rooftop solar installations in residential areas, and the implementation of smart street lighting systems. Through detailed case studies, the research explores the specific obstacles faced during the development of these projects, using data collected from interviews with key stakeholders and a review of relevant policy documents and investment data.

LITERATURE REVIEW

Foreign Investment in Malaysia for Renewable Energy

FDI plays a pivotal role in the development of renewable energy projects, providing essential capital, technology, and expertise needed to scale up initiatives (Wei, Mohsin, & Zhang, 2022). In recent years, Malaysia has made efforts to attract FDI into its renewable energy sector, but it continues to face challenges in matching the levels of investment seen in neighbouring ASEAN countries (Vakulchuk, Overland, & Suryadi, 2023). According to the Malaysian Investment Development Authority (MIDA), in 2021, Malaysia's renewable energy sector attracted a total investment of RM 29.5 billion, with foreign investments contributing RM 0.7 billion, or approximately 23.3% of the total (MIDA, 2022). While these figures indicate a growing interest in Malaysia's renewable energy market, they are modest compared to other Southeast Asian nations. For instance, countries like Vietnam and Thailand have been more successful in securing substantial foreign investments due to more aggressive policy incentives and streamlined regulatory processes (World Bank, 2021).

One of the significant barriers to increasing FDI in Malaysia's renewable energy sector is the perception of regulatory and procedural challenges (Oh et al., 2018). Investors often cite the lengthy and complex approval processes at the local and state levels as deterrents. The current procedures, which involve multiple agencies and extensive documentation, can delay project implementation and reduce the potential returns on investment. This bureaucratic inefficiency contrasts with the more investor- friendly environments in countries like Vietnam, where the government has simplified regulatory requirements to fast-track renewable energy projects (IRENA, 2022). Malaysia's reliance on conventional energy sources, particularly natural gas and coal, has historically overshadowed the development of renewable energy (Bong et al., 2017). In 2019, coal accounted for 44.5% of Malaysia's energy mix, while natural gas contributed 38.6%. Renewable energy, including solar and biomass, represented only a small fraction of the total energy supply (Suruhanjaya Tenaga, 2020). This dependence on fossil fuels has made it challenging to transition to greener energy sources, which is necessary to attract more significant foreign investment.

The Malaysian government has introduced several initiatives to enhance the attractiveness of its renewable energy sector to foreign investors. These include the Net Energy Metering (NEM) scheme, Feed-in Tariff (FiT) program, and Green Technology Financing Scheme (GTFS), all designed to incentivize the adoption of renewable energy technologies (Lau et al., 2022). However, the effectiveness of these initiatives in significantly boosting FDI remains limited by the structural challenges mentioned earlier. Moreover, achieving Malaysia's ambitious renewable energy targets such as the goal to increase the share of renewables to 31% of the energy mix by 2025 will require not only attracting more foreign investment but also addressing the underlying issues that deter investors. These include enhancing the transparency and efficiency of the approval processes, providing more robust financial incentives, and ensuring consistent policy implementation across different levels of government. In conclusion, while Malaysia has made strides in attracting foreign investment into its renewable energy sector, there is still much work to be done. Addressing the regulatory and financial barriers will be crucial in ensuring that Malaysia can fully capitalize on its renewable energy potential and attract the level of FDI necessary to meet its energy and environmental goals.

Energy Target for Malaysia

Malaysia has set ambitious targets in its new energy policy, Dasar Tenaga Negara (DTN) 2022–2040, with a clear objective to increase the share of renewable energy and reduce reliance on fossil fuels. The key consideration of the plan is not only limited to projecting future demand and generation capacity but also includes monitoring the progress of transmission projects to support the government's policies in achieving 31% renewable energy (RE) capacity by 2025 (Suruhanjaya Tenaga, 2020). In general, Malaysia aims to generate at least 31% of its energy from renewable sources by 2025, with a further projection of 40% by 2035 (MIDA, 2022). This target is achievable with greater public commitment to adopting renewable energy sources.

To successfully integrate renewable energy into the current power supply system, the implementation of a smart grid is essential. Smart grids are critical for ensuring energy security and facilitating the integration of renewable energy resources into the grid (Othman, 2020). Therefore, renewable energy plants must enhance their capabilities to achieve high efficiency, improve performance with appropriate technologies, and explore low-cost financing options to support diverse renewable energy generation resources within the power system. Currently, as of 2016, Malaysia's installed electricity capacity was approximately 23,000 MW, with 6,000 MW allocated to Sabah and Sarawak (Suruhanjaya Tenaga, 2017), as in Table 1 below.

Table 1. Installed Electricity Capacity as 2016

Energy as of 2016	Installed Capacity (MW)	Peak Demand (MW)	Reserve Margin (%)
Peninsular Malaysia	23,249	17,788	28.7
Sabah	1,567	944.9	37.9
Sarawak	4,437	3,315	34

(Source: Suruhanjaya Tenaga, Malaysia Energy Statistic in 2016)

According to the Suruhanjaya Tenaga report in 2022 (Report on Peninsular Malaysia Generation Development Plan 2020 [2021–2039]), the growth in energy demand between 2015 and 2020 increased from 16,822 MW to 18,808 MW, representing an average annual growth rate of 2.3%. However, the COVID-19 pandemic significantly impacted energy consumption in 2020 due to the Movement Control Order (MCO) imposed by the government. Prior to the MCO, a peak demand for electricity was recorded on 10 March 2020, just one week before the restrictions were enforced on 18 March 2020. Moving forward, energy demand is forecasted to grow at an annual rate of 0.9% between 2021 and 2030, and at 1.7% annually from 2030 to 2039 (Suruhanjaya Tenaga, 2021).

To meet Malaysia's target of achieving 31% renewable energy in the total energy mix by 2025, a total of 1,178 MW of new renewable energy capacity is planned for development in Peninsular Malaysia from 2021 onwards. Of this capacity, 1,098 MW will be from solar energy, while 80 MW will come from non-solar sources (SEDA, 2021). Solar energy, while being the most attractive source of renewable energy in Malaysia's power system, is inherently limited by its intermittent nature, as it is not available 24 hours a day. This poses a challenge to the stability of the existing power grid, which must maintain a constant and reliable power supply (Burke et al., 2019). By 2035, solar power is expected to generate 30% of the forecasted peak demand, and the share of renewable energy in Malaysia's energy mix is projected to rise to 40%, equating to approximately 2,414 MW of renewable energy capacity in Peninsular Malaysia between 2026 and 2035 (SEDA MyRER, 2021; New Straits Times, 2022).

Despite these ambitious targets, renewable energy generation in Peninsular Malaysia remains low, accounting for less than 1% of the total energy supply. The country continues to rely heavily on fossil fuels, which contribute to 90% of the total power generation fuel mix (Malahayati, 2020). To address this issue, Malaysia has introduced an ambitious new energy policy, the Dasar Tenaga Negara (DTN) 2022–2040, which focuses on reducing carbon emissions and shifting to low-carbon activities by 2040, with a baseline established in 2018. Further details of these targets are presented in Table 2.

Table 2. Key Target for Malaysia, Low Carbon Aspiration by 2040

No	Selected Target	2018	Low Carbon Nation Aspiration
1	Percentage of urban public transport modal share	-20 %	50%
2	Percentage of electric vehicle (EV) share	< 1%	38%
3	Alternative fuel standards for heavy transport	B5	B30
4	Percentage of Liquefied Natural Gas (LNG) as alternative fuel for marine transport	0%	25%
5	Percentage of industrial and commercial energy efficiency savings	< 1%	11%
6	Percentage of residential energy efficiency savings	< 1%	10%
7	Total installed capacity of RE	7,597 MW	18,431 MW
8	Percentage of coal in installed capacity	31.4%	18.6%
9	Percentage of RE in TPES (Total Primary Energy Supply)	7.2%	17%

(Source: DTN, 2022–2040)

The low-carbon national aspiration for 2040, as outlined in Table 2, focuses on three key targets that underscore Malaysia's commitment to transitioning towards a low-carbon or net-zero emissions future by 2050. These targets include the phased retirement of existing coal power plants, a strong emphasis on driving energy efficiency and renewable energy development, and the promotion of electric vehicles (EVs). Through these initiatives, Malaysia aims to significantly reduce its carbon footprint, mitigate the impacts of climate change, and support sustainable development, particularly in the energy and transportation sectors.

Challenges in Renewable Energy Implementation

Despite Malaysia's significant potential for renewable energy development, several critical challenges and barriers continue to hinder the widespread adoption and implementation of renewable energy projects. These challenges are multifaceted, encompassing regulatory, financial, technical, and social dimensions, each of which plays a significant role in shaping the country's renewable energy landscape. One of the most significant obstacles to the development of renewable energy in Malaysia is the complex and often inconsistent regulatory framework (Ismail, Rahadi, & Kokchang, 2023). The approval process for renewable energy projects involves multiple government agencies and layers of bureaucracy, leading to delays and increased costs. For example, projects often require approval from both federal and state-level authorities, with each level potentially imposing different requirements and procedures. This complexity can discourage investors, particularly foreign ones, who may find it challenging to navigate the regulatory environment (Marzukhi, Jaafar, & Leh, 2019).

The establishment of the One-Stop Centre (OSC) by the Ministry of Housing and Local Government Development (KPKT) in 2007 was intended to streamline the approval process for development projects, including those in renewable energy. However, issues such as insufficient staffing, lack of expertise, and inconsistent application of regulations across different local authorities have limited the effectiveness of this initiative (Marzukhi, Omar, Leh, & Jaafar, 2019). Developers frequently report frustration with the slow pace of approvals and the lack of clarity in the requirements, which can lead to project delays and increased costs (Sahid, Suratman, & Ali, 2021). Financial constraints represent another major barrier to the growth of the renewable energy sector in Malaysia (Tseng et al., 2021). The high upfront costs associated with renewable energy technologies, such as solar photovoltaic (PV) systems and wind turbines, are often prohibitive for many potential investors and consumers. While the Malaysian government offers various financial incentives, such as the Feed-in Tariff (FiT) and the Green Technology Financing Scheme (GTFS), these measures are sometimes insufficient to offset the significant initial investment required (Lau et al., 2022).

Access to financing remains a challenge, particularly for small and medium-sized enterprises (SMEs) and residential consumers. Many financial institutions are hesitant to provide loans for renewable energy projects due to perceived risks, including the long payback periods and uncertainty in returns (Mekhilef et al., 2012). This lack of financing options limits the ability of businesses and households to invest in renewable energy technologies, thereby slowing the overall growth of the sector. The integration of renewable energy into Malaysia's existing energy grid presents technical challenges, particularly regarding grid stability and reliability. Renewable energy sources such as solar and wind are inherently variable, depending on weather conditions and time of day. This variability can create difficulties in maintaining a stable and consistent energy supply, particularly when a significant portion of the energy mix is derived from renewable sources (Othman, 2020). Malaysia's current grid infrastructure may require significant upgrades to accommodate a higher penetration of renewable energy. The implementation of smart grid technologies, which allow for better management and distribution of electricity, is crucial for ensuring that the grid can handle the fluctuating supply from renewable sources (Huang, Kittner, & Kammen, 2019). However, the high cost and complexity of these upgrades present additional challenges, particularly in securing the necessary investment and technical expertise (Lee et al., 2020).

In Malaysia, there is still a significant gap in public understanding of the benefits and potential of renewable energy. Many consumers are unaware of the financial incentives available or the long-term savings that can be achieved through the adoption of renewable energy technologies (Gadenne, Sharma, Kerr, & Smith, 2011; Muhammad-Sukki et al., 2011). Moreover, there is often resistance to change, particularly in communities where traditional energy sources like coal and natural gas have been the norm for decades. This resistance can be exacerbated by concerns on the reliability and cost of renewable energy, as well as a general lack of trust in new technologies (Kardooni, Yusoff, Kari, & Moeenizadeh, 2018). Educational campaigns and community engagement efforts are needed to address these concerns and build public support for renewable energy initiatives. Addressing these challenges is crucial for Malaysia to meet its renewable energy targets and attract more investment in the sector. Regulatory reforms enhanced financial incentives, investment in grid infrastructure, public education, and support for market development are all essential components of a strategy to overcome these barriers. By addressing these issues, Malaysia can accelerate its transition to a sustainable energy future and solidify its position as a leader in renewable energy within the region.

METHODOLOGY

Research Design

This research adopts a qualitative research design with a focus on case studies to examine the implementation of renewable energy initiatives in Malaysia and their potential to attract foreign direct investment (FDI). The case study approach is suitable for understanding complex, context-specific issues, allowing for in-depth analysis of real-world projects. By exploring three specific cases of EV charging infrastructure, rooftop solar installations, and smart street lighting systems, the study aims to uncover key challenges and opportunities related to the adoption and integration of renewable energy in Malaysia.

Case Study Selection

The case studies were carefully selected based on their relevance to Malaysia’s Dasar Tenaga Negara (DTN) 2022–2040 energy policy and the role each initiative plays in achieving the country’s renewable energy targets. The three case studies represent different areas of renewable energy:

- EV Charging Stations along Expressways

This case explores the deployment of electric vehicle charging infrastructure along Malaysia's major expressways. The objective is to understand the regulatory, logistical, and financial challenges involved in developing this key component of Malaysia's push towards electric vehicle adoption.

- Rooftop Solar Installations

This case focuses on residential rooftop solar installations, which are central to Malaysia’s strategy for increasing solar energy capacity. The study aims to assess the financial and regulatory barriers faced by homeowners and small businesses in adopting solar power.

- Smart Street Lighting Systems

The case study examines the implementation of energy-efficient LED street lighting systems in urban areas. It assesses the challenges related to public acceptance, financial feasibility, and technical integration in the broader energy infrastructure.

Data Collection

Data were collected using a combination of primary and secondary sources to ensure a comprehensive analysis of the selected case studies.

Primary Data:

The primary data were obtained through semi-structured interviews with key stakeholders, including project developers, government officials, financial analysts, and end-users. The interview questions were designed to explore regulatory barriers, financial challenges, technological issues, and public acceptance of renewable energy initiatives.

- Sampling: The sample consisted of seven respondents, each representing key stakeholder groups in the renewable energy sector. The interviewees were selected based on their expertise and involvement in the relevant projects.
- Interview Structure: The interviews were conducted using a semi-structured format to allow flexibility while ensuring that key themes were addressed. Interviews lasted between 45 minutes and 1 hour, either in-person or via online platforms such as Zoom and Teams.

Table 2. Key Target for Malaysia, Low Carbon Aspiration by 2040

Interviewee Code	Position/Role	Organization Type	Sector	Years of Experience
INT-01	Project Developer	Renewable Energy Company	Solar Energy	10+
INT-02	Government Official	Ministry of Energy	Regulatory (Energy Policy)	15+
INT-03	Financial Analyst	Banking/Financial Institution	Financing Renewable Energy	7
INT-04	Municipal Officer	Local Government	Public Infrastructure (Street Lighting)	12
INT-05	Energy Consultant	Private Consultancy Firm	Electric Vehicle Infrastructure	8
INT-06	Homeowner	Private Individual	Solar Energy (Residential)	N/A
INT-07	Utility Company Official	National Power Utility Company	Energy Transmission and Grid	20+

(Source: DTN 2022–2040)

The sample of seven respondents was selected to ensure representation of key stakeholders involved in renewable energy projects, including government officials, project developers, financial analysts, and end-users. Although small, the sample is appropriate for this qualitative case study approach, as it focuses on gathering in-depth insights from individuals with direct involvement and expertise in the renewable energy sector. Additionally, the thematic analysis reached data saturation, where no new themes emerged after the final interviews, confirming the adequacy of the sample size for this research.

Secondary Data Collection:

Secondary data were gathered from government reports, policy documents, investment records, and previous studies on Malaysia's renewable energy policies and projects. Key sources include the Suruhanjaya Tenaga (Energy Commission), Sustainable Energy Development Authority (SEDA), and relevant academic research. These secondary sources provided additional context for understanding the broader policy framework and historical trends in renewable energy adoption in Malaysia.

Data Analysis

Thematic analysis was employed to analyse the data obtained from the interviews and secondary sources. The analysis was conducted using NVivo 12, a qualitative data analysis software that facilitates the organization and coding of large amounts of qualitative data. The software enabled efficient identification of recurring patterns and themes across interview transcripts.

- Thematic Coding Process: Interview transcripts were transcribed and imported into NVivo 12 for coding. The thematic coding process identified key themes related to the challenges and opportunities in Malaysia's renewable energy sector. Each theme was categorized into areas such as regulatory challenges, financial barriers, technological integration, and public awareness.
- Comparative Analysis: The findings from each case study were compared to identify commonalities and differences in the challenges faced by the different sectors (solar energy, electric vehicles, and smart grids). This comparative approach allowed for a holistic understanding of the factors influencing renewable energy adoption in Malaysia.

RESULT AND DISCUSSION

Case Study 1: EV Charging Stations Along Expressways

Regulatory Challenges in Renewable Energy Implementation

The implementation of EV charging stations along expressways in Malaysia faces significant regulatory hurdles, primarily due to the fragmented and complex approval processes required by various governmental agencies. Investors aiming to develop EV charging stations at strategic locations, such as along expressways or in shopping malls, must first apply to local authorities for site approval. One project developer commented, *"We often face long waiting periods because each local authority has different requirements, and it is hard to get all the necessary approvals in a timely manner."* This initial step, although essential, can lead to delays, as different districts and states enforce varying regulations and processes, adding to the complexity.

Before installation, investors are required to obtain a license from Suruhanjaya Tenaga (Energy Commission), the main regulatory body overseeing energy-related projects in Malaysia. This license ensures compliance with operational standards and safety regulations. However, as several interviewees pointed out, the licensing process is time-consuming and overly complicated. Industry stakeholders agree that this procedure needs to be streamlined, with fast-track approval mechanisms to expedite the deployment of charging stations. One developer added, *"If we had a more efficient approval process, we would see much faster growth in the EV infrastructure sector."* In addition to securing a license from Suruhanjaya Tenaga, ministerial approval is required before projects can proceed. The responsible minister must review and evaluate the project to ensure alignment with the government's broader objectives for EV infrastructure development. While necessary, this ministerial review introduces another layer of bureaucracy that contributes to delays. An interviewee from the regulatory sector stated, *"The minister's approval is important, but it often slows things down. We need better coordination between the various agencies involved."*

Moreover, standardizing the Development Order Approval process across state and district levels was highlighted as a critical solution by multiple interviewees. Currently, investors must navigate inconsistent regulations depending on the location of their project, which increases both costs and timelines. A municipal officer explained, *"It is frustrating that approvals vary so much between districts. A more uniform process would save everyone a lot of time."* Several stakeholders recommended the establishment of a centralized regulatory authority to oversee the entire process, ensuring consistency and reducing bureaucratic delays.

Another challenge lies in the involvement of Tenaga Nasional Berhad (TNB), the sole electricity provider in Peninsular Malaysia, which plays a crucial role in providing grid connections for EV charging stations. Interviewees noted that the TNB application process is complicated, with high fees and lengthy approval periods. A project developer remarked, *"TNB holds the key to getting connected, but the process is slow and expensive, making it harder to roll out charging stations at scale."* It is recommended that TNB revises its framework to simplify the process, making it more accessible for investors and reducing the associated costs (refer to Table 3).

Table 3. Overall Estimated Development Process Flow Indicating the Lengthy Procedures: The Process for EV Charging Station Installation

Simplified Process Flow for EV Charging Point Along Expressways		
Pre-Consultation Process		**Estimated Duration**
Availability of land or space required for EV Charger	Assess the power availability	1 months
Application for EV Charging Point to Authority		**Estimated Duration**
Submission of Approval or Development Order to Majlis	ePTL (Pembangunan Tepi Lebuhraya) submission to LLM for Kelulusan Konsep Bersyarat (KKB)	3 months
Application for Power Supply to TNB		**Estimated Duration**
Wayleaves approval/Land possession to site TNB Equipment	Forwarding power supply application to TNB via Electrical Consultant	Up to 12 Months
Work Permit & License		**Estimated Duration**
Apply work permit with LLM and Highway Concessionaire	Application to ST for Charging Point Operator Public Distribution License	Up to 9 Months
Construction & Operation		**Estimated Duration**
Apply for Sijil Kesempurnaan Pembinaan (SKP) from LLM & Concessionaire	Energies Power from TNB	Up to 3 Months

In addition to addressing regulatory issues, the government is encouraged to explore setting up a revolving fund to facilitate private-sector access to financing for energy-efficient projects, including EV charging stations. This would lower the financial barriers currently hindering investment in large-scale infrastructure projects. One financial analyst suggested, *"If the government established a revolving fund, it would provide much-needed capital to developers and help push these projects forward."* Other interviewees pointed out that policies promoting sustainable procurement and private-sector financing within the banking sector would further encourage investment. A banking official noted, "We need clearer guidelines and incentives from the government to make financing these projects less risky."

In conclusion, the regulatory challenges for developing EV charging stations in Malaysia are significant and multifaceted. Addressing these challenges requires streamlining and centralizing the regulatory process, standardizing state and district approvals, and revising TNB's framework to ensure more efficient grid connections. Additionally, setting up financial mechanisms such as a revolving fund and encouraging private-sector financing would support the growth of Malaysia's EV infrastructure. One government official concluded, *"By simplifying the process and improving access to financing, we can meet our renewable energy goals much faster."*

Financial Barriers

In addition to regulatory challenges, the implementation of EV charging stations in Malaysia faces significant financial barriers, particularly regarding access to affordable financing and the high initial costs associated with infrastructure development. Many investors are reluctant to engage in the EV sector due to the perceived long payback period and uncertainty over returns. The high upfront costs required to establish charging stations, especially along high-traffic expressways, was a recurring theme in the interviews. One project developer explained, *"Setting up a single charging station is a major financial commitment, and without substantial government incentives or easier access to capital, many developers simply cannot afford to take on such projects."* This lack of accessible funding deters many potential investors, slowing the rollout of EV charging infrastructure across the country. Moreover, the current financing options available for EV infrastructure are seen as inadequate by many stakeholders. Banks and financial institutions often view EV infrastructure projects as high-risk investments, given the relatively low number of electric vehicles on Malaysian roads and the uncertainty around the future growth of the market. One financial analyst shared, *"Without more government backing or guarantees, it's difficult for banks to justify providing low-interest loans for these projects. They still see too much risk in the EV sector."*

Several interviewees suggested the establishment of a revolving fund to address this issue. This fund could provide low-interest loans or financial incentives specifically targeted at renewable energy and EV infrastructure projects. One government official noted, *"If the government could create a dedicated financial mechanism to support energy-efficient infrastructure, we'd likely see more private sector involvement in EV charging stations."* This fund would reduce the financial burden on developers and provide the necessary capital to spur investment in the sector. In addition to direct financing, interviewees highlighted the need for broader government incentives to support EV infrastructure development. Many pointed out that while incentives such as tax breaks or subsidies are available in other sectors, the EV charging infrastructure sector has yet to receive the same level of support. A project manager explained, "*The government needs to provide more targeted incentives for EV infrastructure if we're going to see real progress in this space."*

In summary, the financial barriers to EV charging station development in Malaysia are significant, with high upfront costs and limited access to affordable financing being the key challenges. The introduction of a revolving fund, coupled with government incentives and efforts to mobilize private–sector financing, would help overcome these obstacles and accelerate the deployment of EV infrastructure. By addressing these financial hurdles, Malaysia could encourage greater private sector participation and meet its renewable energy and transportation goals more effectively.

Public Awareness and Acceptance

In addition to regulatory and financial challenges, public awareness and acceptance of electric vehicles (EVs) and their associated infrastructure have emerged as significant barriers to the widespread adoption of EV charging stations in Malaysia. Although the government is actively promoting the transition to renewable energy, there remains a general lack of public understanding regarding the benefits of electric vehicles, which hinders the expansion of charging infrastructure.

Interviews revealed that low public awareness about the availability and benefits of EV charging stations is a key factor slowing the adoption of electric vehicles. A municipal officer remarked, *"Most people are still unaware of where charging stations are located or how they work. There is a lot of skepticism about whether EVs are practical in Malaysia, especially when it comes to long-distance travel."* This skepticism has made potential EV buyers hesitant to make the switch from traditional vehicles, limiting the demand for charging infrastructure. Moreover, many respondents pointed to a general lack of trust in the reliability of EV infrastructure. A project developer stated, "*People worry about being stranded if there aren't enough charging stations available, and this 'range anxiety' is a major deterrent."* This concern is compounded by the perception that EVs are only suitable for urban areas with more readily available charging stations, while rural regions remain underserved. As a result, the demand for EVs remains concentrated in major cities, reducing the incentive for developers to invest in charging stations nationwide.

Another key issue highlighted in the interviews was the public's limited understanding of the long- term financial and environmental benefits of adopting electric vehicles. Many consumers view EVs as expensive compared to traditional gasoline-powered vehicles, and the potential cost savings from reduced fuel and maintenance costs are not widely recognized. A financial analyst pointed out, *"There needs to be more education about how owning an EV can save money in the long run, especially as fuel prices rise and maintenance costs decrease."* To address these challenges, interviewees stressed the need for comprehensive public education campaigns that would promote the benefits of EVs and the growing availability of charging infrastructure. A government official suggested, *"We need a coordinated effort to raise awareness, not just about the environmental benefits but also the cost savings and convenience of using EVs."* These campaigns should focus on reducing public scepticism and educating consumers about the reliability and practicality of EVs, particularly in relation to the expanding charging network. In addition, incentive programs such as subsidies for EV purchases, reduced road taxes for electric vehicles, or tax breaks for individuals and businesses installing EV chargers could also play a crucial role in promoting public acceptance. Finally, interviewees emphasized the importance of collaboration between government and private sector stakeholders to improve the visibility and accessibility of charging stations.

Partnerships with shopping malls, gas stations, and other high-traffic areas could help increase the presence of charging infrastructure, making it more convenient for potential EV buyers to access charging points.

Case Study 2: Rooftop Solar Installations

Regulatory Challenges in Renewable Energy Implementation

The development and deployment of rooftop solar installations in Malaysia face considerable regulatory and policy challenges, particularly concerning the procedures for grid connectivity and approval processes. Although the government has introduced policies like the Net Energy Metering (NEM) scheme to encourage solar adoption, many potential users face obstacles that discourage widespread implementation. One of the main regulatory challenges highlighted during the interviews is the complexity of connecting residential solar systems to the national grid. Several project developers and homeowners expressed frustration with the lack of clarity regarding the procedures for grid connectivity. A project manager explained, *"The grid connection process is not straightforward, and it involves dealing with multiple agencies. The guidelines are often ambiguous, which delays the entire installation process."* These challenges create uncertainty for potential adopters, making them hesitant to invest in rooftop solar systems.

In addition, lengthy approval processes for solar installations continue to be a significant barrier. Homeowners and businesses seeking to install solar panels must navigate a bureaucratic approval process that often involves multiple layers of government regulation. A homeowner who considered installing a solar system shared, *"I thought it would be a simple process, but I had to get approvals from different agencies, and it took much longer than expected."* This regulatory bottleneck has deterred many from pursuing rooftop solar installations, as the extended timelines increase costs and reduce the attractiveness of solar energy investments. Another issue is the lack of harmonization in regulations across different states and local authorities, which adds complexity to the solar installation process. Depending on the region, requirements for obtaining permits and connecting to the grid can vary, leading to inconsistent outcomes. A solar energy consultant remarked, "*What works in one state might not be accepted in another, and this lack of consistency makes it harder for companies to scale their operations."* These regional differences in regulatory frameworks create confusion for both solar developers and end-users, further slowing the adoption of solar energy.

Additionally, while the NEM scheme provides an opportunity for homeowners to offset their energy consumption by selling excess solar energy back to the grid, many consumers remain unaware of how the scheme works or how to participate. A government official stated, *"The NEM scheme is a good initiative, but the communication around it has not been sufficient. Many people do not know they can benefit from it, or they do not understand how it works."* This lack of public understanding limits the scheme's potential to drive broader adoption of rooftop solar energy.

Financial Barriers

The deployment of rooftop solar installations in Malaysia is also hindered by significant financial challenges, particularly regarding the high upfront costs and limited access to affordable financing options. Even though solar energy can result in long-term savings, the initial investment required for purchasing and installing solar panels remains a major barrier for many homeowners. A project developer explained, *"The initial cost is one of the biggest hurdles. Many homeowners see the long- term benefits, but the upfront investment is too steep for them to move forward."* While the government has introduced initiatives such as the Net Energy Metering (NEM) scheme to incentivize solar adoption, these financial incentives have not been enough to overcome the cost barrier for most residential users. Homeowners and small businesses often face difficulties in securing low-interest loans or financing options tailored to renewable energy projects. One homeowner expressed, *"I wanted to install solar panels, but when I went to the bank for a loan, they were not very familiar with financing for solar projects. It was hard to find a good option."*

Interviewees noted that many financial institutions in Malaysia still view solar energy projects as high-risk investments, given the relatively slow pace of adoption and the uncertain payback period. A financial analyst mentioned, *"The banks are still cautious. They do not see solar as a proven investment yet, especially for residential projects, which makes it harder for individuals to get favourable loan terms."* This lack of accessible financing options continues to deter widespread adoption, even among those who are interested in transitioning to renewable energy. To address this issue, several stakeholders recommended the introduction of government-backed loan programs, or a revolving fund specifically designed to support solar energy projects. Such a fund would provide low-interest loans or subsidized financing to make solar installations more affordable for homeowners. One government official suggested, *"If we had more targeted financial support, like low-interest loans for solar projects, I believe we would see a significant increase in adoption rates."* Additionally, simplifying access to financing through clearer guidelines and support from banks could help make solar energy more accessible to a broader segment of the population.

Public Awareness and Acceptance

Public awareness and education play a crucial role in the adoption of rooftop solar installations in Malaysia. Despite government efforts to promote solar energy through initiatives such NEM scheme, many homeowners remain unaware of the benefits and opportunities available to them. A significant challenge in driving solar adoption is the lack of comprehensive information about how these systems work, the financial incentives available, and the long-term savings they offer. This lack of understanding is compounded by the technical complexity of solar energy systems and the misconception that solar panels are only suitable for large-scale, industrial projects. One government official remarked, *"Many people still think solar is for big companies or factories. They do not realize how beneficial it can be for residential use, especially with the incentives the government provides."* As a result, homeowners are often hesitant to explore solar as an option for their energy needs.

Additionally, the benefits of the NEM scheme are not well understood by the public. The scheme allows homeowners to sell excess energy back to the grid, effectively reducing their electricity bills. However, many homeowners are unaware of how the scheme operates or how to participate. The interviews also highlighted the importance of clear and accessible information about solar energy, especially regarding the financial aspects. While solar installations require a significant upfront investment, the long-term cost savings can be substantial. Yet, this message has not been effectively communicated to potential users. A solar project developer noted, *"We need more education around the financial benefits of solar. Homeowners need to see that while the upfront costs are high, the savings over time, combined with the incentives, make it a worthwhile investment."*

To address these gaps, interviewees emphasized the need for public education campaigns and outreach programs that explain the technical, financial, and environmental benefits of solar energy. These campaigns should focus on simplifying the process of adopting solar energy, highlighting the ease of installation, the incentives available, and the potential for long-term savings. One energy consultant suggested, *"There should be a more coordinated effort to educate the public, both online and in communities, about how simple it can be to install solar panels and how they can benefit from it."* Furthermore, stakeholders recommended that the government and solar energy providers collaborate to provide hands-on demonstrations and workshops to increase awareness and build confidence in the technology. By showcasing successful residential solar projects and offering practical advice on how to participate in the NEM scheme, these efforts could significantly increase public interest and trust in solar energy solutions.

Case Study 3: Smart Street Lighting Systems

Technological and Grid Integration Challenges

Since smart street lighting systems rely on the existing power grid, Tenaga Nasional Berhad (TNB) plays a crucial role in their implementation. However, navigating the regulatory relationship with TNB presents its own set of challenges. TNB's approval process for connecting smart systems to the grid is often slow, with high associated costs. These delays and financial burdens have become a key obstacle for municipalities looking to implement smart street lighting. One project developer shared, *"Working with TNB is difficult because their approval process takes too long, and the fees they charge for grid connections are quite high. This discourages smaller municipalities from even attempting to adopt smart street lighting."* Additionally, there are no clear frameworks for the integration of smart grids with smart street lighting, which has led to confusion about how energy consumption data will be managed and utilized. Smart street lighting systems are designed to communicate with the grid, allowing real- time adjustments based on energy demand and usage. However, without proper regulatory support, these technologies cannot be fully integrated into the existing infrastructure, limiting their effectiveness.

Many local governments face challenges in adopting smart street lighting due to limited technical expertise and capacity to manage complex energy systems. The implementation of smart street lighting requires a deep understanding of both the technology and the regulatory requirements surrounding it. However, most municipalities do not have the necessary resources to navigate the regulatory complexities or manage the technical aspects of smart lighting projects. A municipal officer remarked, *"We simply don't have the expertise or manpower to manage these smart systems. It's a new technology, and we're still trying to figure out how to operate it within the current regulations."* Without capacity- building programs or guidance from higher levels of government, many municipalities are hesitant to invest in smart street lighting systems, fearing that they will not be able to meet regulatory requirements or maintain the systems effectively in the long term. To overcome these regulatory challenges, it is essential to standardize regulations across municipalities would ensure a more consistent approach to smart lighting projects, reducing uncertainty for developers and investors. Clear standards should be developed to guide the integration of smart street lighting with the power grid, addressing the technical and operational challenges posed by the existing infrastructure. Finally, building local government capacity through training programs and technical support is crucial. Municipalities must be equipped with the necessary skills and knowledge to manage smart street lighting systems, ensuring they can meet regulatory requirements and maintain the technology effectively.

Financial Barriers

The initial capital costs for smart street lighting systems are considerably higher than traditional lighting systems, as they involve the purchase of energy-efficient LED lights, sensors, communication systems, and energy management software. These systems also require specialized installation and integration with existing infrastructure, adding to the overall project cost. A municipal officer explained, "The upfront costs for smart street lighting are huge, and although we know there are long-term savings, it's hard to justify the investment when we have immediate budget constraints." This financial challenge is particularly pronounced in smaller municipalities or rural areas where budgets are already stretched thin, and the potential for large-scale implementation is limited. Furthermore, many local governments struggle to secure adequate funding for smart street lighting projects due to limited access to affordable financing options. Banks and financial institutions often perceive smart city technologies, including smart lighting, as high-risk investments due to their relatively new and unproven nature in the Malaysian context. A financial analyst noted, *"While smart street lighting has a lot of potential, the technology is still seen as a risky investment by banks, especially in municipalities with smaller tax bases. This makes it difficult for local governments to secure the loans they need."*

Although there are government programs aimed at supporting energy-efficient projects, many municipalities are unaware of these programs or find the application process too complicated to navigate. Additionally, government subsidies and financial incentives for smart street lighting are currently limited, leaving municipalities to bear most of the financial burden. A project manager stated, *"We need more financial support from the federal or state governments. Right now, the financial incentives are not enough to make smart street lighting a viable option for many local governments."*

Interviewees emphasized that without affordable financing options or government grants, the initial cost of smart street lighting is a major deterrent for local governments, even though these systems offer significant energy savings over time. While the long-term financial benefits are well understood, the inability to overcome the high upfront costs prevents many municipalities from adopting this technology.

To address these financial barriers, stakeholders recommend for expanded government incentives and subsidies that would make smart street lighting systems more accessible to local governments. These incentives could include tax breaks, grants, or co-funding arrangements that reduce the financial burden on municipalities. One municipal officer remarked, "*If the government could provide more subsidies or co-fund these projects, it would make a big difference. The long-term benefits are clear, but we need help to get over that initial hurdle."* In conclusion, the financial barriers to implementing smart street lighting systems in Malaysia are significant, with high upfront costs and limited access to affordable financing being the key challenges. By introducing dedicated financing mechanisms, such as revolving funds and low-interest loans, and expanding government incentives, the financial challenges could be alleviated, allowing more municipalities to invest in smart street lighting. This would not only lead to greater energy savings but also contribute to Malaysia's broader sustainability goals.

Recommendations for Overcoming These Barriers

Streamlining Regulatory Processes

A critical issue across all three case studies is the fragmented and complex regulatory framework that creates delays and confusion for project developers and local authorities. To overcome this, it is recommended that the Malaysian government to establish a centralized regulatory body responsible for overseeing renewable energy and smart infrastructure projects. This body would coordinate approvals across local, state, and federal agencies, standardizing regulations and reducing bureaucratic bottlenecks. Additionally, a simplified and uniform approval process for renewable energy projects should be implemented across all states and districts. This would ensure that project developers can operate with greater clarity and predictability, accelerating the deployment of EV charging stations, rooftop solar installations, and smart street lighting systems. A centralized authority would also promote consistency, making it easier for both local and foreign investors to navigate the regulatory landscape.

Expanding Financial Support Mechanisms

The high upfront costs and limited access to affordable financing were identified as major barriers in each of the case studies. To alleviate these financial constraints, the government should introduce dedicated financing mechanisms tailored to renewable energy and smart infrastructure projects. Establishing a revolving fund or offering low-interest loans specifically for EV infrastructure, rooftop solar, and smart lighting systems would reduce the financial burden on both municipalities and private developers, encouraging more widespread adoption. In addition to dedicated financing, the government should consider expanding its existing financial support through incentives and subsidies. These could include tax breaks, direct grants, or co-funding arrangements that help offset the high initial investment required for renewable energy projects. By providing clearer and more substantial financial incentives, the government can encourage more local authorities, businesses, and homeowners to invest in sustainable energy solutions.

Raising Public Awareness and Education

The lack of public awareness and understanding regarding renewable energy technologies remains a significant barrier to adoption. To address this, a comprehensive public education campaign should be launched to increase awareness of the financial, environmental, and practical benefits of EV charging infrastructure, rooftop solar installations, and smart street lighting systems. These campaigns should focus on simplifying complex technical and financial information, making it more accessible to the general public. Highlighting the long-term cost savings and environmental advantages of these technologies, alongside available government incentives, would help dispel misconceptions and encourage wider participation. Engaging in community outreach and offering hands-on demonstrations of the technologies in action would further build public confidence and acceptance.

Building Technical Capacity and Expertise

Many municipalities lack the technical expertise and capacity required to manage renewable energy and smart infrastructure projects effectively. To address this issue, the government should invest in capacity-building programs that provide local governments and stakeholders with the skills and knowledge necessary to implement and maintain these technologies. Training programs, workshops, and partnerships with the private sector could equip local officials and project managers with the technical skills needed to operate and manage EV charging stations, rooftop solar installations, and smart street lighting systems. Strengthening local capacity will ensure that these technologies are not only implemented successfully but also maintained and operated efficiently over the long term.

By addressing the regulatory, financial, and public awareness barriers identified in the case studies of EV charging stations, rooftop solar installations, and smart street lighting systems, Malaysia can create a more conducive environment for the widespread adoption of renewable energy and energy- efficient technologies. Implementing these recommendations streamlining regulatory processes, expanding financial support, raising public awareness, building technical capacity, and enhancing private sector participation will be critical to achieving the country's renewable energy goals and promoting a sustainable energy future.

CONCLUSION

This study examined the regulatory, financial, and public awareness challenges faced by Malaysia's renewable energy sector, with a specific focus on the deployment of EV charging stations, rooftop solar installations, and smart street lighting systems. Through the analysis of these three case studies, several key insights have emerged that highlight the critical barriers hindering the country's transition toward renewable energy and energy-efficient infrastructure. The regulatory framework for renewable energy implementation remains fragmented and complex, contributing to project delays and increased costs. Streamlining these processes by establishing a centralized regulatory authority and standardizing approval procedures across local, state, and federal agencies will be essential to removing these obstacles and accelerating project deployment. From a financial perspective, the high upfront costs and limited access to affordable financing have posed significant challenges to developers, local governments, and consumers. Establishing dedicated financing mechanisms, such as revolving funds or low-interest loans, will help ease the financial burden and encourage greater private-sector involvement. Expanding government incentives, such as tax breaks and grants, is also necessary to make these projects more attractive and feasible. In terms of public awareness and acceptance, there is still a significant gap in understanding the benefits of renewable energy technologies among the general public. Comprehensive education campaigns are needed to raise awareness about the long-term savings, environmental benefits, and government incentives available for adopting these technologies. By simplifying complex information and engaging directly with communities, the government and private sector can foster greater public trust and participation. Finally, building technical capacity within local governments is crucial for the successful implementation and maintenance of renewable energy systems. Investing in training programs and technical support will equip municipalities with the expertise needed to operate and manage these technologies effectively. In conclusion, addressing the regulatory, financial, and public awareness barriers identified in this study is crucial for advancing Malaysia's renewable energy goals. By implementing these recommended solutions, Malaysia can position itself as a regional leader in renewable energy and attract significant foreign direct investment to drive sustainable development and long-term energy security.

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FIRE SAFETY EVACUATION FOR PERSON WITH DISABILITIES: A CASE STUDY AT WORKPLACE IN SUPER HIGH-RISE OFFICE BUILDING IN MALAYSIA

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Abstract
Building evacuation during fire becomes a big challenge when it concerns people with disabilities. To date, person with disabilities (PWDs) are still being discriminated against in either education, employment, or even undergoing their daily routine as normal people. The risk of injuries and fatalities among PWDs is high. Therefore, this study is performed mainly to identify the needs of disabled people and how occupants with disabilities at workplace responded during a fire evacuation. The analysis contains a single case study of super high-rise office building and indicators are created by distributions of questionnaires, observation of evacuation drills, and semi-structured interviews. A total of 218 questionnaires were analysed using Statistical Package for the Social Science (SPSS) statistic and presented in a form of three sections. Seven parameters highlighted the experience and knowledge of respondents on fire evacuation with still very low awareness among respondents. Based on the results, evacuation by the PWDs took significantly longer to complete in comparison to able-bodied evacuees due to lack of awareness by building management, building owners, lack of regular reviews by certified parties, lack of technology involvement, and lack of safety culture among the society and communities. Recommendations in improving the process of evacuating PWDs are highlighted. Developing a personalized evacuation plan i.e. personal emergency evacuation plan for the PWDs can be one initiative to be taken up by the Management for an improvement towards a better quality of life (QoL) particularly in regard to their well-being at the workplace.

Keywords: *business continuity management; evacuation; fire risk assessment, high-rise office building; person with disabilities*

INTRODUCTION

To date, person with disabilities (PWDs) is still being discriminated against in either education, employment, or even undergoing their daily routine as normal people (Groce, 2004). They were denied having privileges like others. It is found that people with disabilities are among the poorest people in the world (Pinilla-Roncancio, 2018; Yeo, 2005). To help the PWDs undergoing normal life and get the same rights as others, a National Disability Council is established to ensure that PWDs were not discriminated against in employment. They were given the same opportunity to choose the job that fits their education level. However, the problem that was faced by these people is the facilities that were provided at their workplaces could not cater to their needs (Purdie, 2009).

Since 1993, persons with disabilities (PWDs) were given great concern (attention) and their behavior and capabilities during fire evacuation are studied. A report published by Shields (1993) mentioned that much work still needs to be done on the knowledge sharing and references for designers and engineers regarding PWDs and fire in buildings. Then, much of the early work only focused on wheelchair users' challenges concerning building evacuation (Shimada & Naoi, 2006; Tsuchiya, Hasemi, & Furukawa, 2007). Studies on PWDs are still lacking and have only focused on an individual's ability. In general, for greater understanding of the impact, there should not only focuses on an individual's disability but should also consider differences on physical, physiological and medical conditions. To date, there are still lack of studies concerning the impact of fire evacuation and the need to adopt accessibility during multilevel evacuation is to be considered especially in high-rise building (Agyemang & Kinateder, 2021; Bahrami, Etessam, & Shahcheragi, 2021; Bukvic et al., 2021).

In Malaysia, a person with disabilities (PWDs) is protected by regulation. According to the Malaysian Disabilities Act (2008), the definition of PWDs are those who have a long-term physical, mental, intellectual, or sensory impairment, which in interaction with various barriers may hinder their full and effective participation in society. As part of the community and legal citizens, PWDs have the rights to enjoy all the existing facilities and participate in all aspects of national developments including employment. Lack of understanding about PWDs, such as stereotyping and obstacles at workplace are often the challenges faced by these people (T. Ta & Khoo, 2013). The Malaysian Disability Strategy has shown some development in terms of universal design in built environment to cater for PWDs to promote universal accessibility. According to Bashiti and Abdul Rahim (2016), accessibility in the building is an issue relevant to Malaysia. The provision of facilities in buildings is important for the person with disabilities to help improve their quality of life (QoL).

Apart from the design of the building, human behaviour surrounding the workplace has also been an issue. This may have less to do with limitations arising from the person with disabilities (PWDs) themselves as it was assumed that person with disabilities is less capable and lack of productivity (Colin Barnes & Geof Mercer, 2005; Colin Barnes & Geoffrey Mercer, 2005). Minegishi (2021) mentioned that in the event of fire in a high-rise office building, problems related to difficulties owing to long-distance with few staircases, long evacuation times, and the congestion of evacuees. These problems arise from the PWDs' evacuation to the ground by staircases, which is not necessarily realistic and the difficulty of participating in vertical evacuation has also increased. Studies by Bendel and Klüpfel (2011) through simulation on occupants including disabled people were not generalized due to little empirical data and evidence. PWDs required appropriate evacuation strategies and purposes as mentioned by some studies (Bashiti & Abdul Rahim, 2016; Koo, Kim, Kim, & Christensen, 2013; Pinilla-Roncancio, 2018).

Not much research is being studied on the experiences of person with disabilities at the workplace. To our best knowledge, there have been only a few studies on evacuation that explicitly considered people with disabilities in Malaysia. One of the recent studies conducted was completed in 2019 by Zahari, Che-Ani, Rashid, Tahir, and Amat (2019) who considered disabled people and senior citizens in their accessibility and evacuation in a railway station. In a country such as Malaysia, laws and regulations concerning building design are prescriptive in nature. However, there are arguments described that performance-based laws and regulations are better in allowing flexible alternative building evacuation to achieve the required benchmark (Jang, 2016; Zhang & Issa, 2015). This study aims at identifying the needs of disabled people and how it regards occupants with disabilities in the workplace during a fire evacuation. This work adopted a case study approach of an evacuation drill at the second tower of a super-high rise building in Kuala Lumpur.

LITERATURE REVIEW

Often, people all over the world have raised issues in the discrimination or bias towards people with disability. Commonly, the disabled people would be known as ‘handicapped person’, or ‘person with disabilities’ or physically and/or mentally challenged person’. The phrase disability refers to a multidimensional occurrence (from what) that has evolved from people and surroundings (Organization, 2016). Every country has a different legislative approach in defining, determining, and considering disability. According to Malaysian Act 685 (2008) – Person With Disabilities Act defines a person with disabilities includes those who have long-term physical, mental, intellectual, or sensory impairments which in interaction with various barriers may hinder their full and effective participation in society. Meanwhile, the American with Disabilities Act (1990), defines the terms disability, concerning an individual (A) a physical or mental impairment that substantially limits one or more major life activities of such individual; (B) a record of such impairment; or (C) being regarded as having such an impairment. The United Kingdom through the Disability Discrimination Act (1995) in section 1 of the Act defines ‘disability’ as a physical or mental impairment that has a substantial and long-term adverse effect on his ability to carry out normal day-to-day activities.

The person with disabilities (PWDs) can be categorized into six (6) main categories which are visually impaired, hearing impaired, physically impaired, learning disabilities, speech disabilities, and mental disabilities. According to Table 1, PWDs registration issued by the Department of Social Welfare has increased each year. From year 2016 to 2019, the statistic shows an upward trend in number of PWDs registered from 409,269 to 548,195 (Jabatan Kebajikan Masyarakat, 2019). As any other developing countries, issues regarding PWDs in Malaysia has received less attention by community, especially in the public acceptance (Aizan & Jamiah, 2015). Studies of PWDs in Malaysia have shown that negative people and environment are the major social factors that inhibited full participation of PWDs in regard to accessibility support facilities (Hashim et al., 2012; Kamarudin, Hashim, Mahmood, Ariff, & Ismail, 2012; Maidin, 2012). As stated in laws, regulations, and guidelines implemented in Malaysia, the rights of PWDs in the accessibility of facilities and services can promote participation and perception of PWDs into society without any barriers.

Table 1. Registration of PWDs by A Different Type of Disability

Type of Disabilities	Year (Person with Disabilities)			
	2016	2017	2018	2019
Visually Impaired	36,834	40,339	36,309	48,645
Hearing Impaired	33,560	34,447	44,765	38,676
Physical Impaired	140,151	159,546	179,060	197,414
Learning Disabilities	143,244	157,733	170,107	189,698
Speech Disabilities	4,323	2,270	2,499	2,812
Mental	31,922	37,620	41,283	45,401
Other	19,235	21,303	23,377	25,549
Total	409,269	453,258	497,390	548,195

In some studies, person with disabilities (PWDs) are often being prejudiced and misconceptions are prevalent among the public due to their lack of ability or disabilities in conducting work (Jayasooria, Krishnan, & Ooi, 1997; Narayanan, 2018; T. L. Ta & Leng, 2013). However, not all PWDs were stereotyped, especially in the employment sector. To ensure broad opportunities for PWDs, the Malaysian Government has issued an enactment to allow and offer at least one percent (1%) policy for public sectors to PWDs (Human Resources Development Fund, 2019). From 1990 to 2018, there are about 14,252 PWDs out of 13.74 million workforces that have been employed in the private sector. Hence, this shows a growing awareness for a safe and healthy environment at the workplace. In the context of providing a safe and healthy conditions at the workplace, accessibility is an important element in the everyday life of PWDs, especially when dealing with movements either from the inside or outside of the building (Arenghi, Camodeca, & Almici, 2021; binti Jusoh & bin Omar, 2018; Hendrarso, 2021; Peterson, 2021).

The demand for provision of facilities either inside or outside of the building for person with disabilities (PWDs) are emphasized in legislation, regulations, and guideline. The implementation of Malaysian Standard 1184 (2014): Person with Disabilities Act 2008 by local authority provides a guideline to plan and cater to the needs of disabled person to be utilized in fire safety while in the building. This should cater to all requirements needed by PWDs for comfort and safety which required the building to be designed with response requirements such as functional, user, performance, and statutory requirement (Watt, 2009). However, the implementation of this practice into the built environment seems to have raised problems among PWDs. This was because the access and services do not cater to the needs of the PWDs (Soltani, Abbas, & Awang, 2012). Zahari et al. (2019) mentioned that financial resources as the greatest challenge in providing facilities and services needed by PWDs. Thus, PWDs experienced difficulty to carry out activities due to ~~a~~ lack of physical access. To ensure the safety and comfort of PWDs, it is a must to provide efficient and excellent facilities outside and inside of the building.

METHODS OF DATA COLLECTION AND ANALYSIS

Data Collection Procedure

A case study building chosen for this analysis was the second tower of a super high-rise building in Kuala Lumpur. The height of the building is 451.9 meters, with 88 floors and additional five basement floors. A case study was considered as an appropriate approach as the study required a real scenario-based study on the evacuation process in identifying the person with disabilities (PWDs)s' needs when evacuating the building. The tower was selected based on the access granted and is the tallest building in the country at the time of this work was carried out. The research scope comprises of a real scenario-based study on the evacuation process. The evacuation drill was performed with the help from nearest fire stations. The building consists of two towers linked with a double-decker sky bridge on the 41st and 42nd floors. The sky bridge is a building element that plays an important role in case of any emergency where the occupants need to evacuate one of the two towers. The site observation during the evacuation drill was conducted throughout the drill exercise. The observation through video recording at the exit door which involved three (3) cameras was conducted to study the behaviors of participants during the evacuation process. In this drill, fire breaks at level 66. In the study, building occupants at the second tower were selected.

Once the tenants of the building safely arrived at the assembly point, the questionnaires were distributed to the PWDs and able-bodied occupants to explore the situation during evacuation especially during pre-movement in depth.

Instruments

The questionnaires were distributed randomly at the evacuation event targeted to person with disabilities (PWDs) employees and able-bodied employees in the second tower of a super high-rise building in Kuala Lumpur. About 300 questionnaires were distributed and 218 questionnaires were returned back. The questionnaire contains three (3) sections with 19 questions to explore the experiences of the evacuees during evacuation especially during the pre-movement in depth. In Section A – Demographic Section Analysis is about the demographic distribution of respondents. While Section B – is Experience and Knowledge of Respondents seeking to understand about the experience of evacuees either PWDs or able-bodied respondents and their knowledge about evacuation drill and fire safety. Section C – is about Problems and Suggestions for the Development of Evacuation Procedure for the Person with Disabilities (PWDs).

In addition to this, information was also gathered through expert's interviews during feedback sessions at the end of the evacuation exercise with one (1) officer-in-charge from the local fire and rescue service providing feedback and offering advice at improving the process of fire evacuation based on the drill that was just concluded. The interview has also been conducted with one (1) out of 14 persons with disabilities (PWDs) that were categorized as mobility impairment to obtain a clearer view and experience during the building evacuation process.

Data Analysis

All the data obtained from the questionnaires were collected and analysed by using Statistical Package for the Social Science (SPSS). The data were interpreted by using descriptive and inferential analysis. The data from Section A questionnaire which was on demographic information of respondents (gender, age, type of disabilities, working floor level, and type of evacuation medium) was analysed by using descriptive analysis in the form of frequency and percentage. As for data from Section B questionnaire in terms of experience and knowledge on fire evacuation (briefing, involvement, feeling, trust, factor that initiate evacuation, action, and routes taken) was also analysed by using descriptive analysis in the form of table and chart. Meanwhile, Section C questionnaire was about problems and suggestions, and there were analysed using the inferential analysis in a normal distribution to discover and make predictions from the data taken.

RESULTS

Section A: Demographic Information

From the surveys, 218 completed questionnaire responses were collected and reported. The demographic characteristics of the respondents of the questionnaire survey are summarized in Table 2.

A total of n = 218 respondents with 134 (61.5%) male and 84 (38.5%) female is included in the study. The age of the respondents according to the gender is analysed and found that the biggest number of respondents were between 25 – 34 years old (102 respondents), followed by 35 – 44 years old (53 respondents), 18 – 24 years old (38 respondents), 45 – 54 years old (17 respondents) and the least 55 – 64 years old (8 respondents). Most of the respondents are within the age of 25 to 34 years and can be considered matured and well thought-out.

In Table 2, the survey on the type of disability of respondents was identified. It can be divided into three categories such as mobility, hearing, and visual impairments. In all, 14 out of 218 respondents have disabilities with 11 respondents (5.0%) with mobility impairment, two (2) respondents (0.9%) with hearing impairment, and one (1) respondent (0.5%) with visual impairment. It is noted that they shared the same types of accessibility in the building. Based on the survey, there are a few specific causes of the impairment such as accidents, bone's fracture, and bone's problems.

Table 2. Characteristics of The Survey Respondents

Analysis	Items	Category	Frequency	Percentage (%)
Gender of Respondents	Gender	Male	134	61.5
		Female	84	38.5
Age of Respondents	Age	18 – 24	38	17.4
		25 – 34	102	46.8
		35 – 44	53	24.3
		45 – 54	17	7.8
		55 – 64	8	3.7
Disability of Respondents	Disabilities / Impairments	None	204	93.6
		Mobility	11	5.0
		Hearing	2	0.9
		Visual	1	0.5
Floor Level of Respondents' Working	Floor Level	<10	15	6.9
		11 – 20	37	17.0
		21 – 30	49	22.5
		31 – 40	14	6.4
		41 – 50	21	9.6
		51 – 60	11	5.0
		61 – 70	53	24.3
		71 – 80	12	5.5
		>81	6	2.8
Evacuation Medium of Respondents	Non-Disable Respondents	Stair	52	23.9
		Lift	83	38.1
		Both	69	31.7
	Mobility Impairment Respondents	Stair	0	0
		Lift	11	5.0
		Both	0	0
	Visual Impairment Respondents	Stair	1	0.5
		Lift	0	0
		Both	0	0
	Hearing Impairment Respondents	Stair	0	0
		Lift	2	0.9
		Both	0	0

Accessibility challenges were sorted into several levels of categories, defined and discussed below. It is found that most of the respondents were in floor level 61 – 70 with 24.3% followed by 22.5% in floor level 21 – 30, 17.0% in floor level 11 – 20, 9.6% in floor level 41 – 50, 6.9% in floor level less than 10, 6.4% in floor level 31 – 40, 5.5% in floor level 71 – 80, 5.0% in floor level 51 – 60 and 2.8% in floor level more than 81. Many of the respondents were working at a higher level. In the survey, it is found that PWDs were given equal rights in employment and positions because they were located on the higher floor level in the building. Therefore, it proved that PWDs were not discriminated against and were given the same treatment as able-bodied respondents. The person with mobility impairment were about 78.7% (11 respondents) followed by 7.1% with hearing impairment (1 respondent) and 14.2% person with visual impairment (2 respondents). There were three types of evacuation methods used; staircase, lift, or both. Based on the result, about 38.1% of the non-disabled respondents used lift to evacuate followed by 31.7% of the respondents that used both stairs and lift to evacuate and the rest with 23.9% of the respondents evacuated the building by using staircase. For the mobility and hearing impairments respondents, a total of 11 respondents (5.0%) and two (2) respondents (0.9%) respectively, used lift as a method of evacuation. One (1) out of 14 respondents with disabilities, (0.5%) used staircase as method of evacuation.

Section B: Experiences and Knowledges of the Respondents on Fire Evacuation

Briefing About Evacuation

One of the major concerns for this study is to identify if employees in the building had been given briefing or information either from the building administrators or safety managers regarding building evacuation especially in the event of a fire. Figure 1 showed the percentages of the responses briefed about building evacuation. Based on the survey, most of the respondents are likely to be more proactive and cooperative rather than reactive and competitive. There are about 14 persons with disabilities out of 218 respondents in the second tower of the super high-rise building. Able-bodied respondents recorded about 162 out of 218 have been briefed about the building evacuation with 74.3% and the rest of 42 respondents with a percentage of 19.3% showed that they have not been briefed about building evacuation information.

For person with disabilities, there are about 3 categories of disabilities reported. Mobility impairment respondents with five (5) respondents at a percentage of 2.3% reported that they had been briefed about building evacuation from the management. For visual and hearing impairment reported no data. Meanwhile, there are about six (6) mobility impairment respondents, one (1) visual impairment respondent, and two (2) hearing impairment respondents who were not briefed about building evacuation with the percentage of 2.8%, 0.4%, and 0.9%, respectively. Based on this information, it can be noted that respondents with disabilities did not get any briefing about building evacuation, and they may find it difficult to evacuate the building due to lack of knowledge and strategies about evacuation method.

The lack of briefing about building evacuation by building administrators or safety managers seems to be the main issue faced by the employees. Lack of responsibilities by building administrators or safety managers in this building can be seen towards able-bodied and disabled respondents. Respondents faced difficulty to evacuate the building due to unfamiliarity with the concept of evacuation, especially in a high-rise office building. Study by Rostami and Alaghmandan (2021) at school, briefing about the details and procedures of evacuation makes the student familiar with the building and evacuation procedures. Thus, contributing to the smooth process of building evacuation in any emergency event.

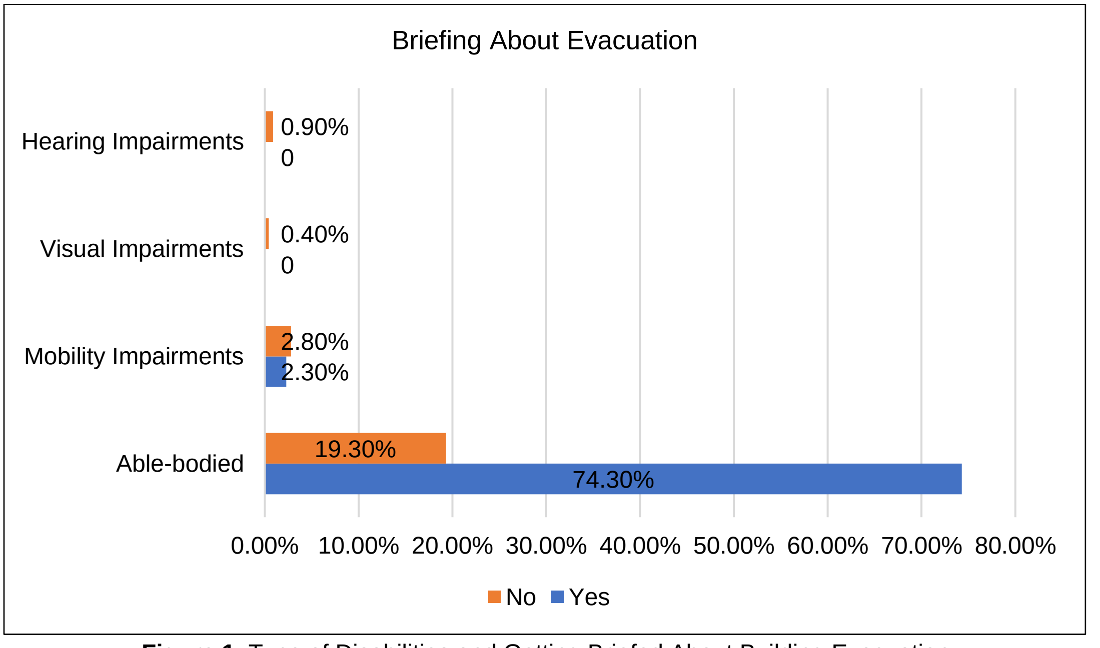

Figure 1. Type of Disabilities and Getting Briefed About Building Evacuation

Involvement in Any Emergency Evacuation Training and Education

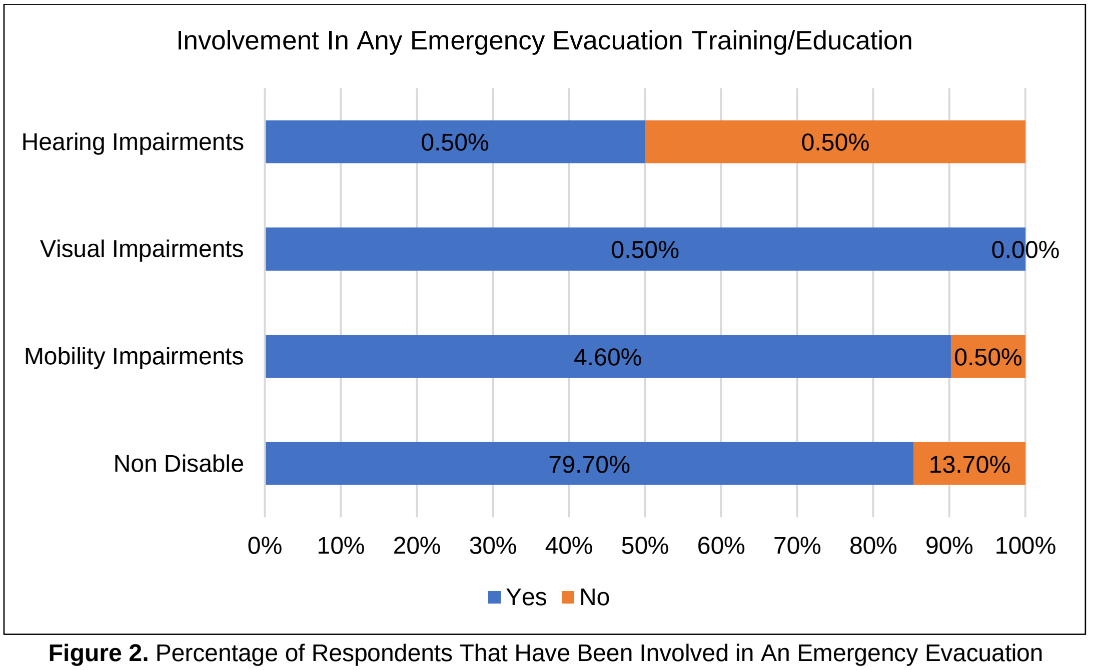

Figure 2. Percentage of Respondents That Have Been Involved in An Emergency Evacuation Training/Education Before

Figure 2 illustrated the result of respondents' involvement in any emergency evacuation training and education before. In general, past evacuation experience is an important predictor of evacuation behaviour. Based on this study, about 174 of able-bodied respondents had experiences in previous emergency evacuation training/education with a percentage of 79.7%, and 30 of able-bodied respondents with a percentage of 13.7% reported that none had been involved in any emergency evacuation training/education before. Out of the 14 PWDs responded to the questionnaire, 10 mobility impaired, one (1) visual impaired, and one (1) hearing impaired respondents had experienced some level of emergency training/education in the same building or other buildings that have worked in before with the percentage of 4.6%, 0.5%, and 0.5%, respectively. In the meantime, there are about 0.5% of PWDs respondents reported no prior emergency experience in any emergency evacuation training/education representing one mobility and one hearing impairment respondent.

Feeling When Hearing The Fire Alarm

The respondents' feeling when hearing the fire alarm in the event of an emergency was tabulated in Figure 3. Based on the study, the majority of respondents tend to feel calm and do not feel panic during evacuation purposes. Results showed that respondents feel calm when they hear an alarm (47.7%), followed by the feeling of mild stress (26.1%), not affected (17%), feeling fear and acting in fluster (4.6%) and feeling extremely fear (4.1%). Based on the study by Kangedal and Nilsson (2002), they mentioned people's behaviour in emergencies. In general, when people do not feel the danger, they tend to react slowly. There are two states of feeling; people either underestimate the capability of other individuals during an emergency or they may underestimate the likelihood of encountering an emergency as it is a rare event (Shiwakoti, Wang, Jiang, & Wang, 2019).

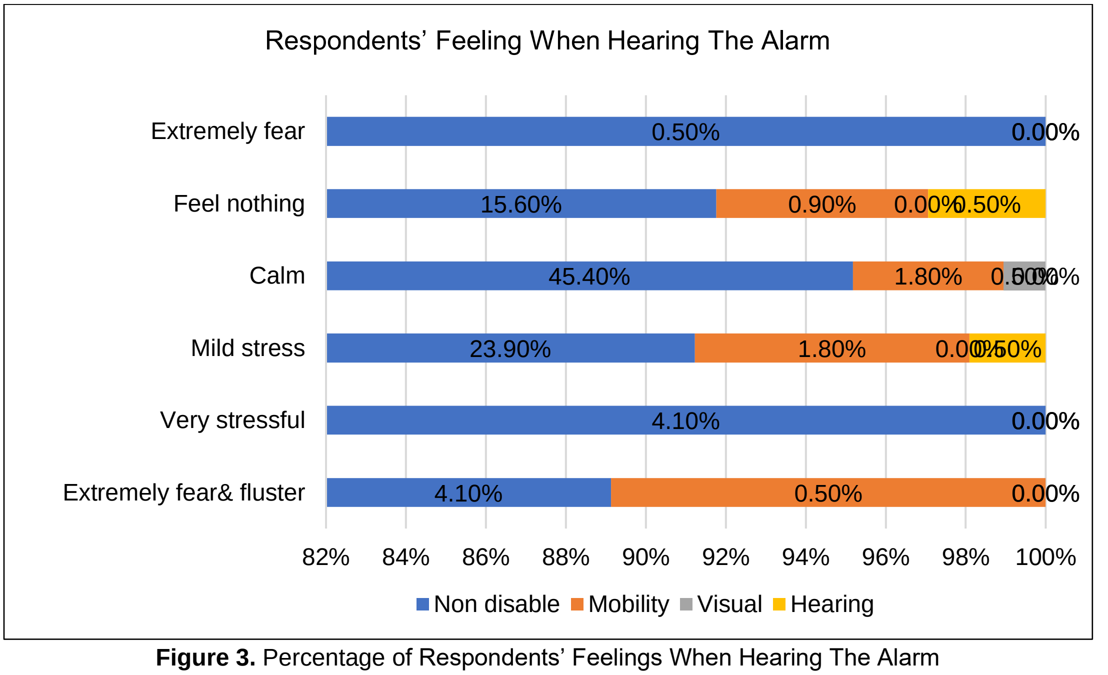

Figure 3. Percentage of Respondents' Feelings When Hearing The Alarm

Trust In Warning Messages/Alarm

Figure 4 illustrated the trust in warning messages/alarms among respondents. The trust in warning messages/alarms was categorized into six (6) scales. Based on the survey, the warning messages/alarm can be fully trusted without doubt (Yes – 8.7%, No – 7.3%), trusted (Yes – 17.0%, No – 30.3%), Neutral (Yes – 7.8%, No – 11.9%), doubting the situation (Yes – 6.0%, No – 9.6%), cannot be trusted at all (Yes – 0.5%, No – 0.5%) and not applicable (No – 0.5%).

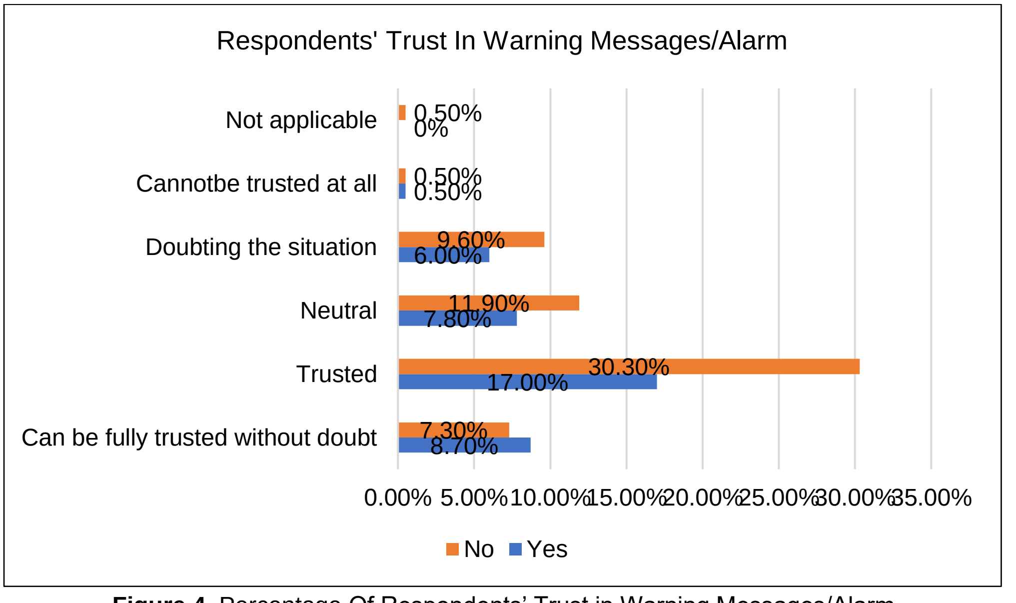

Figure 4. Percentage Of Respondents' Trust in Warning Messages/Alarm

Factors That Initiate Evacuation

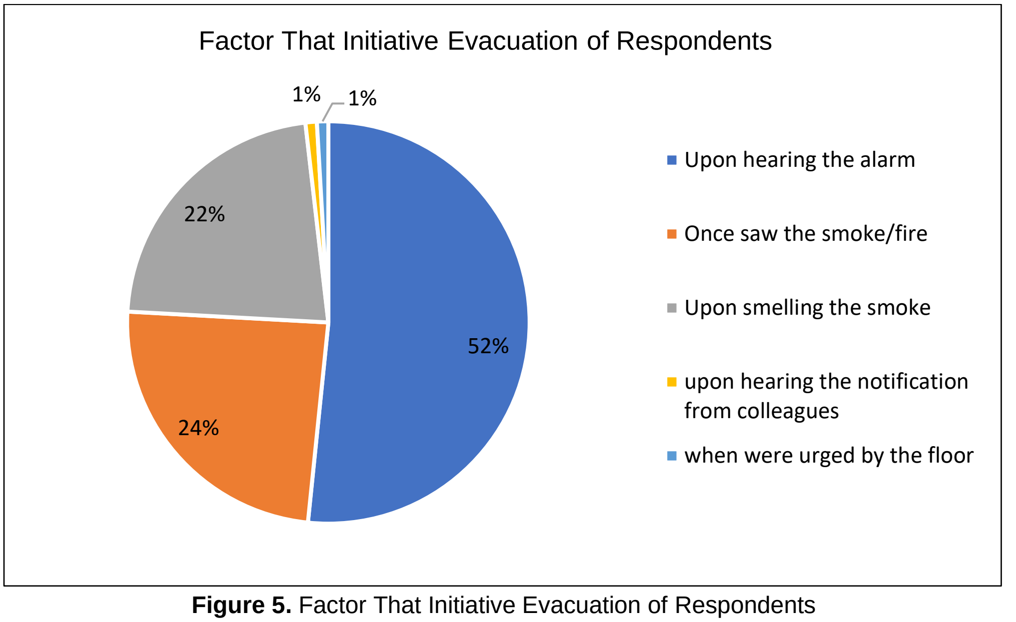

Figure 5. Factor That Initiative Evacuation of Respondents

Figure 5 presented factors that initiate the evacuation of respondents in the building. Several factors that initiated the evacuation of respondents in the building had been identified through works of literature. Based on the study, 52% of the respondents started to evacuate upon hearing the alarm, followed by 24% that started to evacuate once they saw smoke/fire, 22% of respondents evacuated the building upon smelling the smoke, and 1% each upon hearing the notification from colleagues and they were urged by the floor, respectively.

First Action Taken When Hearing The Fire Alarm

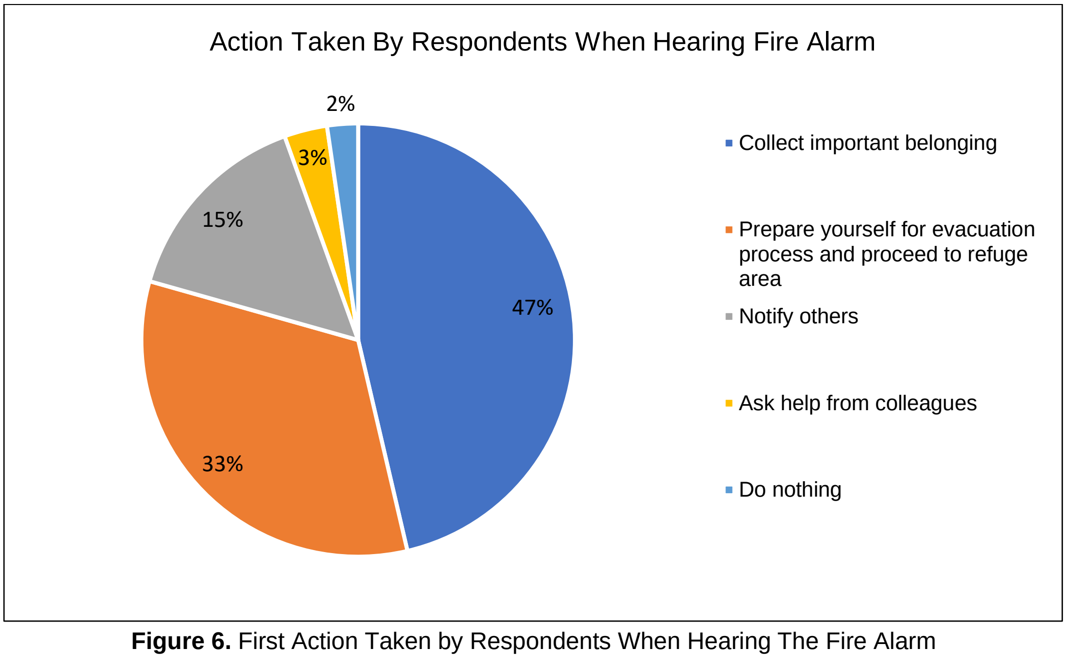

Figure 6. First Action Taken by Respondents When Hearing The Fire Alarm

Figure 6 shows the behaviour of respondents in their first action taken when hearing the fire alarm. The highest percentage of action taken by respondents once they heard fire alarm was collecting important belonging at 46.3%, followed by preparing themselves for evacuation process and proceed to refuge area/ meeting point with evacuation assistance (33.0%), notify other colleagues (15.1%), asking help from other colleagues for evacuation process (3.2%) and do nothing (2.3%).

Evacuation Routes Taken During The Evacuation

Figure 7 shows the evacuation routes taken by respondents during building evacuation. Based on the result, the majority of respondents reported that the evacuation routes were taken by following the instruction of the floor warden or fire warden with the percentage of 51.8%, followed by 33.5% of respondents reported that they followed the crowd, 10.1% of respondents were using emergency staircase as evacuation method and 4.1% of respondents had taken the lift to evacuate the building during an emergency event. This finding is consistent with studies on the unannounced evacuation of buildings by (Fahy & Proulx, 2001; Lovreglio, Kuligowski, Gwynne, & Boyce, 2019; Yoon, Lee, & Yee, 2013) which proved that direction guidance and help from the management staffs helped evacuee to exit the building. This in turn reduced the time taken to evacuate the building.

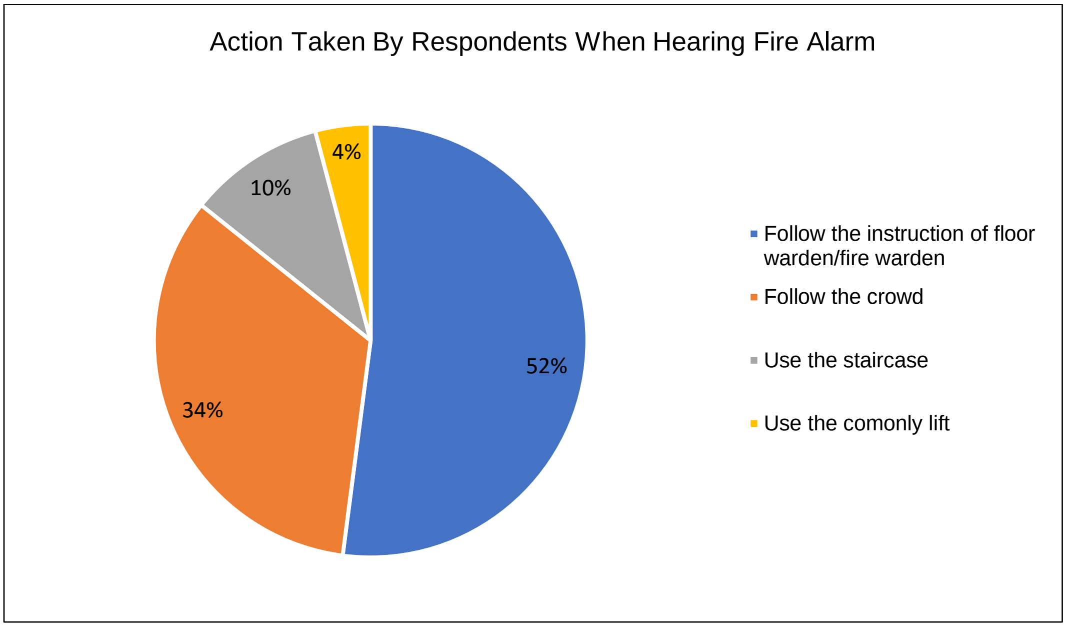

Figure 7. First Action Taken by Respondents When Hearing The Fire Alarm

Section C: Problems and Suggestions for the Development of Evacuation Procedure for The Person with Disabilities (PWDs)

Section C was answered by the person with disabilities (PWDs) only. The purpose of this section is to determine whether a person with different kinds of disabilities have different problems and thus required different measures. The problems reported from different groups of persons with disabilities are presented in Table 3.

Based on findings, a person with mobility impairment found that they tend to slow down the evacuation flow and other evacuees seemed to ignore them. Therefore, a person with mobility impairment could be in danger of being pushed over by people behind them. This was reported by six (6) out of 11 respondents with mobility impairment while evacuating from a building. The person with hearing impairment reported that no problem concerning moving along the escape route. However, due to hearing impairment, they cannot analyse the warning signal for evacuation. They look for warning signal for evacuation from other colleagues before moving out from the building. Respondents with visual impairment reported that orientation in the building is very important. The orientation at KLCC Tower was designed for ease of comprehension and ease to create a mental map of the building. Therefore, they were able to find the staircase easily to find a way out of the building. Also, the ability to move out of the building with help from colleagues. However, a person with visual impairment also reported that they experienced some difficulties in opening doors along the escape routes as it requires a two-hand grip to open the door. In terms of staircase design, they did not experience any difficulties since the staircase was designed according to the requirement with handrails located on the side of the steps and steps are wide.

There was a consensus amongst all person with disabilities (PWD) respondents relating to the problems emerging during evacuation. The respondents had different opinions relating to the accessibility and emergency evacuation safety for the person with activity limitations.

The respondents with disabilities are of the opinion that it is extremely important that person with limitation is being identified, recognized and given due consideration when devising emergency evacuation plan that would work for PWDs. Respondent with mobility impairments agreed that measures to improve the emergency evacuation safety for a person with mobility impairment were reasonable and be given priority. To enable a person with mobility impairment to evacuate on their own, the evacuation routes in the level differences should be designed especially for the person with wheelchairs as a medium of transport. This can be separated from the evacuation routes using fire-protected elevators/lifts as an alternative to compensate for level differences. Also, a person with mobility impairment felt safer staying on the wheelchair at all times compared to being lifted by a helper. They further acknowledged the presence of building staff or emergency response team member with them to help through the process. In some situation, person on a wheelchair must be lifted from the wheelchair to help them maneuver the evacuation route. The respondents also suggested that building staff or emergency response teams should be trained in lifting techniques to assist in an evacuation event.

The person with hearing impairment had trouble perceiving the alarm signal. Since evacuation in the building is using sound, they cannot analyse the sign of evacuation. Hence, they suggested that evacuation alarms and signals should be supplemented with the use of flashing lights together with low-frequency sound alarms to improve the evacuation purposes for a person with hearing impairments. There is one person with visual impairment who claimed that understanding a clear layout of a building and easy to understand the layout especially the route to the emergency staircase is a must to help them get away from danger. He also suggested that for a person with partial visual impairment, large evacuation signage or direction with a good contrast showing arrows on the floor and low- placed illuminated evacuation signage should be installed in the evacuation route. Such signage provides a good message to give clear direction to a person with visual impairment on how to get away from danger.

Table 3. Barriers and Suggestions Based on Different Disabilities

No	Type of Disabilities	Barriers	Suggestions
1	Mobility	• Pushed over by other evacuees	• Priority be given to PWDs • Different evacuation routes • Lifting by others
2	Hearing	• Cannot hear the alarm sound signal	• Flashing light • Low-frequency sound alarm
3	Visual	• Orientation in the building • Opening door to emergency staircase	• Large evacuation signage • Arrow on the floor • Illuminated signage

Interview

Interviewee A

The interview was done with an officer from the fire and rescue department who acted as an observer during the evacuation drill after the exercise was concluded. This was done during a post-mortem session with the presence of the observer team from the local fire and rescue department and the facilities management team of the building. Based on the interview session, it was established that a group of officers from the fire and rescue department was stationed at the assembly point, ground level, and level 42 (sky bridge). Based on the observation, persons with disabilities (PWDs) together with able-bodied respondents that were located at the level above 42 will go down to level 42 through a lift. The main reason that the respondents went to level 42 was to move to the first tower through the sky bridge. There were PWDs located at the lower level than 41 going up to level 42 by using lift to cross over the sky bridge to the first tower before proceeding to the assembly area which is located at the ground level. Based on the observation on able-bodied respondents, they proceeded to the assembly area by staircases if they are able to. However, some respondents used lift. For able-bodied respondents located at the level below 42, the majority of the respondents will evacuate through staircases in the second tower and proceed to the assembly area. Only a few respondents were detected using a lift to evacuate the building. During the evacuation drill, all the lifts in the second tower were still functioning. Table 4 shows the summary of interviews.

Table 4. Summary of The Interview

Interviewee	Location	Observation
A	Level Assembly Area, Ground Level, Level 42 (Sky Bridge)	Person with disabilities in the second tower located above level 42 would go down to level 42 through a lift. Then crossed the sky bridge to go to the first tower and evacuate through the lift to the ground level before proceeding to the assembly area. Non – disabled respondents in the second tower who were located above level 42 would evacuate through staircases and cross the sky bridge at level 42 before evacuating through a lift in the first tower. Some of the respondents located above 42 would continue to evacuate the building through staircases if they were able to. Non – disabled respondents at the second tower who were located below level 42 evacuated through staircases and proceeded to the assembly area. However, some respondents evacuated the building through a lift.
B	Level Assembly Area, Level 42 (Sky Bridge), Level 64	A respondent with mobility impairment who was located on level 64 of the second tower would go down to level 42 through a lift before crossing to the first tower. While waiting for the lift at the first tower, the condition became too crowded. As a PWDs, she did not receive any privilege or priority to enter the lift to proceed to the assembly area.

Interviewee B

Interviewee B who is a person with disabilities (PWDs) with mobility impairment participated in the drill and was located on level 64 of the second tower of the super high-rise building. Her actions, responses, and observations were summarized in Table 4. As noted, interviewee B had experiences in evacuation. In the early stages, she did seek information and confirmation from co-workers, but did not feel any urgency to evacuate. This happened because she was on a wheelchair and experienced some discomfort. However, as time passed with more urgency in activity, she sought for some help from a co-worker to move her wheelchair to the lift. At level 64, she and her co-worker took the lift to go down to level 42. When she transferred at level 42 to the first tower, condition was more crowded and merging flows were experienced. She explained that many able-bodied evacuees were waiting for the lift, and she did not get any privilege to use the lift in the first place even though she is a person with disabilities. However, with help from the emergency response team (ERT), she was able to be evacuated through a lift to ensure her safety during evacuation. As aforementioned, it was clear that interviewee B evacuated the building with difficulty and delay due to waiting for the lift. Clearly, other evacuees have deferred (denied) her privilege as a person with disabilities to use the lift first. She was very disappointed in getting out of the building as the other evacuee did not give her a chance to use the lift in the first place.

Yet, interviewee B was very aware of her vulnerability in an emergency. With the help from ERT, they immediately ensured that she was given the privilege to safely evacuate.

DISCUSSION

The objective of this study is to identify the needs of disabled people and how it regards occupants with disabilities at the workplace during a fire evacuation. This leads to the gathering of information from the respondents on building evacuation gathered from questionnaire survey and interview, what motivates them to protect themselves, and how they cope with danger to evacuate a building. The study highlights the self-confidence, experience, trust, beliefs, and knowledge of the respondents. According to the experts, quantitative data like a questionnaire survey is a good judgment that leads to interpretations and interaction between behavior, feeling, and thoughts of an individual (Slovic, 2000). In a nutshell, the process of building evacuation in any emergency response led to the interpretations of cognitive and emotional processes. Findings from the questionnaire survey reported that there is still very low awareness among respondents including persons with different types of disabilities. The results from the interviews with one (1) expert and one (1) person with disability (PWDs) respondent showed that the majority of people draw on their own resources to deal with dangerous situation such as evacuation during a building fire.

The barriers and problems faced by a person with disabilities (PWDs) had invited a global view thus further recognized the requirements and needs to facilitate during building evacuation in case of fire emergency. The study recognized the barriers that obstructed the implementation of such fire evacuation procedures for PWDs in a high-rise office building. These include the lack of awareness by building management and building owners, insufficient regular reviews by certified parties, lack of technology involvement, and lack of safety culture among the society and communities. Similarly, Bashiti and Abdul Rahim (2016) highlighted the need to provide a more inclusive environment based on their types of disabilities. There is a need for more research and assessment studies to identify building environment measures to simultaneously improve the safety and smoothness in building evacuation.

Several suggestions from building evacuation improvement based on person with disabilities (PWDs)' needs were made in this study. For example, priority to evacuate should be given to PWDs regardless of any kind of disabilities. Such measures must be further evaluated and thus the study highlighted what needs to be done to educate others concerning safety measures for persons with disabilities. Besides, different evacuation routes for persons with disabilities due to activity limitations were considered in case of emergency. The previous finding proved that building occupants tend to use a familiar or similar exit route (Bahrami et al., 2021; Bashiti & Abdul Rahim, 2016; Koo et al., 2013).

The interview also reported that due to the crowded environment, the evacuation process tends to slow down, and longer time is required to evacuate the building. This seems to be related to the problems in alarm sounding systems as well as inadequacies in building design and technical systems. This may be caused by the fire alarm that was not clear enough to be heard on some floor levels of the building. The study showed that only respondents with experience in building evacuation had knowledge concerning how to vacate a building safely. This group of people tends to be able to help and address the needs of person with disabilities

(PWDs) in an evacuation scenario. Such findings further highlighted the need to focus effort on understanding occupant behaviour as proposed by Ronchi & Nillson (2013) and Akashah et al. (2020). Also, building staff or floor wardens/ marshals need to be properly educated and trained to ensure the safety of evacuation and how it can be adapted to meet the needs of PWDs. These results reflect those of Ab-Aziz et al. (2019) who also found that risk communication in managing fire incidents has shown to have a lot of contribution in reducing disaster risk impact. The behavior of respondents concerning the attitudes towards person with disabilities seems to be lacking and inadequate in fire safety and building evacuation. Hence, this is an important area for improvement.

CONCLUSIONS

The paper presents the needs in fire evacuation from high-rise office buildings with particular emphasis on person with disabilities (PWDs). Ensuring the safety of building occupants is a serious challenge and must involve all, including PWDs as well. Findings from this study showed that the importance of evacuation briefing, training, and education, feeling, trust, initiative, and action can determine realistic life safety capabilities of individuals together with PWDs. The more experienced individuals will react upon hearing the fire alarm as they are aware of the right evacuation procedures. The barrier identified throughout the study could be improved with full attention from the management and users. In this study, few needed to be done to serve better safety and accessibility in emergency evacuation especially for person with disabilities in line with the global trend towards the quality of life (QoL).

Several recommendations are proposed to help overcome the barriers and challenges. The first one is to educate building occupants in terms of giving priority to the person with disabilities (PWDs) and providing different routes. This will give an advantage to solve the problem, be useful in information sharing, and eliminate conflict among building occupants. This type of education is more suitable in organizations with PWDs. Secondly, the organization may consider introducing technological tools to help facilitate communication and wayfinding especially among PWDs such as flashing lights and low-frequency sound alarms for hearing impairment persons, use floor marking indicating arrow on the floor, and illuminated signage for visual impairment person. Consideration in using technological tools such as assistive devices can help improve building evacuation process among PWDs. Lastly, organization needs to provide trainings to their employees and emergency response team (ERT) with basic emergency skills as this will could help improve effectiveness in emergency evacuation for employees especially among PWDs. Such training needs to be able to response to the needs of PWDs identified. This is to be reflected when developing a personalized evacuation plan for the PWDs. Such effort could further enhance quality of life (QoL) for the PWDs especially in regard to their well-being at the workplace.

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ON-SITE WASTE SEGREGATION PRACTICE IN MALAYSIA: MRT POLICE QUARTER PROJECT

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Abstract
In Malaysia, construction waste generation increases annually, with the majority of construction waste ending up in illegal dumping sites. Indeed, construction waste can be effectively recycled if it is segregated. Waste segregation is currently enforced and mandatory in Malaysia's states that have enacted the Solid Waste and Public Cleansing Management Act 2007 (Act 672). However, construction companies are not required to practise sustainable waste management practices such as waste segregation. In Malaysia, there has been no widely published research describing the practice of on-site waste segregation. The research aims to identify the approaches to on-site waste segregation that have been implemented and the factors that influence their implementation. The data collection method used was a case study of the MRT police quarter project in Gombak, where a literature review, site survey, and interviews were conducted. It was discovered that waste segregation had become a more integral part of routine construction activities in Malaysia. Disruption to normal site activities, management effort, and project stakeholders' attitudes are the most critical factors. In contrast, cost, site space, environmental confinement, and facility demand are no longer identified as factors to consider when implementing on-site segregation. Rather than that, education is now viewed as a new potential factor in these practices. The study's findings can be used to assess the state-of-the-art and effectiveness of current on-site segregation in Malaysia and develop benchmarking strategies and best practices for on-site segregation.

Keywords: *On-site waste segregation practice; Approaches; Factors; MRT police quarter project*

INTRODUCTION

Due to the country's growing waste generation, solid waste is one of Malaysia's environmental problems. The waste originated from a variety of sources, including residential, industrial, commercial, and institutional construction, as well as new construction, renovation, and demolition. Waste generation in West Malaysia has increased by approximately 25,000 tons per day. Despite this, only 5% of waste is recycled (Mohammadinia et al., 2019). This demonstrates that waste generation on a domestic and industrial scale continues to grow year after year.

The construction industry generates 29% of solid waste in the United States of America (Mukherjee et al., 2020). According to waste statistics in the United Kingdom, the construction industry accounted for half of all waste in 2012, accounting for 50% of total waste (Department for Environment, 2015). Malaysia generates an estimated 627kg of construction waste per capita each year, according to the Construction Industry Development Board (CIDB). According to studies conducted by the Solid Waste and Public Cleansing Corporation, construction waste was expected to increase to 1.34 million metric tonnes annually by 2020. This demonstrates that the generation of construction waste has developed into a serious problem in Malaysia (Islam et al., 2019). An irresponsible contractor turned a protected tropical mangrove swamp along the Bandar Hilir coastline into a construction dump in Malacca. The estimated 30 tonnes of construction debris discovered along the Bandar Hilir coastline (Murali, 2011). The debris could wreak havoc on the mangrove swamp's eco-system. Additionally, a study conducted in the Johor district revealed that 42 percent of 46 illegal dumping sites are comprised of construction waste (Rahmat & Ibrahim, 2007). Since the construction industry generates a significant amount of waste and consumes a substantial amount of landfill space, it is critical to implement an effective waste management system.

On the other hand, Kuala Lumpur has approximately 300 hotspots for illegal dumping. According to PPSPPA, 80 percent of 300 hot spots illegally discarded construction waste contained concrete, rock, wood, steel, and other construction materials that could be reused as basic materials for roads and buildings. This demonstrates the critical nature of waste management practices such as waste minimisation, reuse, and recycling.

If construction waste is not properly managed, it will have a negative impact on the environment, society, and economy. Prior to disposal, construction waste should be reduced, reused, sorted, and recycled (Ann, Poon, Wong, Yip, & Jaillon, 2013). However, construction firms have no mandatory requirement to practice sustainable resource and waste management, and authorities continue to deal with illegal dumping (Papargyropoulou, Preece, Padfield, & Abdullah, 2011). Now, a small number of industrial sectors utilise source segregation as a method of waste minimisation in order to achieve the goal of on-site recycling (Babu, Bhanu, & Meera, 2009).

However, effective recycling is contingent upon effective segregation. In short, this research aims to enhance on-site waste segregation practises for construction waste, as the implementation of a planned recycling programme is critical for Malaysia to meet its target of 22% recycling by 2020. Thus, it is critical to ensure that on-site segregation is as effective as possible.

LITERATURE REVIEW

Construction waste segregation refers to the process of separating, sorting, or classifying waste generated at the point of generation based on its composition. In layman's terms, construction waste segregation is the practice of categorising construction waste to facilitate subsequent management. Construction waste is frequently a blend of inert and organic materials in the form of building debris, concrete, steel, wood, and a variety of site clearance materials.

Segregating construction waste is a good practise that entails separating and sorting waste generated during construction or demolition activities based on its composition and characteristics. Additionally, waste separation on-site significantly reduces construction and demolition waste (Wang et al., 2020). Several valuable components can be identified and collected for reuse or recycling through construction waste segregation. It is possible to increase reuse and recycling rates while reducing transportation and disposal costs by segregating construction waste on-site (Bao et al., 2020; Véliz et al., 2022).

However, only 5% of waste is recycled in Malaysia (Umar et al., 2021), and recycling accounts for only 11% of total solid waste produced (Kutty, 2015). Since the construction industry generates significant waste, waste management on construction sites should be emphasised and addressed. Thus, this research will examine on-site waste segregation practices, as they have the potential to increase recycling rates.

On-Site Segregation

According to the Solid Waste Management and Public Cleansing Corporation, segregation is one method for preventing and reducing construction solid waste (PPSPPA). Segregation is the process of separating recyclable and non-recyclable solid waste according to the type and composition of the waste being disposed of. Its objective is to increase the monetary value of segregated materials and to promote 3R activities on the jobsite. It contributes indirectly to the reduction of solid waste disposed of in landfills (Samsudina et al., 2021). Waste segregation is the process of categorising waste at the source. Construction and demolition waste are separated on-site. The contractor should provide and label skips for a variety of materials, including wood, bricks, metals, and hazardous waste. When mixed wastes are separated off-site, the term "sorting" is used instead of "segregation" (Lu et al., 2021).

On-Site Segregation Malaysia

Construction waste segregation is encouraged. Each construction site must have at least one location or location for separating and collecting construction waste, according to the Solid Waste Management and Public Cleansing Corporation (PPSPPA). All recyclable and reusable construction waste, including concrete, brick, wood, and metal, must be separated or divided by type and clearly labelled. Each type of construction waste can be separated or isolated based on its material composition, including land clearing debris, wood or timber, glass, plastic, metal, natural aggregates, concrete, clay, plaster, asphalt, electric and electronic material, and paper. However, if the area or location designated for waste segregation is limited and the waste generated is impractical to separate due to its volume and composition, the waste can be mixed and then separated from non-recyclable materials (Samsudina et al., 2021).

Roll-On-Roll-Off (RORO) bins are used to segregate waste and are also encouraged. However, waste can be segregated without using barrels if it is not mixed with food waste or non-recyclable waste. The size and area allotted for segregation should be adequate to contain all types of waste without spilling over. A minimum of one set of blue, brown, and orange coloured recycling bins shall be provided for the development of which has operational offices near the construction site to facilitate the separation of recyclable materials such as bottles, glass, plastic, paper, and aluminium cans (Samsudina et al., 2021). According to the general compliance statement in the Construction Waste Management Plan (CWMP), construction waste must be classified into at least two categories: those that can be reused and recycled and those that must be disposed of. Segregation of waste for concrete, wood, and steel is required for those that can be reused and recycled. Meanwhile, residual waste generated on-site, such as food waste from the office, workers' quarters, and canteen, is not permitted to be mixed with construction solid waste bins (Samsudina et al., 2021).

To summarise, different countries implemented various on-site waste segregation methods for construction waste. Despite studies providing context for understanding waste segregation practises in Malaysia, no widely published research has been conducted.

On-Site Segregation in Hong Kong

Construction waste is classified in Hong Kong as inert or non-inert materials. Sand, bricks, and concrete are considered inert materials, whereas bamboo, plastics, glass, wood, paper, vegetation, and other organic materials are considered non-inert. By separating inert waste from non-inert waste, the inert portion of construction waste can be accepted by public fill reception facilities and deposited in general filling areas for land reclamation, while the non-inert portion can be disposed of in landfills as solid waste (Wu et al., 2019; Lu et al., 2021; Chen et al., 2021).

On-site waste segregation can be accomplished in three ways. Alternatively, each building block could have two refuse chutes, one for inert waste and another for non-inert waste. Separate refuse chutes will collect inert and non-inert waste, which will be emptied and disposed of separately at public filling stations and landfills. The second option is for each building block to have a single refuse chute that is dedicated to a single type of waste, inert or non-inert. On a regular basis, such as every one or two days, separate inert and non-inert waste will be collected and removed. The third option is to have one refuse chute per block, with waste being manually sorted in a ground-level temporary storage pit. The sorted waste will be removed separately (Lu et al., 2021).

According to Lu et al. (2021)'s survey, the most effective method of on-site segregation in Hong Kong appears to be alternative one, which outperforms the other two alternatives. Alternative one is preferred for large construction projects with sufficient site space to accommodate two refuse chutes. Alternative two should be used for small projects that do not require the use of multiple debris chutes, whereas alternative three should be used as a last resort unless minimal interference with site activities becomes prevalent and impairs normal site operations.

In Hong Kong, a Waste Disposal Charging Scheme (WDCS) was implemented to promote on-site construction waste segregation. Producers of construction waste are required to pay the applicable fees for the disposal of various types of construction waste under the scheme. Construction waste containing less than 50% by weight of inert substances will be charged HK$125 when disposed of in landfills, HK$100 when disposed of in off-site segregation facilities, and only HK$27 when disposed of in public fill reception facilities (Wu et al., 2019).

On-site segregation, on the other hand, is not yet a widely used measure in the construction industry for a variety of reasons, including the need for skilled workers, available site space, cost, management effort, and investment in necessary equipment. Additionally, segregation work may cause delays in the normal course of construction (Chen et al., 2021). As a result, it's unsurprising that approximately 70% of contractors refuse to conduct on-site waste segregation unless specifically requested in the contract (Lu et al., 2021).

On-Site Segregation in China

Construction waste is classified in China in two ways: by material type and by construction stage. Construction waste is classified into two categories based on the inert and non-inert nature of the materials: inert and non-inert. According to the stage of construction, construction waste is classified into three categories: structure waste, finishing waste, and demolishing waste. Structure waste includes concrete fragments, steel reinforcement, abandoned timber plates and pieces, and plastic packaging, whereas finishing waste includes excess cement mortars, finishing material packaging, and broken raw materials such as mosaic and tiles. Waste demolition is always method dependent and encompasses a diverse range of waste types and their status, whether mixed or not (Tamiz et al., 2021).

On-site waste segregation can be accomplished in three ways. Alternatively, only those construction wastes with current economic value, such as steel reinforcement, could be classified. The remainder of the construction waste, or mixed construction waste, is collected in a fixed location, typically on the ground floor, and cleaned up on a weekly or ten-day basis. The second option is to separate waste into distinct substances or materials and to create multiple pits on the ground level for each type of waste to be removed separately over time, such as every week or ten days. The third option is to segregate the poisonous waste in accordance with the law's requirements, separating the waste that generates economic value from the toxic waste. It then collects and separates the remainder of the construction wastes or mixed construction wastes over a period of time, such as every week or ten days (Tamiz et al., 2021).

According to Bao et al. (2020), the most effective method of on-site segregation in China appears to be the alternative method, which outperforms the other two alternatives. Alternative one is preferred for large construction projects with adequate site space for collection facilities, whereas alternative three should be used as a last resort unless the government specifies the toxic waste. According to the survey findings, approximately 90% of contractors are hesitant to conduct on-site construction waste segregation unless the contract specifically requires it. Even with a relatively high waste tax of between 2 and 5 yuan per tonne, the construction industry has little incentive to implement on-site segregation.

Factors Affecting On-Site Segregation

Cost is one factor that affects on-site segregation. Waste must be segregated on-site, stored, and transported to a processing centre to begin the recycling process. Therefore, the contractor's bid must include the increased handling and processing fees (Blaisi, 2019). Thus, the increased cost acts as a deterrent in this instance.

Separating each material prior to recycling necessitates increased waste handling, which results in additional work for the contractor (Dolan et al., 1999). This operation is not only time consuming, but it also delays the work indirectly, as contractors must complete numerous steps. Additionally, the attitude of contractors toward segregation is a factor to consider.

The other factor is site space availability. There may be insufficient space for waste storage, separate waste containers, and haulier access to the debris on some construction sites. Much waste, such as wood and gypsum, takes up much space because these materials are frequently transported in large pieces (Dolan et al., 1999). Once the waste has been separated, it must be stored on-site for a specified period to reach the required level for transport to the processing centre.

Following that, a dearth of rehabilitation facilities contributes to the problem. Even if contractors desired to separate debris for recycling, they are unable to do so due to a lack of waste recovery facilities, especially for small-scale construction and demolition projects such as office remodels or small building construction (Dolan et al., 1999).

Poon et al. (2001) identified seven possible factors affecting on-site waste segregation in Hong Kong. These factors include the availability of site space, management effort, labour, and cost, the impact on normal site activities, waste sortability, the market for recyclables and environmental benefits, and project stakeholder attitudes toward implementing on-site waste segregation. In Hong Kong, the primary factors affecting on-site waste segregation are available site space, labour and cost, management effort, and disruption of normal site activities. In comparison, minor factors include waste sortability, the market for recyclables, the associated environmental benefit, and project stakeholder attitudes toward on-site waste segregation.

According to Ghaffar et al. (2020), the most critical factors affecting on-site waste segregation are available site space, management effort, and project stakeholders' attitudes toward implementing on-site waste segregation, whereas labour and cost are no longer major concerns when implementing on-site segregation. This is because waste is separated immediately after construction waste is generated, and the project does not require specialised labour. On the other hand, waste sortability, the recycling market, and environmental benefits are becoming increasingly important in implementing on-site waste segregation, as recycling traders are insufficient, the Hong Kong construction market is contracting, and environmental considerations are becoming more important in construction projects.

According to a survey conducted by Bao et al. (2020), the primary factors influencing on-site segregation of construction waste in China are cost, impact on construction duration, site space availability, disruption of normal site activities, market for recyclables, environmental constraint, management effort, waste sortability, labour demand, and facility demand. The term "site space availability" refers to the amount of original site space, the layout, and the space available for waste management, particularly poisonous waste, whereas "waste sortability" refers to the ease with which wastes can be separated. Contractors' costs will increase, and project completion times will be extended due to on-site waste segregation. Additionally, the size of the recycling market affects the incentives for waste segregation. Implementing on-site waste segregation affects normal site activities by interfering with and constraining them by the surrounding environment, which includes noise control, dust control, roads, and time for waste transportation. On-site segregation is impacted by labour requirements, necessitating additional labour to complete the task. Enhancing current waste management practices is critical for implementing on-site segregation effectively (Bao et al., 2020).

Another survey, however, identified six critical success factors for adequate on-site waste segregation: manpower, a market for recycled materials, waste sortability, improved management, site space, and construction waste segregation equipment (Huang et al., 2021).

According to prior research, manpower is critical in determining the effectiveness of waste management in construction (Wu et al., 2019; Kabirifar et al., 2020).

Contractors cannot profit from recycling materials because there is no market for them, leaving contractors with few incentives to promote on-site segregation. Because Chinese environmental regulations prohibit the reuse, recycling, or landfilling of contaminated waste materials, respondents reported difficulty separating waste materials from the mixture to ensure the remainder was suitable for reuse and recycling. Compared to some western countries, China's construction industry has a lower management level (Bao et al., 2020). In Shenzhen, no space has been set aside for on-site segregation of construction waste, and on-site segregation is primarily manual.

To summarise, several factors influence on-site segregation, including available site space, labour and cost, management effort, interference with normal activities, waste sortability, market for recyclables and environmental benefit, and project stakeholder attitudes. By examining the factors affecting on-site segregation in Table 3, we discovered that a common barrier exists while the factors affecting on-site segregation implementation vary by country. On-site segregation is influenced by site space availability and cost in Malaysia, Hong Kong, and China. It is critical for both researchers and industry practitioners to understand the factors that influence on-site segregation in order to conduct effective on-site segregation. Additionally, more improvements are needed by identifying the factors that influence on-site segregation.

RESEARCH METHODOLOGY

Qualitative research is data collection, analysis, and report writing. The qualitative method was chosen because the research question sought to elucidate the reality of the information retrieved and transferred, rather than to examine people's beliefs, understandings, opinions, views, and perceptions (Bresler, 2021). The second reason was that the question should be answered from a broad perspective that can yield findings about the phenomenon, rather than from specific and detailed findings from multiple studies.

Participating in a real-world construction site environment is critical for determining the on-site segregation techniques used on the MRT police quarter project. This study aimed to increase awareness of the current reality of on-site segregation practises in the MRT police quarter. The instruments used to collect data for this study were observations, interviews, and recording. Following a review of the research objectives and purpose, it was determined that the best method for this study would be participant observation. On the other hand, semi-structured interviews were conducted with the environmental officer, site supervisor, and project manager to ascertain their familiarity with on-site segregation practises.

The research population, in this case, is the construction company that has implemented on-site waste segregation in new construction projects, whereas the research samples are contractors that have implemented on-site waste segregation in new construction projects. On the other hand, the interview sample included an environmental officer, a site supervisor, and a project manager who practised on-site segregation. The sample chosen satisfied the research objectives and title by having subsets of the variables "Construction Company" and "on-site segregation."

Additionally, content analysis was used to analyse the data for this study. Content analysis is a systematic technique for condensing large amounts of text into a smaller number of content categories using explicit coding rules (Joung & Byun, 2021). Content analysis enables the systematic identification of large quantities of textual data properties. The analysis focused on determining the state-of-the-art on-site segregation and the relative importance of factors affecting on-site segregation implementation.

Figure 1. The Research Methodology Process Adopted in This Research

FINDINGS AND DISCUSSIONS

On 31 March 2016, Mass Rapid Transit Corporation Sdn. Bhd. (MRT Corp.) awarded WCT a contract worth RM133.93 million to redevelop the existing police quarters (Block 10 & 11) in Taman Keramat, Bandar Ulu Kelang, Selangor. This is a residential (government) project that is included in one of the MRT Line 2 packages. WCT will design and construct a 20-story police quarters that will consist of 300 Police Quarters Class F units, a five-story podium car park, and amenities such as a multipurpose hall, shops, and surau. The project began in April 2016 and is scheduled to conclude in August 2018. WCT will also perform external and infrastructure work during the 28-month project, including landscape, pedestrian linkages, road and road signage, security fencing, and earthwork.

Respondents Backgrounds

Table 1 showed the respondents' background involved in the survey through interviews conducted by the researchers. The respondents' perspective is from several parties, including environmental officer, site supervisor, and project manager.

Table 1. Background of Respondents

No. of Respondents	Position	Working Experience
Respondent 1	Environmental Officer	Almost 3 years
Respondent 2	Site Supervisor	1.5 Years
Respondent 3	Project Manager	2 Years

Approaches of Implementation of On-Site Segregation

According to respondent 1, there are numerous stages involved in the approval of a WMP. To begin, a Waste Management Plan (WMP) or Environmental Management Plan (EMP) must be developed prior to initiating on-site segregation. The WMP/EMP must then be revised as necessary and approved prior to being sent to the client, such as a project partner.

Client will review and then submit for approval to MRT. Following that, the MRT is returned to the authority for approval.

> *"We got the waste management plan. I am doing the WMP, and it is compulsory to have the WMP that need to be checked first and then approved. After that, our EMP will go to the client; the client will review. After approval, it will be sent to another client and then sent back to the MRT; after approved, send it back to the authority to approve, many stages, it is challenging." (Respondent 1)*

On-site segregation will be implemented largely following the plan. Segregation of materials will occur according to construction waste, household waste, scrap metal, chemical waste, and scheduled waste. Workers will carry out waste segregation once construction waste is generated to avoid mixing waste materials. The waste will be stored in a store or bins on the site, and general workers will perform housekeeping once a week or every two or three days. Waste will be disposed of monthly.

> *"...the materials we will segregate based on the construction waste, the domestic waste, scrap metal, chemical waste and scheduled waste. We give the construction and domestic waste to the approved contractor by our authority and local authority. And some of the waste we will recycle back like scrap metal." (Respondent 1)*

> *"...Approved dumpsite for this project, not for the demolishing is Sungai Kertas at Gombak and also the domestic waste is Alam Flora [Sdn Bhd]. We have the general workers, and they will do the housekeeping every week or every two or three days. They will segregate, and I will monitor and analyse. So, we will dispose every month, but we will locate at the store here, every week we do housekeeping and make some segregation on plastic, [waste that] can recycle. We got the 3R bins for recycling." (Respondent 1)*

According to respondent 1, the MRT police quarters project will utilise RORO bins for on-site segregation. RORO bins are available in two colours: blue and green. The larger Blue RORO bins are used for construction waste, while the smaller Blue RORO bins are used for household waste. Green RORO bins are used to collect scrap metal.

> *"Yes, currently is two types. Blue and Green. The large size is for construction [waste] for the Blue bin, and the small size is for domestic waste. The Green bin is for scrap metal. But for the scrap metal, we will send it back to our WCT store then recycle back." (Respondent 1)*

Besides that, the MRT police quarter project also adopts the 3R system in the site. There are three types of recycling bins for which Green, Orange and Blue colours are used for different categories of domestic waste. Green recycling bins are for glass; Orange recycling bins are for aluminium, whereas Blue recycling bins are for paper.

> *"...currently this site practices the recycle, the 3R [system]." (Respondent 1)*

Respondent 1 claimed that MRT police quarter project did not adopt the national colour coding scheme to segregate different categories of construction waste because they are not familiar with these practices, and DOE did not focus on this coding scheme. Based on respondent 1, the national colour coding scheme is an excellent method to adopt in the future, but Malaysia is not ready to embrace this scheme as Malaysia is having difficulty in waste segregation practice.

"No. not so familiar. Because we do not have the requirement as strict as this, it depends on the waste bin sizes, not the colour. Maybe this one is practice for the segregation centre or also the manufacturing. Because construction is not focusing too much on that, also the DOE not stress on that." (Respondent 1)

"…Our level now, they are not focusing on what types of your bins, to educate the people to segregate the waste already difficult. I think Malaysia is not ready for that. But we can propose to implement it." (Respondent 1)

Factors Affect The Implementation of On-Site Segregation

According to the literature review, various factors influence the implementation of on-site segregation. Based on a literature review, the researcher identified 11 distinct factors that will affect the performance of on-site segregation. Cost, impact on construction duration, site space availability, disruption to normal site activities, the market for recyclables, environmental constraint, management effort, waste sortability, labour demand, facility demand, and project stakeholder attitudes are the factors. This section tabulates and analyses respondents' feedback on the factors identified during the literature review and their actual impact on on-site segregation in the MRT police quarter project.

Table 2. Factors Affect The Implementation of On-Site Segregation in MRT Police Quarter Project

Factors	R1	R2	R3
Cost			
Impacting to construction duration		√	
Availability of site space			
Disruption to normal site	√	√	√
market for recyclables		√	√
Confining by the environment			
Management effort	√	√	√
Waste sortability			√
Labour demanding		√	
Facility demanding			
Project stakeholder's attitudes	√	√	√
Others	Level of Education	-	-

Several factors were identified as potential constraints on on-site segregation practises in other countries' construction projects, including cost, impact on construction duration, availability of site space, disruption of normal site activities, the market for recyclables, environmental constraints, management effort, waste sortability, labour demand, facility demand, and project stakeholder attitudes.

According to the survey findings, seven factors contributed to on-site segregation in the MRT police quarter project. These factors included the impact on construction duration, disruption of normal site activities, the market for recyclables, management effort, waste sortability, labour demand, and project stakeholder attitudes. The factors identified in this study were identical to those identified in the literature review. However, four factors affecting the implementation of on-site segregation in the MRT police quarter project are not identified: cost, site space availability, environmental constraint, and facility demand. Meanwhile, education level has emerged as a new factor affecting the implementation of on-site segregation in the MRT police quarter project, which was not previously considered in the literature review.

Table 3. The Relative Importance of Factors Affecting On-Site Segregation Practices in MRT Police Quarter Project

Factors	R1	R2	R3
Major Factors			
Disruption to normal site	√	√	√
Management effort	√	√	√
Project stakeholder's attitudes	√	√	√
Middle factors			
Market for recyclables		√	√
Minor Factors			
Impacting to construction duration		√	
Waste sortability			√
Labour demanding		√	
New factor			
Level of education	√		

According to Table 3, all interviewees in this study believed that disruption to normal site activities was the primary factor affecting on-site segregation practises in the MRT police quarter project. Bao et al. (2020) stated that disruption to normal site activities was only one of the factors influencing on-site segregation practices. However, as the researcher discovered in his case study, all interviewees argued that these factors are critical in that implementing on-site construction waste segregation may reduce worker productivity and cause disorder in other activities. Due to the limited site space in the case studied, allocating dustbins for waste segregation is particularly challenging and may cause disruption to normal site activities by blocking access for workers or site personnel. This is likely to reduce worker productivity and cause interruptions in the construction process, obstructing the normal flow of operations. Thus, disruption of normal site operations is now viewed as a critical aspect of these practices.

The role of management in reducing construction waste generation has been extensively researched and highlighted in previous studies (Wu et al., 2019). The findings of this study indicate that management effort is a significant factor influencing the implementation of on-site waste segregation in the MRT police quarter project. All interviewees agreed that management, particularly top management, was critical in facilitating the implementation of on-site waste segregation. The top management support is required, as an effective management effort results in adequate on-site segregation practices. Additionally, several interviewees stated that management effort is critical for site team enforcement. The management team must compel the site team to adapt to the on-site segregation practice to ensure that all personnel are aware of the implementation's benefits and consequences. This is reinforced by Wu et al. (2019), who stated that strengthening management capacity for construction waste management, including on-site segregation of construction waste, is a lengthy process that requires the collaboration of managerial and operational staff. Thus, coordination among the various practitioners involved is critical to maximising the effectiveness of on-site waste segregation. This, in turn, necessitates improved construction management.

By comparing the findings from the case studies to those from Bao et al. (2020) and Ghaffar et al. (2020), project stakeholders' attitudes toward implementing on-site segregation are consistently viewed as the most critical determinants of on-site segregation. Managing construction waste places additional demands on the environmental officer and the site management team. Senior management must empower workers and site managers to achieve successful waste management. Both practitioners and researchers are now aware that the expansion of all stakeholders' roles is crucial to ensure the effectiveness of on-site segregation implementation. Stakeholders have varying stakes in a system and can positively or negatively impact it (Bao et al., 2020). The case study interviewees endorsed this concept. The following quote from an interviewee provides a reasonable justification for this: "the success of on-site segregation is contingent upon the project stakeholders" attitude. As previously stated, project stakeholders are critical in implementing waste segregation.

The market's growth for recycled materials is ranked as the second most important factor affecting the effectiveness of on-site waste separation in the MRT police quarter project. During interviews, most respondents asserted that the market for recycled material is quite limited. Only a few recyclable materials are readily available in the market, for example, plastic, paper, steel, and metal. A dearth of markets for recycled materials was a significant factor in the slow adoption of on-site segregation practices. Without such a market for recycled materials, construction industrialists would have little incentive to promote on-site segregation practices.

> *"Market for recycling such as construction waste is less. So, we just appoint sub-contractor to handle this waste." (Respondent 3)*

This is because the market for recycling construction waste is smaller. This statement is backed up by Bao et al. (2020), who stated that total recycling equipment market for construction waste is only 11%. This example appears to shed light on the construction waste recycling market's scarcity. By cultivating a market for recycled construction materials, it is hoped that construction industrialists will take the lead in implementing on-site segregation if alternate markets for each recyclable material are readily available, thereby encouraging on-site segregation implementation.

According to Table 3, affecting construction duration has a negligible effect on on-site segregation practises in the MRT police quarter project. According to Yu et al. (2020), additional time will be required for construction waste segregation activities, resulting in project delays.

> *"Sometimes, if poor planning and no control over the on-site segregation, it might create impact to the construction duration." (Respondent 2)*

Inadequate planning may affect the construction duration, causing the project to be delayed. This is most likely the result of poor planning and scheduling tasks in an illogical order or sequence. For instance, placing dustbins at corners that are inconveniently located to the site container—additionally, attempting to adhere to that schedule without considering other factors that may cause delays may lose control over the project, affecting the construction duration. Although only one interviewee mentioned this factor, the supporting statement from the literature review and the interviewee's response indicates that impacting construction duration is also a significant factor affecting the operation of on-site segregation practice. Additionally, it is a factor to consider when implementing on-site segregation. However, the acceptance of time spent on waste management should not be viewed as a time-consuming inconvenience but as a critical necessity.

By comparing the results from the case studies to those reported by Bao et al. (2020), it is clear that waste sortability's influence on on-site segregation practices is consistently regarded as minor. This is consistent with the findings of Bao et al. (2020), who concluded that it was difficult to separate waste materials once they had been mixed. The respondent asserted that separating specific waste from the mixture is difficult.

> *"Sometimes, it is quite difficult to separate out contaminated waste from the mixture, and some labours will make mistakes on this task. So monitoring is always needed." (Respondent 3)*

Since waste segregation is performed by general workers from foreign countries such as Bangladesh, it is undoubtedly challenging to separate waste from the mixture. This partially explains the difficulty associated with waste sortability in the construction industry. Thus, providing appropriate education to general workers regarding the proper separation of specific construction waste may be a good solution for the effective implementation of on-site segregation.

Interestingly, the case studies revealed that labour demand is no longer a primary consideration when conducting on-site segregation practices. This is in stark contrast to the findings of Poon et al. (2001), who discovered that labour demand is the essential factor in determining the construction waste segregation scheme among various alternatives.

> *"Not really. We have the general workers, they will do the housekeeping every week or every two or three days. They will segregate, and I will monitor and analysis." (Respondent 1)*

As reported above, it is clearly justified that enough general workers are to carry out housekeeping and segregation. In this sense, labour demand is the most negligible decisive factor in affecting on-site segregation mainly because general workers do waste segregation in the project and no specialised labour is required and assigned for this task. This practice involved all team members, whether educated or non-educated. It is not surprising to see that education level is perceived as a new factor affecting the effective implementation of on-site segregation of construction waste in MRT police quarter project. This reflects a fundamental impediment to on-site segregation of construction waste, which echoes with an interviewee claiming that education level is a critical factor affecting the implementation of on-site segregation.

In construction, there are different levels of education. The higher level of education people may refer to engineer, contractor, environment officer, site supervisor and others whereas the lower level of education people may refer to labours. Since the education level is different, the knowledge attained is also additional. The survey results revealed that even the engineer currently does not know how to segregate, although they know the environmental aspect. So, it is quite difficult for non-educated people such as general workers and labours who have zero knowledge of environmental knowledge to carry out the on-site segregation practice. Thus, it should be noted that education on environmental aspects such as the implementation of on-site segregation practices for general workers and labours is needed for effective implementation of on-site segregation practices.

CONCLUSION AND RECOMMENDATIONS

The findings of this study paint a clear picture of how on-site segregation should be implemented. The approaches used to implement on-site segregation in the MRT police quarter project provide a more detailed understanding of current on-site waste segregation practices in real-world projects. The factors affecting on-site segregation implementation in the MRT police quarter project aid in identifying the obstacles on-site waste segregation practice. Due to the lack of widely published research describing on-site waste segregation practises in the Malaysian construction industry, this study is expected to contribute to future researchers conducting additional research on this field topic. Thus, the contribution of this study signifies that the improvement of on-site segregation practices is crucial and should continue to enhance and applied in future construction projects in Malaysia. Finally, we hope that the research findings will benefit the Malaysian construction industry by facilitating the implementation of on-site segregation practices.

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GUIDE TO AUTHORS

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Articles submitted will be reviewed and accepted on the understanding that they have not been published elsewhere. The authors have to fill out the **Declaration of the Authors** form and return the form via fax/email to the secretariat. The length of articles should be **between 3,500 and 8,000 words** or **approximately 8 – 15 printed pages (final version)**. **The similarity index must be lower than 20% and proofread in UK English.** The Similarity Report and summary of the article (less than 250 words) for editorial must be submitted together with the manuscript.

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CODIFICATION AND APPLICATION OF SEMI-LOOF ELEMENTS FOR COMPLEX STRUCTURES

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

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

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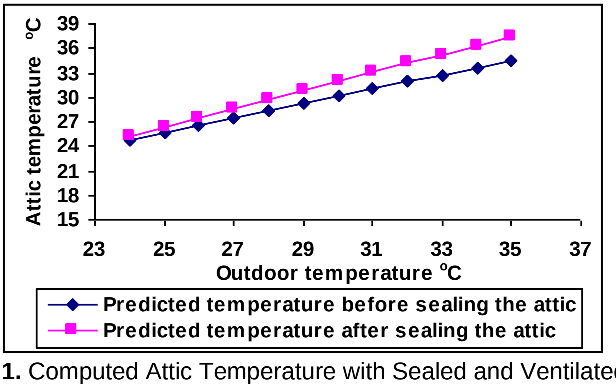

Figure 1. Computed Attic Temperature with Sealed and Ventilated Attic

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

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Table Line: 0.5pt.

Table 1. Recommended/Acceptable Physical Water Quality Criteria

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

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

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

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Passage Type	First Reference in Text	Next Reference in Text	Bracket Format, First Reference in Text	Bracket Format, Next Reference Marker in Text
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Three authors	Bradley, Ramirez, and Soo (1999)	Bradley et al. (1999)	(Bradley, Ramirez, & Soo, 1999)	(Bradley et al., 1999)
Four authors	Bradley, Ramirez, Soo, and Walsh (2006)	Bradley et al. (2006)	(Bradley, Ramirez, Soo, & Walsh, 2006)	(Bradley et al., 2006)
Five authors	Walker, Allen, Bradley, Ramirez, and Soo (2008)	Walker et al. (2008)	(Walker, Allen, Bradley, Ramirez, & Soo, 2008)	(Walker et al., 2008)
Six or more authors	Wasserstein et al (2005)	Wasserstein et al. (2005)	(Wasserstein et al., 2005)	(Wasserstein et al., 2005)
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