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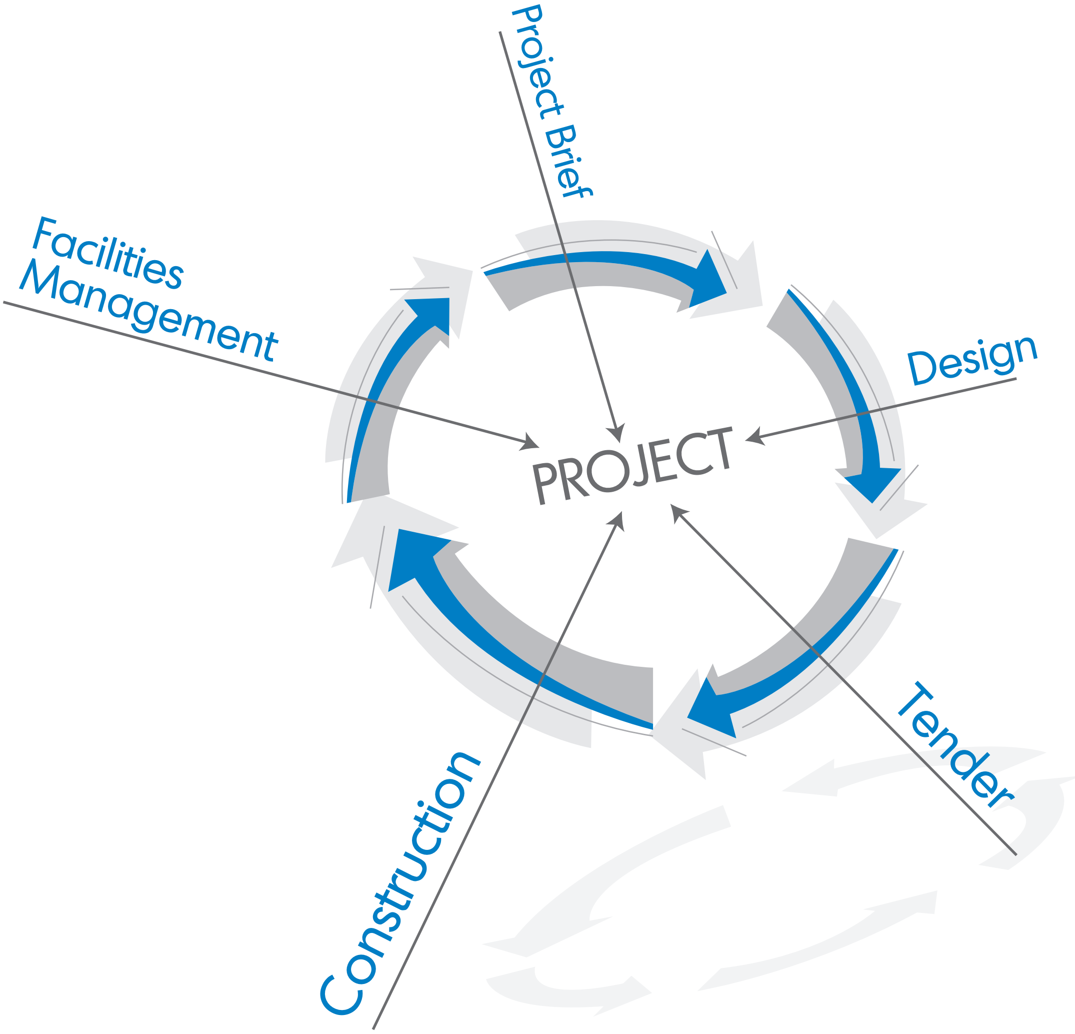

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Editorial

Welcome from the Editors

Welcome to the forty-fifth (45th) issue of Malaysian Construction Research Journal (MCRJ). In this issue, we are pleased to include six 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:

Tze Shwan Lim et al., aimed to explore the evolution of innovative technologies in the construction industry especially construction works at the site, unmanned aerial vehicle (UAV) has been widely used as a tool to improve project management by assisting in site inspection and monitoring the site progress. UAVs help in cost and time saving which also improve safety management and increase the quality and efficiency of the construction work. However, there are issues and limitations that may affect the adoption rate of UAVs among the construction players as the rate of adoption of UAVs in Malaysia is relatively low. Therefore, this study aims to investigate the issues that hinder the adoption of UAVs and to encourage the implementation of UAVs in a construction project. Quantitative method is used in this study and the data analysis method used is Relative importance Index (RII), Mean and Standard Deviation. The findings of the research show that UAVs is mainly used for aerial photography and camera surveillance system such as for business advertisement, camera surveillance system, and construction claim. While the main issues faced by the construction player are the technical issues of UAV, especially the short battery capacity and flight time of the UAVs to operate. The government plays a critical role in regulating the usage of UAVs to enhance the construction performance in the future.

Jiang Min et al., aimed to develop a holistic approach to land valuation by applying the multi-functional value theory. The study evaluates the impact of five key functions—safeguard, production, assets, ecology, and culture—on rural residential land value. A quantitative research design was employed, utilizing participatory rural assessment (PRA) as the primary data collection method. A semi-structured questionnaire was administered in Chuanshan District, Suining City, Sichuan Province, yielding 300 responses. Findings indicate that the current compensation value of rural residential land is only 63.83% of its calculated value, reinforcing widespread concerns among farmers about undercompensation. This study proposes a multi-functional valuation framework and a corresponding calculation model to improve rural residential land valuation practices.

Marhani et al., emphasised persistent safety challenges, with frequent workplace accidents highlighting the need for improved safety management. This study examines the effectiveness of toolbox talks as a crucial safety measure among G7 contractors registered with the Construction Industry Development Board. While toolbox talks are widely implemented, challenges such as time constraints, language barriers, and passive communication hinder their effectiveness. The research suggests key improvements, including structured task delegation, multilingual support, and an engaging narrative approach to enhance participation and comprehension. These findings emphasise the need to elevate toolbox talks as a fundamental component of safety culture in the construction industry. By addressing these challenges, stakeholders can foster a safer working environment, supporting sustainable urban development in Malaysia.

Saleha et al., studied the integration of Lean Six Sigma (LSS) into Building Information Modelling (BIM)-based construction projects to improve performance by reducing waste, enhancing efficiency, and ensuring better quality outcomes. The study identifies the critical barriers limiting LSS adoption in BIM-based projects and recommends effective strategies for successful implementation. Using a quantitative research approach, the study reveals barriers such as lack of awareness of LSS needs and benefits, insufficient specialised training, time constraints, low involvement from top management, and satisfaction with existing quality management systems. Key strategies for overcoming these barriers include implementing leadership and management training and securing strong support from top management. The findings offer industry practitioners practical solutions for addressing these barriers and successfully implementing LSS in BIM-based construction projects. The study also sheds light on future research to explore further integrating LSS and BIM in construction contexts.

Hashim et al., investigate the combined impact of BIM and IBS on construction waste minimisation and assess how modern construction methods can enhance efficiency, safety and sustainability in industrialised construction projects. Data was collected from 325 construction professionals. PLS-SEM was used to analyse the data with regard to the relationships between BIM, IBS, and construction waste minimisation The path from BIM Implementation to CW Minimization shows a coefficient of 0.425 with a highly significant p-value (0.0000) and a T statistic of 6.513, indicating that BIM Implementation positively influences CW Minimization. The path from BIM Implementation to IBS Implementation exhibits a strong coefficient of 0.757, a T statistic of 21.561, and a p-value of 0.0000, suggesting that BIM Implementation significantly supports IBS Implementation. The study found that the integration of BIM and IBS significantly reduces construction waste, with strong relationships between BIM's material optimisation and clash detection capabilities and IBS's prefabrication and modularisation processes. The findings suggest that the synergy between BIM and IBS provides a comprehensive solution for construction waste reduction, making projects more sustainable, safe and cost-efficient. The study concludes that broader adoption and integration of BIM and IBS are essential to achieving significant waste minimisation across various construction projects.

Sanmargaraja et al., conducted a study to identify critical sustainable design criteria for green office buildings in Malaysia amid rising concerns over urban carbon emissions and climate change. The research utilised a questionnaire survey distributed to 143 professionals during the ARCHIDEX 2024 exhibition, targeting stakeholders from the architecture, engineering, and construction sectors. The analysis identified energy efficiency as the most critical design consideration, followed by renewable energy integration, sustainable materials, water conservation, waste reduction, indoor air quality, and biodiversity enhancement. Reliability analysis validated the consistency of the responses, with waste reduction and water conservation showing the highest contribution to scale reliability. The study emphasises the importance of holistic and multidisciplinary collaboration among construction stakeholders to achieve green building objectives, including reduced energy consumption, greenhouse gas mitigation, and ecological preservation. The findings offer practical insights for developers and policymakers aiming to promote sustainable office-building practices and advance Malaysia’s low-carbon urban agenda by 2030.

Editorial Committee

THE APPLICATION OF UNMANNED AERIAL VEHICLES (UAVs) IN THE CONSTRUCTION INDUSTRY

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Abstract
In the evolution of innovative technologies in the construction industry especially construction works at the site, unmanned aerial vehicle (UAV) has been widely used as a tool to improve project management by assisting in site inspection and monitoring the site progress. UAVs help in cost and time saving which also improve safety management and increase the quality and efficiency of the construction work. However, there are issues and limitations that may affect the adoption rate of UAVs among the construction players as the rate of adoption of UAVs in Malaysia is relatively low. Therefore, this study aims to investigate the issues that hinder the adoption of UAVs and to encourage the implementation of UAVs in a construction project. Quantitative method is used in this study and the data analysis method used is Relative importance Index (RII), Mean and Standard Deviation. The findings of the research show that UAVs is mainly used for aerial photography and camera surveillance system such as for business advertisement, camera surveillance system, and construction claim. While the main issues faced by the construction player are the technical issues of UAV, especially the short battery capacity and flight time of the UAVs to operate. The government plays a critical role in regulating the usage of UAVs to enhance the construction performance in the future.

Keywords: *Unmanned Aerial Vehicle; Project Management; Application; Adoption; Quantitative Method; Relative Importance Index*

INTRODUCTION

With the implementation of new construction technologies, Malaysia construction sector has grown quickly in recent years. UAVs, also called drones, is one of the innovative technologies that help build innovation and influence in the industry due to its accessibility and functionality. Drones can help in short completion time, safer environment, greater quality of workmanship, and lower expenses. An unmanned aerial vehicle is an aircraft operating under remote/ autonomous control without a pilot on board, where a pilot is controlling from the ground. Drones are mainly controlled via electronic devices such as mobile phones along with a camera and sensor such as Global Positioning System (GPS) (Dastgheibifard and Asnafi, 2018). However, the implementation rate of UAVs in construction industry is still relatively low as compared to other industries (Hewitt and Gambatese, 2008). For example, the productivity of manufacturing sector showed a great improvement from adopting technologies like UAVs to increase their effectiveness in the production. Thus, it is necessary to investigate the factors affecting the slow implementation of UAV systems in the construction industry. In this research, the aim of the research is to identify the application of the UAV system with the limitation of UAV adoption in the construction industry. In addition, this research also aims to investigate possible solutions to boost the adoption rate of UAVs in the construction industry.

PROBLEM STATEMENT

Nowadays, construction industry demands a highly precise planning, work scheduling, effective and efficient project management to help in cost reduction, better quality and shorter completion time (Zainudin, 2015). One of the ways to increase construction effectiveness is by adopting automation systems. As discussed in the introduction, there are numerous usages of Unmanned Aerial Vehicle in the construction industry. However, the rate of implementation of UAVs in the construction industry is still relatively low. There are still many limitations faced by the construction players to adopt UAVs for their projects.

A study conducted in 2015 showed that 92% of the respondents are aware of the usage of UAVs to take photography for job monitoring followed by 80% agreed that UAVs can be utilized for site inspection and quality inspection. The study showed that the construction players are still not fully aware of various applications of UAVs for the construction industry (Wang, Hollar, Sayger, Zhen, Buckeridge, Li, Chong, Duffied, Ryu and Wei, 2016). UAVs can be utilized for various usages such as 3D modeling, site monitoring, safety inspection, camera surveillance system and more. Thus, it is important to raise the awareness of UAVs application among construction players to boost the adoption rate of UAVs for better construction performance.

There is still a lack of development on UAVs application for the construction industry. In order to increase the knowledge and awareness on how UAVs can be integrated into the construction industry, more research and further development are needed to explore the various applications of UAVs (Costa, Melo, Alvares & Bello, 2016). Lastly, this study also aims to investigate possible solutions to reduce the limitation of UAVs that hindered the construction players to implement UAVs.

AIM

The overall aim of this paper is to identify the usage of unmanned aerial vehicles applications and its limitation in the construction industry. Then, to investigate possible solutions to reduce the limitation of UAVs in the construction site.

RESEARCH OBJECTIVES

1. To identify the application of Unmanned Aerial Vehicles in the construction industry.
2. To examine the issue of UAVs application in the construction industry.
3. To investigate possible solutions to reduce the issues of UAVs application in the construction industry.

LITERATURE REVIEW

The US Federal Aviation Administration (FAA) defined an unmanned aerial vehicle (UAV) as “an aircraft operated without the possibility of direct human intervention from within or on the aircraft”. The control function of an unmanned aerial vehicle may be either on-board or by remote control (Opfer and Shields, 2014). UAVs is also recognized as drones, unmanned aerial system (UAS) or unmanned aircraft. The UAVs are utilized in three major market segments: military, civil government and commercial. Each segment shares a few common objectives with other segments that is to improve the productivity, work efficiency and to provide services that cannot be performed manually at safer and better efficiency (Wang, et al., 2016). UAVs vary widely in terms of size, function, and shape. The common types that are mainly used are DJI Phantom, Yuneec Typhoin and GoPro cameras (Wang, et al., 2016). UAVs can be categorized into two categories: fixed wing and rotary blade. Rotary-blade UAVs can change direction and route even when maneuvering in a small area and they can take off and land vertically. While fixed-wing UAVs might require a short runway for take-off and landing and there are only able to fly forward which is not flexible for construction use. Rotary-blade UAV is more common than fixed wing UAV in construction as they are more flexible and easier to control. Nowadays, UAVs can be controlled via Smartphone devices, linked by Wi-Fi networks, and their locations can be pinpointed via global positioning system (Schreiber and Teizer, 2014). UAVs are mainly for military purposes in the earliest stage (Siebet and Teizer, 2014). However, UAV has been widely transferred to commercial use in a few industries such as the construction industry (Dupont, Chua, Tashrif & Abott, 2017). Research showed that construction players have started to utilise UAVs in their project sites to provide real-time and high-resolution images for project progress control.

APPLICATION OF UNMANNED AERIAL VEHICLE IN CONSTRUCTION INDUSTRY

The construction industry shows slower adoption of UAVs as compared to other industries (Arslan, Ulubeyli and Kazaz, 2019). The application of UAVs in the construction industry is categorized into three main categories: project management, aerial photography and surveillance system and 3D Modelling.

Project Management

Good project management is the key to meet the project's requirements and making the project succeed. Site monitoring and inspections are key elements to achieve project success. UAVs are greatly utilised for monitoring and inspection of remarkable buildings due to the increase of focus on sustainability and resource efficiency in the infrastructure and building sector to increase the whole life cycle time of a building (Vacca, Dessi and Sacco, 2017).

Under safety inspection, safety concerns are the key element in a jobsite for the construction project success. First, UAVs can help in damage assessment. They can detect damages in a short time at a lower cost of inspection which can eventually enhance the client's understanding in terms of visual data exchange (Dupont, Chua, Tashrif & Abott, 2017). Due to its efficiency in damage quantification, it can discover hidden problems more easily. For instance, in the event of a natural disaster such as earthquake, hurricane or structural fire occurred, UAV can detect damaged parts quickly after occurrence for first response, rescue and recovery planning (Dastgheibifard and Asnafi, 2018). Safety manager can also utilise UAVs to assist in identifying potential hazards or quality issues by offering live streaming on-site progress, whereby providing valuable information in a short period and cost-saving manner (Mosly, 2017). Next, UAV can be used to assist in safety inspection when equipped with thermographic camera. UAVs with thermographic cameras can capture heat flow that allows the mapping of roof insulation or pipe insulation matters (Mosly, 2017). They can also help to inspect water leakage location by showing colder colours on the screen.

For site monitoring, UAV can capture high-resolution images and videos to convey valuable information of site conditions in cases, it can cover a larger area in a very short period for job progress control. Thus, the efficiency of safety managers can be enhanced with the utilization of a UAV. To monitor the project site, UAV can be combined with radio-frequency identification (RFID) to improve the supply chain management in the construction site. RFID reader can be mounted on the UAV to locate RFID tags attached on the materials on-site for more effective valuation (Arslan, Ulubeyli and Kazaz, 2019). Project managers can utilize the aerial images taken daily by the UAV to manage the workflow of vehicles in and out of the construction site and equipment placement. Aerial views of the site can assist to improve project site management and productivity by enhancing the communication links between workers and project managers (Irizarry, 2012; Alizadehsalehi, 2017).

Aerial Photography and Surveillance

The role of UAV is mainly to provide real-time progress and surveillance in the construction site in the form of high-quality images, videos and to create 3D models. These images and videos can be utilized for business advertisement, camera surveillance system and to be used as construction claim records or supporting documents.

For Business advertisements, capturing aerial photos and video from a bird’s eye view is the most common utilization of UAVs for its purposes. Companies can provide a unique perspective of images and videos to demonstrate the project progress and use them for advertising for future projects (Tatum and Liu, 2017).

For camera surveillance systems, conventionally a fixed camera surveillance system will be installed in the construction site (Fang, 2016). However, it may face difficulty in viewing the full range of construction sites without any structural element blocking the view. Thus, with the UAV application, it can fly around any obstacles and view the site clearly in a short time (Mosly, 2017).

For construction claims assistance, aerial photography taken daily from the UAV can act as evidence and information to buttress or refute construction claims. Utilizing UAVs in construction claims provides a significant benefit in either proving or disproving a potential claim (Opfer and Shields, 2014). Aerial photographs and videos can also clearly illustrate work done by the contractor.

3D Modelling

In the construction industry, UAVs can be used to capture images from various angles, 360-degree photos, videos and Light Detection and Ranging to create 3D models. By creating 3D models, they can be integrated with Building Information Modelling (BIM) software to produce BIM models in order to have better management of the project.

For site surveying, UAVs can collect sufficient data to create 3D models. These data captured by the UAV can be used for site surveying (Dupont, et al., 2017). During pre-construction stage, site visits to the proposed site is required prior to the cost estimating of the project. However, it is very time-consuming. Barriers such as fences may also prohibit vehicular travel to some areas thereby requiring foot travel. In this situation, UAV can be used to fly close to the proposed site to inspect the area and identify any potential hazards that should be included in the cost estimation.

For measurement, UAV also can be utilized by roof contractors to conduct roof estimation by using aerial view of the roof top of the building. They can conduct estimation within a safe environment in a shorter period and a safer environment too.

In terms of integration with other software, many researchers stated that UAVs have been greatly used to integrate with BIM software as innovative technology applications (Teizer, 2015; Han and Golparvar, 2017). Aerial photo captured can be integrated with BIM software, as UAV provides high-quality data that can be generated into a 3D BIM model through mosaicking or stitching process to combine photos to create panorama image (Chen, Zhang & Min, 2019).

ISSUES OF UNMANNED AERIAL VEHICLE APPLICATION IN THE CONSTRUCTION INDUSTRY

Recently, with the new technology of UAVs rapidly developed and feast adoption of construction players, it raises both governments and public concerns too. It is necessary to identify the issues encountered by new innovative technology to improve the adoption of technology for construction productivity and work efficiency (Mosly, 2017). The issues encountered can be categorized into four main categories: safety issues, law and regulation issues, weather conditions and technical issues.

Safety Issues

UAV carries a host of jobsite safety to workers on site such as “loss of link” that will cause bodily injuries or property damage (Wang et al., 2016).

Law and Regulation Issues

Restrictive regulations for aviation traffic need to be enforced to avoid in-flight collisions throughout the construction industry (Golizadeh, Hosseini, Edwards and Abrishmai, 2019). According to the Civil Aviation Authority of Malaya (CAAM), Malaysia’s national aviation authority, flying a drone is legal in Malaysia. However, there are also rules and regulations to comply with when flying an UAV. Unfortunately, there are still a lot of construction players have uncertainty and are unclear of changing regulations and laws by the government (Mosly, 2017). Therefore, these issues may prohibit them to invest in UAV applications for their construction project. Highway construction and bridge surveying may inadvertently capture images of nearby homeowners which may invade their privacy concerns and cause an expensive lawsuit (Wang et al., 2016).

Weather Condition Constraints

As UAVs are normally lightweight, thus, weather condition constraint remains a challenge for the UAV to operate on site (Bugakov, Evgenov & Welker, 2015). They may be unstable flying at high wind speed (Opfer and Shields, 2014; Mosly, 2017). Higher wind speed will cause the UAV to vibrate and unstable, thus affecting the quality of the images captured.

UAV does not function well at an extreme temperature too. For instance, extremely cold temperature might cause the loss of functionality and UAV batteries loses their effectiveness (Mosly, 2017). While high temperature is also unfavorable for the engines which will also cause wear and tear on the batteries and engines (Golizadeh et al., 2019).

Technical Issues

Communication loss or interference is the most concern for UAV operation. For instance, the electrical sensors in the UAV, such as gyroscope or compass might be affected when the UAV is flying around magnetic sources that may cause communication interference. In this situation, it may result in loss of link of the UAV and operator which may crash to the ground and cause injuries and damages (Mosly, 2017).

UAV also requires a competent pilot to fly the UAV around the site. Thus, a well-trained pilot is needed to conduct safety inspections effectively in a safe environment (Melo, Costa, Alvares & Irizarry, 2017). Several studies reported that the short battery capacity has become a hindrance for them to adopt in UAV in the construction industry (Opfer and Shields, 2014; Morgenthal and Hallerman, 2014).

A safe and reliable storage platform is required for transferring large data collected during land surveying and inspection (Han and Golparvar, 2017). During the data analysis stage, parties might find difficulty in analyzing the large amount of visual data captured by the UAV in a single visit (Melo, et al., 2017). In addition, when laser scanner is used with UAV during surveying, it may experience a mixed pixel image, which eventually reduces the quality of the data captured by the UAVs (Hamledari, McCabe, Davari, Shahi, Rezazadeh & Flager, 2017). It will eventually lead to difficulty in analyzing the date for the subsequent process (Hamledari et al., 2017).

POSSIBLE SOLUTION TO REDUCE THE ISSUES OF UAVS

There are issues and limitations in using UAVs in construction projects where these issues will hinder construction players to adopt new innovative technologies due to the complexity of new technologies equipment. Therefore, solutions need to be investigated to reduce the issues faced by the construction players who opt to adopt unmanned aerial vehicles in their projects (Nnaji and Karakhamn, 2020).

Client's Project Incentives

Firstly, to encourage contractors to invest in unmanned aerial vehicles to improve their project performance in their project, clients should include requirements such as innovative technology and by providing incentives for the contractors who adopt UAVs in their project.

Local Positioning System

As unmanned aerial vehicles required GPS to be equipped with to fly around the site for regular site monitoring, however, there are some places that have weak GPS signals such as tunnels and basements. The weak GPS signal will cause the loss of connection of UAVs which may cause it to crash to the surrounding property or workers at site. In such situation, Tiemann, Schweikowski and Wietfield (2015) suggested that ultra-wideband (UWB) can be 20 utilized as an alternative local positioning system in tandem with GPS. By using UWB, UAVs can send location tracking data to the UWB receivers fixed at certain positions, to overcome the limitations of GPS signal such as failure in basement or tunnel, forest or blocked line-of-sight (Guo, Qiu, Miao, Zaini, Chen, Meng and Xie, 2016).

Battery Capacity of UAV

Another main issue of unmanned aerial vehicle application in construction industry is the low battery capacities that affect the operation of UAVs during site monitoring or site inspection. New battery nanotechnology types such as those produced by HE3DA and A123 Systems LLC provide better battery capacities and have been used in other products (Wong and Dia, 2017). In addition, photovoltaics can be another alternative solution to solve the current issues of low battery capacities.

Manual Instruction

Furthermore, UAV operators must fully understand and obey the manufacturer’s operational instructions of the device to ensure that no safety hazards on their project (Opfer and Shields, 2014). The UAV operators should also plan the flight route in advance and perform pre-flight checks before the operations to avoid any safety hazards during operations.

Flight Planning

Lastly, artificial intelligence (AI) has also been recommended to reduce the deficiencies of UAVs as facilitators to reduce the flight durations by designing and optimized flight paths for sufficient data collection (Torres, Pelta, Verdegay and Torres, 2016). By integrating AI in UAVs, they can help in planning flight routes and assist in making the operation safer and reduce the risks to the workers on site and the public through trying on various routes to ensure the 21 safety and effectiveness of the work in the future. Lastly, Internet of Things (IoT) and proximity sensors can be used for autonomous navigation of UAVs during operation to ensure a safe work environment (Palossi, Loquercio, Conti, Flamand, Scaramuzza and Benini, 2018).

RESEARCH METHODOLOGY

In this study, a quantitative method with closed-ended structured questionnaire is used where data is collected from a large scale of respondents by distributing online questionnaires. By using this method, data can be obtained within a short period to achieve the objectives of the research. Data can be quantified and interpreted to achieve research objectives easily during data analysis. This study focuses on the developers under the Klang Valley area which are listed in Real Estate & Housing Developers' Association (REHDA) only. In this research, the total number of populations is 410 for developers in Kuala Lumpur area and Selangor from REHDA. The sampling size formula used in this study is “Morgan Sampling Size Calculation”. The sampling size of this research is 199, a total of 410 questionnaires were distributed.

Data analysis is the most important part in the research to achieve the research objectives. Relative Importance Index (RII), Mean, Standard Deviation and percentages are used to analyze the data collected. RII is utilized to determine the significant application of unmanned aerial vehicles, the issues or limitations of the UAVs application and the possible solution to reduce the issues of UAVs application in the construction industry.

DATA ANALYSIS AND RESULT FINDINGS

Data analysis is a systematic method that analyzes and evaluates data by reviewing the data collected from questionnaire distribution. The main purpose of the data collected and evaluate them for the research.

Table 1. Application of UAVs in The Construction Industry

Category	Item	RII	Average	Rank
Aerial Photography and Camera Surveillance System	Business Advertisement	0.829	0.776	1
	Camera Surveillance System	0.746		
	Construction Claim	0.754		
Project Management	Safety Inspection	0.781	0.747	2
	Site Monitoring	0.712		
3D Modelling	Site Surveying	0.782	0.745	3
	Measurement	0.725		
	Integration with other software	0.729		

Table 1 above shows the application of UAVs in the construction industry. The average RII of each category is calculated from the items under each category and shown in the table. From the result above, ‘Aerial Photography and Camera Surveillance System’ is ranked 1 with the highest RII score of 0.776. ‘Business Advertisement’ has the highest rank with RII of 0.829, which shows that majority of the respondents think that UAVs can help in providing aerial photographs and videos for business advertisement purposes.

The Application of The UAVs in The Construction Industry

Table 2 summarized the application of UAVs in construction industry by each category with a few items under each category. The application of UAVs is categorized into 3 main groups: Project Management, Aerial Photography and Camera Surveillance System and 3D Modelling.

There are two items under Category ‘Project Management. Safety Inspection and ‘Site Monitoring’. ‘Safety Inspection’ has the highest rank under this category with an average RII of 0.781 followed by ‘Site Monitoring’ in the second rank with an average RII of 0.712. As safety concern is the key element in a jobsite for the construction project's success. Therefore, usage of UAVs for safety inspection is more significant as compared to site monitoring.

Category ‘3D modeling’ has three items under this category: ‘Site Surveying’, ‘Integration with other software’ and ‘Measurement’. Based on the data collected, most of the respondents think utilizing UAVs for site surveying is the most significant for the construction industry. By using UAs, land surveying can be done at a much faster pace as compared to foot travel and to capture aerial photos and video of proposed site in a short period (Opfer and Shields, 2014). According to Professor Hazry Desa, site surveying is said to be faster and safer with the utilization of drones (Sani, 2020). Drones are also very significant for mine construction as they can help to gather more information while ensuring the safety of the inspector as mine's construction site is dangerous due to its nature characteristics.

Category 'Aerial Photography and Camera Surveillance System' has three items which are 'Business Advertisement', 'Construction Claim' and 'Camera Surveillance System'. 'Business Advertisement' has the highest rank in the category with RII of 0.829, which is classified as the most significant UAVs application in the construction industry. Due to UAVs small size and maneuverability, they can capture data from various heights and angles starting from the surface ground level, sweeping through the project site and the fly-over views about the site where these images or videos can be used as business advertisement. Therefore, companies can provide a unique perspective of images and videos to demonstrate the project progress and use them for advertising for future projects (Tatum and Liu, 2017).

Table 2. The Application of The UAVs in The Construction Industry

The Application of The UAVs		Respondents' Scores				TR	RII	Rank
		SD	D	A	SA			
		1	2	3	4			
Category A: Project Management								
Safety Inspection	Provide thermographic images for better security at night/ for wall inspection	1	0	23	11	35	0.814	1
	Damage Quantification	1	4	21	9	35	0.771	2
	Identify Potential Hazards/ Quantity Issues	1	1	29	4	35	0.757	3
	Average						0.781	1
Site Monitoring	By using RFID reader, to locate RFID tags attached on construction materials	1	7	23	4	35	0.771	1
	To plan on workflow of workers/ vehicles/ machineries at site	1	9	19	6	35	0.714	2
	Provide project manager live contact with workers on site via communicatin tools (Video and Voice transmitter)	1	7	24	3	35	0.707	3
	Average						0.712	2
Category B: Aerial Photography and Surveillance System								
Business Advertiement	Demonstrate project progress for future project	1	0	19	15	35	0.843	1
	Capture aerial photos and video as business advertisement to attract potential buyers	1	1	21	12	35	0.814	2
	Average						0.829	1
Construction Claim	Aerial photographs and videos taken can be used for work progress record for interim claim every month by the contractor	1	3	25	6	35	0.757	1
	Data captured by the UAVs can be used as evidence for construction claims arise from issues such as weather delays, work interference, site constraint and etc.	1	3	26	5	35	0.750	2
	Average						0.754	2
Camera Surveillance System	To monitor the site throughout the project duration	1	3	20	11	35	0.793	1
	UAVs can fly around without having any obstacles blocking the site view and provide bird's eye view of the site	1	4	21	9	35	0.771	2
	Average						0.754	2

Category C: 3D Modelling								
Site Surveying	UAVs can be used for land surveying prior for the cost estimating of the project by flying close to the proposed site to inspect the area and identify any potential hazards that should be included in the cost estimation	1	3	20	11	35	0.793	1
	UAVs can be used for data collection for mines construction as the surveyors always operate in a dangerous environment during site inspection	1	4	21	9	35	0.771	2
	Average						0.782	1
Integration with other software	Ariel photos captured by the UAVs can be generated into 3D BIM model that can eventually enhance the communication between parties involved by providing clear information of the project	1	3	29	2	35	0.729	1
	3D BIM models can be used to compare asplanned model and as-built model for project monitoring	1	2	31	1	35	0.729	1
	Average						0.729	2
Measurement	UAVs can be utilised by roof contractors to conduct roof estimation by using aerial view of roof top from the UAV	1	2	28	4	35	0.750	1
	UAVs can capture HD images and videos to provide sufficient and accurate data for the engineers to generate 3D models for calculation	1	7	25	2	35	0.700	2
	Average						0.725	3

The Issues of UAVs Application in the Construction Industry

Based on Table 3, 'Technical Issues' with an average RII of 0.694 is ranked as the top 1 issue which indicates that technical issues of UAVs are the main hindrance affecting the adoption of UAVs by the developers for their construction industry. The short battery life and limited flight time of UAVs is the most significant technical issue that affects the rate of adoption of UAVs among the construction players. This is the tandem with several studies that have reviewed the short battery capacity has become a hindrance for them to adopt UAV for their construction sites (Opfer and Shields, 2014; Morgenthal and Hallerman, 2014).

Next, 'Weather Condition Constraint' is ranked second in this objective. The most concerned issue by the construction players is the UAVs may be unstable flying at high wind speed due to its size and lightweight which will affect the quality of images and videos produced by the UAVs. Shadows and glares from reflective surfaces may affect the 3D mapping of the construction site during daytime. The third-ranked category is 'Safety Issues'. Safety issues such as loss of links between the operator and the UAV might cause crashes, disabling injuries or even fatality. The 'Law and Regulation Issues' is the least significant issues among the construction players on the adoption of UAVs for their site.

Table 3. Issues of the UAVs in the Construction Industry

Issues of the UAVs in Construction Industry		Respondents' Scores					TR	RII	Rank
		LS	LoS	S	HS	MS			
		1	2	3	4	5			
Technical Issues	Short battery life and limited flight time of UAVs	2	3	9	12	9	35	0.731	1
	When Integrating with BIM software, they might face difficulty in integrating the data collected smartly and fluidly into the 3D BIM model.	2	1	18	8	6	35	0.686	2
	The electrical sensors in the UAV might be affected when the UAV is flying aorund magnetic sources that may cause communication interference.	1	3	16	11	4	35	0.680	3
	During data analysis stage, users might find difficulties in analysing large amount of visual data captured by the UAV in a single visit.	3	4	15	9	4	35	0.757	4
Average								**0.684**	**1**
Weather Condition	UAVs may be unstable flying at high wind speed due to its size and lightweight which will affect the quality of images and videos produced by the UAVs	1	3	12	10	9	35	0.731	1
	During daytime, shadows and glares from reflective 3D mapping of the construction site.	3	7	13	8	4	35	0.617	2
	Extremely cold temperatures might cause loss of functionality and UAVs' batteries loses their effectiveness	2	8	15	5	5	35	0.617	3
Average								**0.655**	**2**
Safety Issues	Loss of links between the operator and the UAV may crashes, disabling injuries or even fatality.	2	2	15	11	5	35	0.686	1
	Utilization of UAVs will affect job site safety to workers on site usch as bodily injuries or property damage.	3	7	12	9	4	35	0.623	2
Average								**0.654**	**3**
Law and Regulation Issues	There are still a lot of construction players have uncertainty and unclear of changing regulation and laws by the government on UAVs.	3	5	9	11	7	35	0.680	1
	Highly trained operator is required to control the UAVs in construction site due to its nature complexity.	1	4	16	10	4	35	0.669	2
	During site surveying, UAVs may inadvertently captured images of nearby neighbourhood which may invade their privacy concern and cause an expensive lawsuit.	4	7	11	9	4	35	0.611	3
Average								**0.653**	**4**

The Possible Solution to Reduce The Issues of UAVs Application

Table 4 shows the summary of the possible solutions reviewed and analyzed with their RII scores and ranking in accordance with RII scores. As technologies become more advanced to improve the effectiveness of the construction project, construction players are encouraged to adopt innovative technologies as a tool for enhancing project performance (Nnaji and Karakhamn, 2020). However, construction players face various issues of UAVs discussed above that will hinder the adoption of new innovative technologies. Thus, solutions need to be investigated to reduce the issues faced by the construction players who opt to adopt UAVs in their projects.

Table 4. The Possible Solutions to Reduce The Issues of UAVs Application

The Possible Solution to Reduce The Issues of UAVs Application	Respondents' Scores				TR	RII	Rank
	SD	D	A	SA			
	1	2	3	4			
Real-time location tracking system (RTLS) can locate the workers, plants and equipment to send warning signal to the UAVs to prevent hazards.	2	3	9	12	26	0.731	1
UAVs operators must fully understand and follow the manufacturer's operational instructions of the particular UAV device to ensure that no safety hazards in their project.	2	1	18	8	29	0.686	2
Photovoltaics can also provide more power of UAVs to operate in longer duration which can increase the efficiency and accuracy of data captured.	1	3	16	11	31	0.680	3
UAV operators should plan the flight route in advance and perform pre-flight check before the operations to avoid any safety hazards during operations.	3	4	15	9	31	0.757	3
UAV operators should also monitor the UAV's battery life and be aware of the maximum battery lifetime to avoid any power failure of UAV.	1	3	12	10	26	0.731	4
AI can also be integrated in ensuring the operational safety and reducing the risk to the workers on site and the public through trying on various routes before the operations.	3	7	13	8	31	0.617	5
Artificial Intelligence (AI) is also recommended to reduce the deficiencies of UAVs as facilitators to reduce the flight durations by designing an optimised flight path for efficient data collection.	2	8	15	5	30	0.617	5
GPS equipped in UAVs might be affected in areas such as tunnels and basement, ultra-wideband (UWB) is a local positioning system that can be utilised to send location tracking data to the UWB receivers fixed at certain positions to overcome the limitations of GPS signal.	2	2	15	11	30	0.686	6
New battery nanotechnology types such as those produced by HE3DA and A123 systems LLC can provide better battery capacities for UAVs.	3	7	12	9	31	0.623	7

From the table shown, unmanned aerial vehicles required GPS to be equipped with to fly around the site for regular site monitoring, however, there are some places that have weak GPS such as tunnels and basements. Therefore, by using real-time location tracking system can prevent loss of connection of the UAVs in construction site. UAVs operators shall also understand fully the operational instruction to control the UAVs safely and efficiently.

Operators should also plan the flight route in advance and perform pre-flight checks to avoid any safety hazards during the operation in site. It is also suggested to replace UAV's batteries to photovoltaics power which can provide more capacity for UAVs to operate in longer duration which will eventually increase the accuracy and effectiveness of data collected.

LIMITATION OF STUDY

In this study, various limitations have been encountered during the development of research. However, the main objectives of the study are said to be achieved. The first limitation for this research is there are 64 bounces back emails throughout the collection of questionnaire responses where a total of 410 questionnaires were distributed to the developers listed in REHDA under Klang Valley area. This will eventually lower the response rate for the questionnaire to achieve the sampling size.

Next, the details of developers on the REHDA official website are insufficient where they do not include the contact information of developers' companies. Therefore, the method used is to obtain the email addresses of developers through their official websites, which is very time-consuming. Furthermore, the limitation of this study is insufficient time to collect more responses and information where the work program is considered as tight schedule for the completion of the research. Lastly, majority of the respondents are not fully aware of the usage of UAVs, therefore, they might not be able to give in dept opinions or perspectives in the questionnaire which results in low diversity.

CONCLUSION

In the construction industry, there are different issues involved in sustainable construction such as design, performance and project management. Recently, there are many types of innovative technologies that have contributed to enhance construction project management and their performance, which include Unmanned Aerial Vehicle (UAV). However, the implementation of UAVs in the construction project is still under development. Therefore, there is a need to increase the research and development in the usage of UAVs in construction projects to improve the industry's performance.

In this study, it determined the application of the UAVs available in the construction industry, issues of the UAVs application faced in the construction site and investigated possible solutions to solve the issues of UAVs and increase the rate of adoption of UAVs in the construction industry.

From the findings of the research, the top rank application is Category B, Aerial Photography and Surveillance System, which shows that UAVs are widely used for business advertisement, camera surveillance systems and for construction claim to provide aerial photographs and videos of the construction site. This application also showed a reduction of time and cost and aid the clients' understanding by having visual data captured by the UAV. Despite the various applications of UAVs in the construction industry, there are still issues that are considered as hindrances for construction players to adopt further UAVs. The top issue investigated from the findings is the technical issues such as short battery life and limited flight time of UAVs. When integrating with BIM software, users may face difficulty in integrating data smartly and fluidly into the 3D BIM model due to its complexity. Software needs to be designed to greatly integrate UAVs and BIM models to create 3D models more easily.

Lastly, the government is also the key player in encouraging the adoption of UAVs in the construction industry by providing more incentives and regulating the standard requirement for the ease of operation of UAVs in the site. However, every construction player also plays a significant role in the implementation of UAVs by involving and adopting in UAVs construction projects for a better performance industry.

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A CALCULATION MODEL FOR EVALUATING RURAL RESIDENTIAL LAND VALUE IN CHINA

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Abstract
Rural residential land is not only the largest source of farmers' assets, but it is also a land resource for addressing the scarcity of urban land for development purposes. Nonetheless, these lands have been idle and unutilized for a long time. In order to revitalize rural residential land and address various issues in the utilization process such as undervalue compensation to farmers, trading prices in private are chaotic and financing mechanisms for residential land are blocked. These issues occur as a result of the consequences of not having a comprehensive method in determining the value of rural residential land. Hence, this research aims to develop a holistic approach for evaluating rural residential land value. The study adopts the multi-functional value theory in which multi-functional values are determined by studying key functions and influences of safeguard, production, assets, ecology and culture on the value of the rural residential land. This study employed quantitative research design with participatory rural assessment (PRA) as the primary method of data collection. The participatory rural assessment method uses a semi-structured questionnaire. Chuanshan District, Suining City, Sichuan Province, was chosen as the study area and a total of 300 questionnaires were received. According to the results, the current compensation value of the rural residential land was 63.83 percent of the calculated value. This reaffirms the majority of farmer villagers' complaints about being undercompensated. The findings from this paper recommended five multi-functional values for evaluating rural residential land as well as its proposed calculation model.

Keywords: *Rural residential land; Multifunctional; Quantitative analysis; Value measurement; Empirical research*

INTRODUCTION

Since the reform and opening up, China's rapid industrialization and urbanization have attracted a large number of rural labor force to work in cities. The rural population has decreased year by year, the phenomenon of rural "hollowing out" has increased, and the idle situation of rural residential land has intensified. In 2018, the idle rate of rural residential land in China reached 10.7% (Wei, Huang, Li, Sun, & Soo, 2019). According to a survey conducted by the Chinese Academy of Social Sciences, the idle area of rural residential land in China is about 2 million hm^2, and about 595 million m^2 of rural idle housing is added every year due to the transfer of rural population to cities, equivalent to a market value of about 400 billion yuan (Wei, Yan, Tan, Cui, & Soo, 2017) .The supply of urban construction land is limited, and rural construction land is primarily rural residential land. Due to the urban-rural dual land system, idle rural residential land cannot enter the market transaction (NPC, 2013), which intensifies the contradiction between supply and demand of urban construction land. The use efficiency of rural construction land is low, and the land assets, as the largest source of farmers' assets, have been in a "sleeping" state for a long time.

Rural Revitalization Strategy is the most important rural development strategy in China at present, and rural residential land reform is an important starting point for Rural Revitalization. Rural residential land accounting for 50% of the total urban and rural construction land (Zheng, 2018). Rural residential land is not only provided land guarantee for the implementation of Rural Revitalization Strategy but also land assets with huge wealth. In order to revitalize rural land assets, in 2019, China newly revised the land administration law of the people's Republic of China, which made it clear from the legal perspective that "farmers who are allowed to settle in cities are allowed to voluntarily withdraw from the rural residential land with compensation according to law, and rural collective economic organizations and their members are encouraged to revitalize and use the idle rural residential land base and idle residence" (NPC, 2020). Hundreds of millions of farmers' families are affected by the reform of rural residential land use. Because land is the foundation for farmers to settle down, and rural residential land is an important space for farmers' production and life. If there are no policies and measures to effectively protect farmers' rights and interests in the process of rural land reform, it may lead to the loss of farmers' assets and the risk of social stability.

How to effectively protect farmers' rights and interests is not only the focus of the state and society, but also the difficulty of rural land reform. Often the rural residential land transferred to the government for construction use are undervalued. As a result, systematically and comprehensively clarifying the value composition system of rural residential land, as well as scientifically and reasonably evaluating the value of rural residential land, will aid in achieving a win-win situation between the efficient utilization of rural residential land and the protection of farmers' rights and interests.

There have been extensive discussions on the function of rural residential land and the construction of its value evaluation system. Firstly, existing studies generally agree that rural residential land has residential and property functions (Qu & Zhu, 2015; Zhang & Fu, 2017; Zhang & Xu, 2018), but there are still differences in other functions of rural residential land, such as political stability function, production function, cultural function, ethical function, etc., especially in the cultural function of rural residential land (Yang, 2018). With the development of social economy, the asset function of rural residential land in China is increasing (Lin & Tan, 2013). At the same time, the asset function of rural residential land is reflected in different space. With the increasing distance from cities and towns, the asset function of rural residential land is decreasing (Qu & Zhu, 2015).

Zhang Yong et al. (Zhang & Xu, 2018) proposed that the housing security value, potential value production factor value and development right value, intergenerational value and cultural emotional value of rural residential land should be included in the rural residential land value system.

There are several research on the evaluation and calculation of rural residential land value. Specifically, the "equivalent substitution method" is generally used to calculate the housing security value of rural residential land (Hu et al., 2013; Zhang, 2017). The asset value of the rural residential land is calculated according to the income reduction method (Hu et al., 2013). The option value of the uncertainty of the rural residential land is estimated by the agricultural land option value model (Hu et al., 2013). Whereas the right to develop rural residential land is valued using the cost approximation method (Zhang, 2017).

In recent years, Chinese academia has conducted a lot of theoretical and empirical research on the value compensation model of rural residential land exit. For example, Cai Guoli (Cai and Xu (2012)) combed and evaluated the rural residential land replacement mode in Shanghai, Zhejiang Jiaxing and Tianjin, and believed that the difference of regional economic development level determines the different ways of rural residential land value compensation. Peng Changsheng (Peng (2013)) made a comparative analysis on the housing resettlement and monetary resettlement modes of rural residential land withdrawal in different regions of Anhui Province. Taking Chengdu as an example, Wang Xining (Wang (2011)). analysed the difference between the withdrawal mode of farmers taking shares in rural residential land use right and the withdrawal mode of replacing urban housing. Shang-guan Caixia (Shang-Guan, Feng, Lv and Qu (2014))compared and analysed the differences and reasons of three different rural residential land exit modes adopted in different regions of the "million hectares of fertile farmland construction project" in Jiangsu Province, and considered that the scarcity of regional land resources, the stability of land transfer, the stability of rural social security and the size of non-agricultural employment opportunities are the reasons affecting the differences of rural residential land value compensation modes. These studies mainly discuss the value of rural residential land from the aspects of location, economic development, social security and employment opportunities, but they are one-sided, do not systematically and comprehensively see the multiple functions of rural residential land, and do not protect the interests of farmers to the greatest extent. At present, there is no unified standard or guidance on the evaluation and compensation model of rural residential land value throughout the country.

To sum up, the research on building the rural residential land value system from the multi-functional dimension of rural residential land and evaluating the rural residential land value standard system is still in its infancy. Although previous studies have paid attention to the multiplicity and spatial differences of rural residential land functions, they have not been systematic and comprehensive. Therefore, based on the existing research results, this study analyses the functional composition of rural residential land from the perspective of farmers' demand and welfare economics, and constructs the multi-functional value evaluation and calculation model of rural residential land based on the multi-functional value theory of rural residential land, in order to improve the rural residential land exit compensation value system and enrich the multi-functional value calculation methods of rural residential land.

RESEARCH METHODS

Study Area

The research area for this paper is Chuanshan District, Suining City, Sichuan Province. Chuanshan district is located in the Sichuan Basin's central region, adjacent to Nanchong to the east, Chengdu to the west, Chongqing to the south, and Mianyang to the north. Suining City's political, economic, and cultural centre. The State Council approved the establishment of the county-level administrative region in 2003, covering an area of 367.1 square kilometres. It governs six towns, one township, five streets, 73 administrative villages, and 48 communities, totalling approximately 400,000 permanent residents.

Chuanshan district is well-positioned for agricultural and rural industrial development. It has been named the national leisure agriculture and rural tourism demonstration zone, the national pilot demonstration zone for the integrated development of primary, secondary, and tertiary industries in rural areas, the advanced county (District) for county economic development in the province, the advanced county (District) for "agriculture, rural areas, and farmers," the advanced county (District) for poverty alleviation, and the advanced county (District) for increasing income.

The Chuanshan district is highly urbanized. By November 2020, 690,686 permanent residents in Chuanshan District lived in cities and towns, accounting for 82.93 percent; 142,177 people lived in rural areas, accounting for 17.07 percent. In comparison to the sixth national census in 2010, the urban population increased by 228,434, the rural population decreased by 52,331, and the urban population proportion increased by 12.55 percentage points. A large number of rural populations entering the city indicates that a large number of rural residential lands are vacant, and that a large number of rural residential lands are underutilised.

Suining has implemented a total of 40 projects since 2008, linking the increase and decrease of urban and rural construction land. The increase and decrease linking mode has resulted in the effective regulation of rural residential land. The increase and decrease linking projects are primarily intended to reclaim idle rural construction land, and the original indicators of rural construction land can be traded in the open land market, thereby resolving the contradiction between idle rural construction land and insufficient urban construction land. Suining has built a number of demonstration sites for new rural construction as part of the increase and decrease linked project, which has effectively changed the appearance of villages, promoted rural economic development, increased rural income, and improved the beauty of villages, and helped promote rural revitalization. As a result, the Chuanshan District of Suining City was chosen as the research area, primarily because Chuanshan District has a good foundation for rural industrial development, a large number of rural land test projects, and more practical data for reference and research.

Data Sources

The data in this paper comes from the field survey, which is conducted from July to September 2021. The survey sites are Longfeng Zhenbao village, Fuxing community, Longbao village, Shiqiao village, Zhaizi village and Zongshu village, Chuanshan District, Suining City, Sichuan Province. The sample size was determined to be 300 based on a population of 10,134 pax.

The participatory rural assessment method (Gao (2003)) mainly adopts the way of semi-structured questionnaire. The researchers assisted the respondents in answering the questionnaires to ensure that the questions were clear. The direct communication with the interviewees provides more validity in the results and increased the participation of the respondents in the research. Random sampling (Yao and Zhang (2012)), also known as convenience sampling, refers to the selection of random people as survey objects to obtain survey data according to the actual situation and in order to facilitate work. A total of 300 questionnaires were obtained using the participatory rural assessment (PRA) and random sampling method, yielding 280 valid questionnaires. The effective rate was 93.33%. The age distribution of respondents is shown in Table 1. The survey objects mainly include local land and resources offices, village offices, village cadres and local farmers. The survey contents mainly include the use and income of rural residential land, farmers' life satisfaction, farmers' willingness to withdraw or transfer rural residential land, as well as various insurance and other social and economic data.

Table 1. Age Distribution of Respondents

Age Status of Respondents	Percentage (100%)
16-19years old	14.39
20-24 years old	4.55
25-29 years old	1.52
30-34 years old	1.52
34-50 years old	5.30
41-50 years old	11.36
51-60 years old	18.18
61-65 years old	12.12
65 years old and above	31.06

MULTIFUNCTIONAL VALUE COMPOSITION AND CALCULATION MODEL OF RURAL RESIDENTIAL LAND

Multifunctional Value Composition of Rural Residential Land

The ownership of rural residential land belongs to the rural collective. The right to use rural residential land is a kind of usufructuary right, including the rights of possession, use, income and limited disposal. Farmers' withdrawal from rural residential land will mean the permanent loss of various possible rights and interests attached to it, and the oblige will lose the long-term holding and inheritance of such rights and interests. Therefore, to evaluate the value of rural residential land, we should not only consider the economic value of rural residential land, but also consider the values of social security, ecological contribution, cultural emotion and so on. We should not only consider the current value but also consider the possible value in the future. At present, the compensation standard for rural residential land withdrawal has not been clearly stipulated in relevant laws, the academic community has not formed a unified opinion on the method of evaluating rural residential land value, and all localities have also adjusted measures to local conditions in practice and have not put forward a calculation method that can be popularized.

Due to the long-term urban-rural dual land policy, China has not formed a land market integrating urban and rural areas, and there are few cases of rural residential land value evaluation. In addition, the rural residential land has the characteristics of usufructuary right attribute, special right subject, free acquisition and long-term use. Therefore, the evaluation method of urban land cannot be directly applied for evaluation and calculation.

In view of this, according to the existing research results on the value of rural residential land, analyse its function from the perspective of the effectiveness of rural residential land for owners or users, and comprehensively consider the loss of property rights and risks faced by farmers after they withdraw from rural residential land. From the perspective of farmers' demand according to the principle of "what function is lost and what value is compensated", Scientifically identify the multifunctional value of rural residential land.

This paper cites the integration concept of "Full integration" in the Rural Revitalization Strategy, that is, the integration of ecology, production and livelihood, and explores the multi-functional value of rural residential land, as shown in Figure 1. In terms of production, as a space for production activities, rural residential land can be cultivated, leased or reclaimed into cultivated land. Based on different location and economic conditions, the possible development in the future is different. Therefore, the concept of option is introduced in terms of production to reflect the asset value of rural residential land; In terms of ecology, the greening landscape and houses inside the rural residential land are part of the beautiful countryside. After the rural residential land is reclaimed into cultivated land, it can also improve the rural ecological environment, In terms of livelihood, rural residential land accounts for a large proportion in farmers' property system. It should not only provide residential security for farmers' life but also undertake certain social security functions. China's economy is developing continuously, people's quality is improving continuously, and the demand for cultural emotion is increasing. Rural residential land has the functions of maintaining family ties, cultural entertainment and local emotion sustenance. The functional value of rural residential land can be calculated by income Capitalization approach, equivalent substitution method, market value method and other methods to build a comprehensive quantitative evaluation model. Some of these functional values can be realized at the same time, and some are substitutable. In order to facilitate comparative analysis in the later stage, this paper summarizes all kinds of functional values as the total functional value of rural residential land.

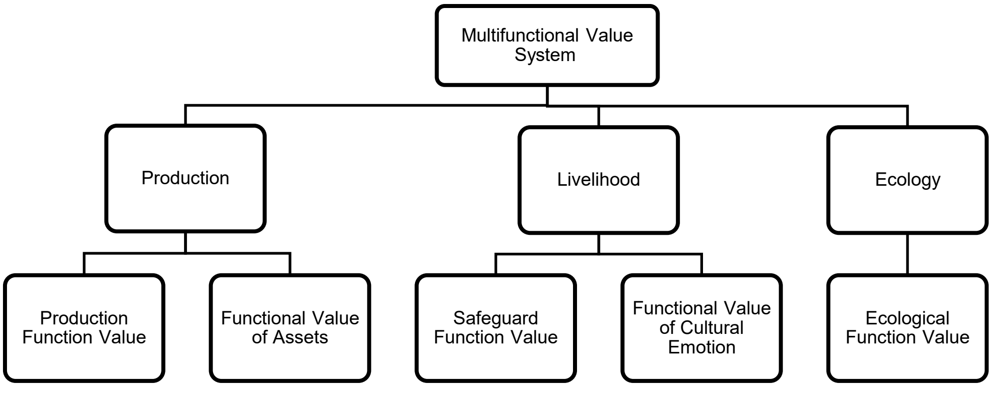

Figure 1. Multifunctional Value System of Rural Residential Land

Calculation Model for The Multi-Functional Value of Rural Residential Land

The multi-functional value calculation model for rural residential land is critical for determining the compensation standard for farmers who withdraw rural residential land voluntarily or for a fee. Compensation for farmers withdrawing from rural residential land should fully safeguard farmers' rights and interests. From the perspective of farmers' needs and guided by the principle of "what to lose, what to compensate," identify the multi-functional value of rural residential land in a systematic manner and evaluate it using scientific and reasonable methods in order to protect farmers' current and future rights and interests to the maximum extent possible.

Quantitative Model of Production Function Value

There are two main scenarios to give play to the production function of rural residential land. The first is as a production place. The second is that after farmers withdraw from the rural residential land, the rural residential land is reclaimed into cultivated land. Based on the hypothesis of "rational economic man", farmers will choose the most beneficial use to maximize their own interests. The differentiation of rural residential land production function is mainly based on the local economic development and the distance from cities and towns. In the suburbs and urban-rural fringe close to the city, most of the rural residential lands are used as production sites for rental operation, and the main income comes from leasing; In remote rural areas, after farmers withdraw from the rural residential land, they are generally reclaimed into cultivated land, and the income mainly comes from the production of crops.

According to the interview and investigation, the breeding, rental income and reclamation of farmers' rural residential land are collected and estimated by income Capitalization approach based on the market transaction price. Income Capitalization approach is one of the most commonly used methods in real estate appraisal. It is a kind of appraisal method that uniformly converts the expected objective income of the real estate to be appraised in the future to the present value of the appraisal period at a certain capitalization rate (reduction interest rate). The income method is based on the expectation principle, that is, the current value of future income rights. It is generally applicable to the valuation of land or real estate with real or potential income (Hu et al., 2013). The formula is:

$$V_1=R/r \tag{1}$$

In formula (1): V_1 represents the production function value of the rural residential land, and r represents the reduction interest rate; R represents the income from rural residential land breeding, leasing or reclamation.

Quantitative Model of Asset Functional Value

There is no mature rural construction land market in China. Although great support has been given in law and practice at the national level, a unified and mature rural construction land trading market has not been formed at present. Therefore, in this uncertain environment, the income of a residential base is also uncertain. As a vulnerable group, farmers must consider the future uncertain income when exiting the rural residential land, so the option equity pricing theory is introduced (Hu et al., 2013).

The option value of rural residential land can be estimated with reference to the agricultural land option model. Assumptions: the contingent interest in the rural residential land is a perpetual American call option; Perfect competition in circulation market; Scale is an exogenous variable; The income satisfies geometric Brownian motion, and the model is:

$$V_2=\frac{R}{r(\beta-1)} \tag{2}$$

$$\beta=\frac{1}{2}-\frac{u}{\sigma^2}\pm\sqrt{\left(\frac{1}{2}-\frac{u}{\sigma^2}\right)^2+\frac{2r}{\sigma^2}} \tag{3}$$

Formula (2) - in Formula (3): V_2 represents the functional value of rural residential land assets; R represents the rent of rural residential land or the income from reclamation into cultivated land; β from σ, r and u decide, σ is uncertainty, u is the expected rate of return of leasing or reclamation, r is 5.94% of the long-term interest rate over 5 years, and R / r = 1 is assumed.

Quantitative Model of Safeguard Function Value

Due to the large gap between the current rural social security system and the social security system of urban residents and employees, the rural residential land still plays an important role in ensuring farmers' life. Withdrawing from the rural residential land means that farmers have no housing security and lose the low-cost lifestyle of "relying on mountains and rivers and water", and the lifestyle of participating in urbanization. Farmers need to re cultivate their life skills, accompanied by the increase of farmers' living costs. Therefore, the security role of rural residential lands should include the most basic housing security and social life security.

(1) Housing Security Function

For the housing security function of rural residential land, the substitution method shall be used with reference to the rental housing subsidy of public rental housing (Yuan et al., 2021). Therefore, the calculation model based on public rental housing subsidy is as follows:

$$S_1=12\times N_1\times a_1 \tag{4}$$

$$V_{31}=\frac{S1}{r}\times\frac{A1}{b} \tag{5}$$

In Equation (4) – Equation (5): S_1 represents public rental housing subsidy (yuan / person · year); N_1 and A_1 respectively represent the guaranteed area of public rental housing per capita and the rent subsidy per unit area (yuan / person · month); V_{31} represents the residential security value of the rural residential land (yuan / m^2); A_1 and b respectively represent the total population of the research area and the total area of rural residential land; r represents the reduction interest rate.

(2) Due to the existence of the urban-rural dual system, China's rural residents cannot obtain the same social security treatment as urban residents, such as medical treatment, pension, career and so on. Rural residential land has the right to use it free of charge and indefinitely. The rural residential land undertakes some functions of social security for rural residents (Yuan et al., 2021). This paper takes the difference of social security subsidies given by the government to farmers and urban workers as the theoretical value, and the formula is:

$$V_{32}=\frac{VUI-VRI}{r\times b} \tag{6}$$

In Formula (6): V_{32} represents the social security value of rural residential land (yuan / m^2); VRI and VUI respectively represent the old-age insurance subsidies provided by the government to farmers and urban employees; b represents the area of rural residential land; r represents the reduction interest rate. To sum up, the guaranteed function value is:

$$V_3= V_{31} + V_{32} \tag{7}$$

In Equation (7): V_3 represents the value of rural residential land guarantee function.

Quantitative Model of Ecological Function Value

According to the ecosystem classification, the agricultural land and vegetation coverage in the current rural residential land and the cultivated land reclaimed in the future in the investigated area are close to the dry land in the secondary classification of land use in terms of climate, hydrology, soil and environment, Therefore, the service value per unit area of dryland ecosystem in the newly improved table of service value per unit area of terrestrial ecosystem in China (Xie et al., 2015) is referred to in the calculation, and the multiple cropping index of cultivated land is used to modify the bioequivalence factor (Yuan et al., 2021) and the formula is:

$$V_4=\frac{E_a \times f \times j}{r} \tag{8}$$

In Formula (8): V_4 represents ecological function value; r is the reduction interest rate; F and Ea respectively represent the bioequivalence factor per unit dry land area and its unit value; J is the corrected value of cultivated land multiple cropping index. Among them, according to previous research results (Gao, Shi, Huang, Zhang & Soo, 2013), Ea takes 1 / 7 of the national average grain yield market value, and the formula is:

$$Ea=\frac{1}{7}\sum_{i=1}^{n} \frac{m_i p_i q_i}{M} \tag{9}$$

In Formula (9): M represents the total sown area of grain crops; i and n represent the type and quantity of food crops respectively; mi, pi and qi respectively represent the sowing area, average unit price and yield of the itch food crop.

Quantitative Model of Cultural Emotional Function Value

As the most important landform in the village space, rural residential land is an important part of rural land. It is closely related to the production and life of farmers' families and carries a long agricultural culture and traditional rural land culture. The local culture contained in rural settlements, and the diligence and wisdom of ancestors also have the important function of educating future generations.

These cultural and emotional values of rural residential land cannot be seen or touched, but they do exist. They have great social influence and are of great significance to maintaining rural social stability. Rural residential land carries farmers' sense of belonging and security. (Zhang, Xu, 2018).

At present, there is no recognized quantitative means for the cultural function value carried by the rural residential land. Referring to the existing research methods, this paper selects the consumption difference between urban and rural residents in terms of culture and entertainment (Liu, Gong, 2020), and the formula is:

$$VCi=(VUC-VRC)/r \tag{10}$$

$$V_5=VCi\times A_1/b \tag{11}$$

In Equation (10) – Equation (11): VRC and VUC respectively represent the expenditure of cultural and entertainment supplies and services of rural and urban residents (yuan / person · year); r is the discount rate, V_5 is the psychological theory value of the rural residential land (yuan / m^2); A_1 and b respectively represent the total rural population and the total area of rural residential land.

RESULTS

The survey data was mapped out according to the five multi-functional values of rural residential land identified in the literature. The following section summarizes the findings for each of the multi-functional values.

Production Function Value

(1) Breeding income. According to the field investigation and interview, farmers' family breeding is mainly chicken and duck, mainly for their own consumption, and the breeding scale is between 8-14. Therefore, this paper obtains the breeding income per unit area of rural residential land by taking the ratio of the profit income of 10 laying hens sold in the market every year to the average rural residential land area of each household. According to the survey, the laying hens raised by retail investors are listed once every 6 months, the average weight is 2kg, the average selling price is 30 yuan / kg, the average cost of chicken seedlings is 3 yuan / piece, and the monthly feeding cost of farmers is 0.5 yuan / piece. The average household rural residential land area is 138m^2. Based on the capital reduction rate of 5.94% of long-term interest rate for more than five years, the production function (breeding income) of rural residential land is 68.8 yuan / m^2.

(2) Income from reclamation into cultivated land. According to the local land transfer market information, the annual average cultivated land transfer price per mu in Chuanshan mountain area of Suining, Sichuan is 9000 yuan / hm^2, and the future reclamation income of rural residential land is 15.14 yuan / m^2.

(3) Rental income. According to the survey data, the average annual rent of the rural residential land in the study area is 1650 yuan / year, so the rental income of the rural residential land is 201.29 yuan / m^2.

After calculation, the production function value of rural residential land is 95.08 yuan / m^2.

Functional Value of Assets

The option value of rural residential land refers to the possible value of rural residential land under uncertain circumstances in the future, that is, the floating value based on the existing value. When other parameters remain unchanged, the option value increases with the increase of uncertainty and expected return growth rate and decreases with the decrease of risk-free interest rate (Liu, 2015).

The future income of the rural residential land varies greatly due to its different purposes. Considering the option value of the houses on the rural residential land for rental operation, and referring to the year-on-year increase of the national rental house rent and the year-on-year increase of the national urban consumer price from 2015 to 2020, it is assumed that the housing rent increases by 4% every year, that is, u = 4%; According to the income growth rate of grain planted for many years, u is taken as 2%. At present, China's economy has entered a stage of high-quality development σ Taking the positive number, referring to the scholars' calculation and analysis of China's potential economic growth rate from 2021 to 2025, the uncertainty (economic development risk rate) is taken as 5.7% (Tang et al., 2020). Different r, u σ Under the combination, assuming R / r = 1 under deterministic conditions, the option values under different land uses are shown in Table 2 below:

Table 2. Proportion of Rural Residential Land Option Value Under Uncertainty

Σ	R	U	B	Option Value	Rural Residential Land Value	Proportion of Options %
5.70%	5.94%	4%	1.458	2.183	3.183	68.59
		2%	2.624	0.616	1.616	38.11

It can be seen from Table 1 that under the current interest rate and u = 2% grain income growth rate, the proportion of cultivated land option value in the total value is 38.11%, and under the current interest rate and u = 4% rental income growth rate, the rent option value accounts for 68.59% of the total value. The value of the rural residential land is equal to the current income of the rural residential land plus the option value, so the option value of the rural residential land is calculated as shown in Table 3.

Table 3. Functional Value of Rural Residential Land Assets Under Uncertainty

u	Rental or Reclamation Value (yuan / m^2)	Proportion of Options%	Option Value (yuan / m^2)
4%	201.290	68.587	439.496
2%	15.140	38.110	9.323

Safeguard Function Value

(1) Housing security function value. The rent subsidy standard of public rental housing in Suining City is calculated according to the guidance of the Ministry of housing and urban rural development and the Ministry of Finance on doing a good job in the rental subsidy of urban housing security families, and the per capita construction area is 20 square meters. For families enjoying the urban minimum living security treatment (minimum living security families), the rent subsidy standard is 7 yuan / m^2 / person / month. Rent subsidy standard for urban low-income families, newly employed workers without housing and migrant workers: 5 yuan / m^2 / person / month. The average annual subsidy per person is 1440 yuan. The reduction interest rate is 5.94% of the bank's long-term deposit interest rate for more than 5 years. The per capita rural residential land area in the study area is 138m^2. r is the five-year national standard capital reduction rate after risk adjustment of 4.99%. According to formula (4-5), the quantitative value of residential security function of rural residential land is 209.11 yuan / m^2.

(2) Social security function value. Rural residential land has free and indefinite use right. It provides farmers with certain social security, which can be reflected by the difference between the social security funds provided by the government for urban residents and urban and rural residents (Zhu et al., 2017).

According to the measures for the implementation of old-age security for land expropriated farmers in Sichuan Province, the upper and lower limits of the payment base are determined respectively at 300% and 60% of the average wages of employees in all urban units in the province in the previous year. In 2020, the average wage of employees in all urban units in Sichuan Province was 74520 yuan (6210 yuan / month). Therefore, the upper limit of payment base is 6210 × 300% = 18630 yuan / month, and the lower limit of payment base is 6210 × 60% = 3726 yuan / month, the minimum amount of individual payment is 298.08 yuan, and the maximum is 1490.4 yuan. The government takes 2 / 3 of the minimum payment base as the payment base for social security subsidies for urban employees. Rural residents participate in the old-age insurance for urban and rural residents. In 2020, the maximum government subsidy will be 200 yuan / year. According to formula (6), the social security function value of rural residential land in the study area is 19.9 yuan / m^2.

According to Formula (7), the guaranteed value of rural residential land is 229.01 yuan / m^2.

Ecological Function Value

Referring to the grain income and grain sowing area in the study area in 2020, this study modifies the equivalent factor of standard unit ecosystem service value (Pei et al., 2021). Referring to the statistical yearbook of Suining City, it is calculated that the yield per unit area of main grain crops in Chuanshan mountain area of Suining in 2020 is 5831.33 kg / hm^2. Referring to the national compilation of agricultural product cost-benefit data 2020, it is sorted out that the unit price of agricultural products and grain crops in China is 2.19 yuan / kg. When the two are multiplied, the market price of grain per unit yield in the study area in 2020 is 12770.61 yuan / hm^2. Finally, the unit equivalent service value in the study area is 1824.37 yuan / hm^2, and the correction J of multiple cropping index is 1.24.

According to Formula (8) and Formula (9), the ecological function value of rural residential land is 3.81 yuan / m^2.

Functional Value of Cultural Emotion

The per capita expenditure on education, culture and entertainment of rural residents in Chuanshan district is 1574 yuan / person, and the expenditure on education, culture and entertainment of urban residents is 2637 yuan / person. According to Formula (10) and Formula (11), the cultural function value of the rural residential land is 140.76 yuan / m^2.

CONCLUSION

According to the calculations, the rural residential land value of typical villages in Longfeng Town, Suining City is 908.156 yuan / m^2 (USD142.3989/ m^2), which is greater than the current compensation price of 579.71 yuan / m^2 (USD 90.8985/ m^2). Thus, the findings of this study reaffirm the farmer villagers' complaints that they were undercompensated. The proposed model had incorporated multi-functional values from the perspective of the farmers' needs and economic wellbeing. The multi-functional values are production function value, assets functional value, safeguard function value, ecological function value and functional value of cultural emotion. This research also recommends several calculation models for each of the multi-functional values. The findings of this study serve as a starting point for compiling additional data in order to establish an appropriate compensation value for trading rural residential land. In future research, additional case studies will be incorporated to examine the multi-functional values found in various other locations.

There are several suggestions that can be considered for policy making based on the proposed calculation model for evaluating rural residential land value. Firstly, according to the functional value theory, the state issued guidance on value evaluation of rural residential land. The model of voluntary paid withdrawal of farmers' rural residential land has been investigated in various parts of the country, resulting in unsystematic practice with diverse value of the land due to a lack of national initiative to develop a standard unified guideline in valuing the rural residential land. According to the theory of functional value, the state can offer guidance on the evaluation of rural residential land value, by including the functional value system, evaluation standards and compensation methods of rural residential land. The guiding opinions which are offered by the state on the value evaluation of rural residential land can not only provide rules for the local government to promote the policy of voluntary and paid withdrawal of rural residential land but also provide laws for the protection of farmers' rights and interests of withdrawing rural residential land. Secondly, based on the classification of different types of villages for rural revitalization, and the differences in the functional needs of rural residential land in different types of villages, a differentiated rural residential land value evaluation scheme is formulated. In the Rural Revitalization Strategy, villages in China are divided into four types: agglomeration and upgrading, relocation and merger, suburban integration and characteristic protection. There are differences in the functional value of four types of village rural residential land. The value evaluation of farmers' rural residential land should be based on the type of village. Among them, the concentration and upgrading villages and the relocation and merger villages should pay attention to the compensation for the production value of the rural residential land, and actively guide the reemployment of farmers who cannot engage in agricultural production after the rural residential land withdrawal; the suburban integrated villages should pay more attention to the compensation of the assets value of rural residential land; The characteristics villages should pay attention to the compensation for the cultural and emotional value of rural residential land.

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THE ENHANCEMENT OF TOOLBOX TALKS FOR SAFETY MANAGEMENT IN MALAYSIA

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Abstract
The construction industry, despite its inherent risks, experiences numerous fatalities and accidents annually, highlighting the inadequate state of safety management on Malaysian construction sites. This research underscores the pressing need to enhance toolbox talks as a means of improving safety management. The study, conducted among G7 contractors registered with the Construction Industry Development Board of Malaysia (CIDB), revealed that the current implementation of toolbox talks for safety management is commendable. However, challenges persist, including time constraints due to heightened workloads, low participation from non-Indonesian foreigners, and the ineffectiveness of passive communication during toolbox talks. To address these challenges, the research recommends implementing task delegation plans, utilising translators for diverse audiences, and adopting a narrative presentation style to enhance engagement. The findings emphasise the urgency of elevating toolbox talks as a cornerstone of safety measures in the construction industry. As the construction sector plays a pivotal role in urban planning and smart city development, stakeholders in Malaysia are urged to prioritise and improve toolbox talks for the sustainability of these initiatives. Future research should focus on refining measurement metrics to establish toolbox talks as an indispensable component of construction industry safety practices.

Keywords: *Toolbox talks; meeting; safety management; enhancement; the Malaysian construction industry*

INTRODUCTION

Construction site fatalities and accidents are increasing in developed countries (Al-Shabbani et al., 2020). According to Oswald et al. (2018), a lack of emphasis on safety issues on construction sites leads to many accidents and deaths in developing countries. Furthermore, Kerry et al. (2021) have highlighted inadequate worker training, particularly in detecting and avoiding occupational dangers, as a major cause of workplace accidents. To control and avoid accidents on construction sites, site supervisors and safety supervisors play critical roles in executing and require a large amount of research and innovative ways to successfully control the hazards from the sites (Jones et al., 2019). According to Hamid et al. (2019), in Malaysia, all construction members must collaborate with safety supervisors to limit the number of accidents and swiftly achieve zero injuries on building sites. However, many companies in Malaysia are struggling to achieve zero accidents and are still facing many challenges to do so; therefore, safety training practises on construction sites will be beneficial to reduce the number of accidents and risks by adapting many new safety practises techniques (Azmi et al., 2020). As a result, Albarkani and Shafii (2021) emphasise that the best new method that can be applied to the construction industry in Malaysia is toolbox talk because it is one of the successful strategies that has been used in developed and developing countries around the world to reduce accidents on construction sites and is carried out on a weekly basis.

Toolbox talks are typically 10-to-15-minute Occupational Safety and Health (OSH) educational meetings either on the construction site or at the contractor's office (Eggerth et al., 2019). According to Versteeg et al. (2019), toolbox talks in developed countries include informal learning as well as formal training to assist establish a significant connection with people's safety experiences and how it directly affects their lives. Toolbox talks, also known as stand-up meetings and tailgate training, enable employers to give critical safety to employees, the majority of whom are on a temporary basis (Feely et al., 2022). Toolbox talks, when managed well, can improve communication, encourage employees, reduce risk, and raise hazard awareness (Geordy et al., 2020). A toolbox talk is one technique of training workers in which all employees gather and meet at a specific location on the job site, and the safety officer informs them about safety themes (Sherratt & Ivory, 2019). Hanna and Markham (2019) concluded that the toolbox talk was the most effective method for providing 'on the job' risk awareness education and practise on the construction site, with the combination of written, verbal, and contextual demonstration techniques proving to be by far the most effective.

Nonetheless, the impacts of the toolbox talks may vary depending on a few factors, including worker ignorance and lack of attention, and workers may not take the information given seriously and will not obey and follow the safety practises even if they attend the toolbox talks (Babu & Devi, 2020). In Malaysia, the way of distributing safety information does not fulfil the workers' intellectual capacities to preserve the toolbox talks knowledge collected (Zaini et al., 2020). The language barrier is another serious issue that can lead to poor safety awareness and injury on the construction site (Amirah et al., 2017). This article is intended to identify current implementation, determine the challenges, and recommend ways to overcome the challenges of toolbox talk for safety management. The article also advocated that the toolbox talks be enhanced to improve employees' safety performance on construction sites to realise the sustainability of urban planning and smart cities.

SAFETY MANAGEMENT IN MALAYSIA

Several researchers in developed countries determined that delivering toolbox talks would squander working time and progressively lose workers' interest, even though the issue is critical to improving safety performance (Babu & Devi, 2020). Furthermore, safety supervisors claimed that the toolbox information supplied is extensive and must be decreased owing to time and work pressure (Al-Shabbani et al., 2020). Workers are not attentive when teams are larger than twenty workers, and the trainer is not a senior staff member such as a site or safety supervisor who has a specialist to assist with any revisions (Lee et al., 2018). Accidents on construction sites in Malaysia are typically caused by workers' disregard for safety practises (Othman et al., 2018). According to Zid et al. (2020), in Malaysia, when workers believe they are working in a safe atmosphere, they disregard the safety conditions mandated by regulations and standards.

As a result, management is not fully equipped to deliver information and relate it to their workforce about safety issues and other safety practises, particularly in developing countries (Park et al., 2020). The substance of safety meetings is not improved and will not encourage workers to engage in the talks (Zid et al., 2020). Although narrative approaches consist of sharing the accidents and injuries experienced by other workers to which workers can relate is one of the formats of effective talks; unfortunately, the explanation for adding stories does not go far by recommending that workers will find stories a lot more appealing and thus will increase greater awareness to the workers (Hamid et al., 2019).

Furthermore, Sherratt and Ivory (2019) underline that language barriers still exist in developed countries, and the incidence of accidents is increasing. In developing countries such as Singapore, construction site accidents were mostly caused by a language barrier between Bangladeshis and their safety supervisors (Eggerth et al., 2019). Furthermore, study conducted by Azmi et al. (2020) demonstrates that there were hurdles in educating foreign workers at the site who could not completely understand the Malay language, particularly workers who are not from Indonesia, even though training content was extensive. Zaini et al. (2020) also show that language challenges occur more frequently among freshly arrived non-Indonesian foreigners than among those who have been here for a few years and can already interact comfortably with the locals. The issue in understanding the language between employees and supervisors on construction sites arise from the fact that the bulk of the workers are from Bangladesh and Myanmar (Abas et al., 2020).

METHODOLOGY

The questionnaire survey aimed to collect data for this research, where several questions relevant to the toolbox talk would be asked and must be completed by the respondents using Google forms and the like. As the data is gathered from many respondents, it is likely to be reliable. The questionnaire is meant to examine how participants perceive the actual implementation, challenges, and improvements to toolbox talk practises. The many inquiries are mostly focused on toolbox talk practises in Malaysia's construction industry. Participants included construction members such as safety and health officers, site supervisors, project managers, site engineers, and others who worked in Selangor and were designated by the CIDB as G7 contractor organisations. Their knowledge of construction sites would be extremely beneficial to the study's success. There are 3,000 registered contractors (CIDB, 2022), and the number of replies required is 341 according to Krejcie and Morgan (1970). From a total of 341 respondents, 29 percent provided input for this research. According to Marhani et al. (2018), the response rate for Malaysian construction industry researchers is relatively low, ranging from 20 to 30 percent. As a result, the response rate for this study was satisfactory and consistent.

DATA ANALYSIS AND FINDINGS

This section gives an analysis of the data gathered through quantitative research to address the objectives of this research. A questionnaire survey was done to discover Malaysians' perspectives on toolbox talks for safety management on construction sites.

Current Implementation of Toolbox Talks for Safety Management in Malaysia

The current state of toolbox talks for safety management in Malaysia is shown in Table 1. To begin, 85.0% of respondents conducted weekly toolbox talks, while just 9.0% conducted them twice a week. Only 6.0% of those polled held toolbox talks every two weeks. Furthermore, most respondents (67.0%) reported that the most common duration for conducting toolbox talks is 31 - 40 minutes. Less than 20 minutes and 21 to 30 minutes had the shortest durations, with 11.0% and 10.0%, respectively. Furthermore, 87.0% of respondents deliver toolbox talks in Malay, while only 9.0% do both. Only 4.0% of respondents delivered the toolbox talks in English.

The toolbox talks are now being used in most respondents' projects. In majority of the toolbox talks conducted by responders, the workers' leaders were entirely responsible for ensuring that all workers participated. It is like a study by Zaki and Kamar (2020), in which workers will be reminded and required to attend toolbox talks by their bosses early in the morning, and if they are late, they will be held accountable. According to Dale et al. (2020), utilising this strategy boosted workers' performance in attending toolbox talks since workers respect the leaders and will swiftly obey their directions. Most respondents reported that toolbox talks on construction sites are generally held verbally by safety officials in a large open space. This finding is like that of Suliaman and Haron (2019), who uncovered a verbal method often employed in Malaysia in which workers gathered in the vacant area on the construction site and safety and health officers gave presentations using speakers to ensure that everyone could listen and understand them. Most respondents reported they held the toolbox talk once a week for between 31 and 40 minutes in Malay, which matches the findings of Shafiq and Afzal (2020).

Table 1. Current Implementation of Toolbox Talks for Safety Management in Malaysia

Item	Descriptions	Frequency	Percentage	Ranking
1	The frequency of conducting the toolbox talks			
	Once a week	85	85.0	1
	Twice a week	6	6.0	3
	Once every 2 weeks	9	9.0	2
2	The common duration of toolbox talks session			
	Below 20 minutes	11	11.0	3
	21 – 30 minutes	10	10.0	4
	31 – 40 minutes	67	67.0	1
	More than 40 minutes	12	12.0	2
3	The languages used during the toolbox talks			
	Malay	87	87.0	1
	English	4	4.0	3
	Both Malay & English	9	9.0	2

Challenges in Implementing Toolbox Talks for Safety Management in Malaysia

Table 2 describes the difficulties involved with implementing toolbox talks for safety management in Malaysia. The statement "due to increased workload pressure, it took less time to prepare materials and content for the toolbox talk" has a maximum mean value of 4.33 (standard deviation (SD)=1.006). Meanwhile, the statement "the lack of workforce on sites affects workers' availability to attend the toolbox talk session" has a mean value of 4.31 (SD=0.896). The statement "The Project Manager's ongoing task pressure increases workload and high stress levels among workers" has the lowest mean value of 4.11 (SD=1.024). This finding is like that of Al-shabbani et al. (2020), who discovered that due to a lack of staff and ongoing tasks, supervisors do not have much time to organise toolbox talks once a week.

In terms of language, the greatest mean value is 4.44 (SD=0.857), which correlates to the statement that newly non-Indonesian foreigners participate in the toolbox conversation session less. Meanwhile, the statement "Poor interaction between foreign workers and supervisors, resulting in misinterpretation and misunderstanding" has the second highest mean value of 4.40 (SD=1.015). The lowest mean value is 4.38 (SD=0.983), showing that non-Malaysian employees and supervisors have trouble comprehending each other's languages. Furthermore, Ahmad et al. (2018) demonstrate that language challenges arose with recently non-Indonesian immigrants compared to those who had been living here for a few years and could converse comfortably with the locals. Consequently, most respondents agree with this assertion, which is consistent with past studies.

The first statement of presentation, with the highest mean value of 4.46 (SD=0.926), is that passive speaking without questions and answers among employees and supervisors makes toolbox talks less effective. Meanwhile, the statement "There is a lack of fresh and exciting content in toolbox talks, which makes them less appealing" has a mean value of 4.43 (SD=0.891). The statement "Safety Officers and Supervisors are insufficiently prepared to provide information and effectively relate it to their workers" has the lowest mean value of 4.28 (SD=1.045). As a result, this finding is consistent with the findings of Azmi et al. (2020), who discovered that passive speaking in toolbox lectures is the least engaging and least successful safety training technique.

Table 2. Challenges in Implementing Toolbox Talks for Safety Management in Malaysia

Item	Descriptions	Mean Value	SD	Ranking
1	**Workload**			
	Due to increased workload pressure, it took less time to prepare materials & content for the toolbox talk	4.33	1.006	1
	The lack of workforce on sites affects workers' availability to attend the toolbox talk session	4.31	0.896	2
	The ongoing task pressure by the Project Manager increases the workload & high-stress level among workers	4.11	1.024	3
2	**Language**			
	Newly non-Indonesian foreigners participate less in the toolbox talk session	4.44	0.857	1
	Poor interaction between foreign workers & supervisors results in misinterpretation & misunderstanding	4.40	1.015	2
	Non-Malaysian workers & supervisors have difficulty understanding each other's languages	4.38	0.983	3
3	**Presentation**			
	Passive speaking without questions & answers among workers & supervisors makes toolbox talks less effective	4.46	0.926	1
	There is a lack of fresh & exciting content in toolbox talks, which makes them less appealing	4.43	0.891	2
	Safety Officers & supervisors are not adequately prepared to provide the information & relate it to their workers efficiently	4.28	1.045	3

Recommendations in Overcoming the Challenges of Toolbox Talk for Safety Management in Malaysia

Table 3 shows the potential methods for addressing the workload challenges of toolbox talk for safety management on construction sites. The statement with the highest mean workload value of 4.34 (SD=1.094) was "Establish a schedule for toolbox talks to facilitate task delegation between supervisors and Safety Officers." The statement "Reduce the duration of the toolbox talk session by focusing only on the most critical topic" has the second highest mean score (SD=1.102). The statement "The Project Manager should reduce the workload to allow more time to prepare the material and content of the toolbox talk" has the lowest mean value of 4.30 (SD=1.040). As a result, this finding is comparable to that of Zhu et al. (2020), who discovered that providing a strategy for supervisors and safety officers to conduct toolbox talks on a regular basis is the best way to reduce staff weariness. When there is a clear schedule, they may set aside time to prepare materials and content for the toolbox talk without having to do so frequently.

The highest mean value of language is 4.41 (SD=0.975), which corresponds to the assumption that toolbox talks will be more understandable with the assistance of a translator for each foreign worker team. Meanwhile, "foreign workers must be provided with basic Malay language training" has the second highest mean value of 4.38 (SD=1.023). The lowest mean value is 4.35 (SD=1.009), indicating that the multilingual safety manual, warning signs, and safety booklets will raise workers' understanding of safe practises. As a result, this finding is like that of Zaini et al. (2020), who suggested that construction companies might improve by utilising a translator for every team of foreign workers. Furthermore, Ammad et al. (2020) argued that it can help foreign workers grasp toolbox talk information, making the site more secure and raising their workers' safety awareness, potentially lowering on-site injuries.

Table 3. Recommendations in Overcoming The Challenges of Toolbox Talk for Safety Management in Malaysia

Item	Descriptions	Mean Value	SD	Ranking
1	**Workload**			
	Establish a schedule for toolbox talks to facilitate the delegation of tasks between supervisors & Safety Officers	4.34	1.094	1
	Reduce the duration of the toolbox talk session by focusing only on the most critical topic	4.33	1.102	2
	The Project Manager must reduce the workload to give more time to prepare the material & content of the toolbox talk	4.30	1.040	3
2	**Language**			
	Toolbox talks will be more understandable with the assistance of a translator for every team of foreign workers	4.41	0.975	1
	Foreign workers must be provided with basic Malay language training	4.38	1.023	2
	A multilingual safety manual, safety warning signs, & safety booklets will increase the workers' understanding of safety practices	4.35	1.009	3
3	**Presentation**			
	Utilising the narrative presentation method to facilitate the workers' ability to relate to their experiences	4.40	1.005	1
	Encourage two-way communication by providing open-ended discussions	4.31	1.107	2
	A simple video & photographic presentation should be provided to demonstrate the safety method	4.28	1.016	3

The first statement, "using the narrative presentation method to facilitate workers' ability to relate to their experiences," had the highest mean value of 4.40 (SD=1.005). Meanwhile, the statement "encourage two-way communication by providing open-ended discussions" receives a mean score of 4.31 (SD=1.107). The statement "a simple video and photographic presentation should be provided to demonstrate the safety method" has the lowest mean of 4.28 (SD=1.016). As a result, this finding is comparable to that of Eggerth et al. (2018), who discovered that incorporating narratives, such as instances from experience, boosted information gain in safety toolbox talks. Madsen et al. (2020) also proposed that toolbox talks be enhanced by including brief stories portraying pertinent events and failed experiences, as well as questions about the stories and experiences.

CONCLUSIONS

Based on the findings, the current toolbox talk implementation for safety management on construction sites is like toolbox talk implementation in other Malaysian projects. According to this conclusion, toolbox talks should take place once a week for 30 to 40 minutes. The duration of the toolbox talk has been a concern in recent years, and most stakeholders in the construction industry must adjust it to ensure that the toolbox talk can be effective. Furthermore, the findings reveal that safety and health officers are among the most important employees on construction sites to perform toolbox talks and continue to rely on verbal communication, restricting their interaction with workers.

The Malaysian construction industry has various challenges in implementing toolbox talks for safety management. In terms of workload, most respondents agreed that increased workload pressure has reduced the time required for the preparation of materials and content for toolbox talks, which respondents considered as the most serious challenges confronting the construction industry. Furthermore, respondents have stated that newly non-Indonesian foreigners participate less in toolbox talk sessions because of the language barrier, which they believe is one of the most significant challenges to toolbox talk. Passive speaking without questions and answers among workers and supervisors makes toolbox talks less successful and is an important challenge in terms of presentation.

Malaysian stakeholders propose several improvements to the toolbox talks for safety management. Most respondents stated that establishing a plan for toolbox talks to promote task delegation between supervisors and safety officers is the most important method for improving toolbox talks in terms of workload. Furthermore, respondents responded that having a translator for each team of foreign workers will make toolbox talks more understandable, which they believe is one of the most important recommendations for the toolbox talk. Finally, utilising a narrative presentation style to assist workers relate to their experiences is a considerable improvement above the presentation chosen by most respondents.

Finally, the researcher suggests that future studies incorporate qualitative and quantitative analysis methodologies. Its purpose is to improve the precision of study results. A combination strategy, on the other hand, may produce more exact answers while avoiding the quantitative method's low data return rate.

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LEAN SIX SIGMA IN BIM-BASED CONSTRUCTION PROJECTS: IMPLEMENTATION BARRIERS AND STRATEGIES

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Abstract
Integrating Lean Six Sigma (LSS) into Building Information Modelling (BIM)-based construction projects can enhance project performance by reducing waste, improving process efficiency, and delivering higher-quality outcomes. However, several barriers hinder its adoption. Therefore, this study aims to deepen the insight into LSS adoption in BIM-based construction projects while enhancing overall project performance. The study has two objectives: identifying the critical barriers limiting LSS adoption and recommending effective strategies for successful implementation. It adopts a quantitative research approach, combining a literature review and a survey of 106 professionals involved in BIM-based construction projects in Malaysia. The study identifies five critical barriers: lack of awareness regarding the needs and benefits of LSS, inadequate specialised training in LSS, limited time available for implementing new quality management methods, lack of active engagement from top management and Satisfaction with the existing quality management system. The most effective strategies for LSS adoption include obtaining effective support from top management and implementing leadership and management training. The analysis reveals differing opinions between contractors/builders and professional consultancies on specific barriers to LSS adoption in BIM-based construction projects. However, both groups share a consensus on the effectiveness of the proposed strategies. The findings of this study provide industry practitioners with actionable frameworks for addressing barriers and successfully implementing LSS in BIM-based construction projects while suggesting avenues for further research to explore the intersection of LSS and BIM in various construction contexts.

Keywords: *Lean Six Sigma; BIM Adoption; Construction Quality; Construction; Barriers; Strategies*

INTRODUCTION

The contribution of the Malaysian construction industry to the nation's economic growth and employment is immense (Basori Bano et al., 2023). However, the construction industry in Malaysia faces substantial challenges that hinder its ability to complete construction projects efficiently and effectively (Dehdasht et al., 2022). Despite technological advancements, many construction firms struggle with inefficiency, project delays, poor quality management, and cost overruns (Hire et al., 2021). BIM has emerged as a promising tool to address these challenges. However, the adoption of BIM in the construction industry remains limited, and its implementation has not achieved the expected level of success (Gardezi et al., 2014). Besides, the challenges of BIM implementation can vary significantly between small-scale and large-scale construction projects (Alwee et al., 2021). Therefore, addressing these challenges through effective implementation of BIM is crucial for improving the industry's performance.

Although the potential benefits of BIM are widely acknowledged, the implementation-based difficulties throughout the construction stage have not been fully addressed. Previous research has highlighted the benefits of BIM in the design and planning stages; however, its integration into construction processes, particularly in maintaining quality and reducing waste, remains underexplored (Aburumman et al., 2024). Besides, while implementing Lean Six Sigma (LSS) has proven successful in manufacturing and other industries (Macias-Aguayo et al., 2022), its adoption within the construction sector, particularly coupled with BIM, is still in its early stages. The limited research on integrating BIM with LSS to improve construction quality management has led to missed opportunities for increasing project efficiency and reducing waste (Mounla et al., 2023). The absence of a structured and comprehensive approach to LSS implementation in construction projects prevents the realisation of its full potential, worsening the existing challenges in the construction industry (De Silva et al., 2023). Thus, exploring the integration of BIM and LSS in construction could significantly improve project efficiency and quality management.

The ability of BIM to improve project coordination and decision-making could offer a promising solution when coupled with LSS's focus on waste reduction and continuous improvement, thus delivering quality outcomes. Using these integrated methodologies, construction organisations can improve their processes by reducing delays, fostering better collaboration, and improving quality management. Therefore, this study aims to deepen the insight into LSS adoption in BIM-based construction projects while enhancing overall project performance. It has two objectives: first, identifying the critical barriers limiting LSS adoption, and second, recommending effective strategies for successful implementation. A quantitative research approach combines a literature review with a survey of 106 Malaysian professionals involved in construction projects where BIM is integrated. Finally, this study contributes to developing a framework to improve quality management in the construction industry, filling the gap in the existing body of knowledge and supporting organisations in enhancing project delivery and operational efficiency.

METHODOLOGY

As Figure 1 shows, the research framework comprises three phases. Phase 1 encompasses the preparation stage, which involves conducting a literature review in order to identify barriers and strategies, developing the survey, and conducting a pilot test with industry experts of relevant exposure for the study. Phase 2 focuses on primary data collection. Phase 3 is for data analysis, including reliability testing, outlier removal, ranking, overlap analysis, agreement analysis, and correlation analysis to achieve the research objectives. Each phase is detailed below.

Survey Development

This study used a quantitative research approach to analyse the barriers and strategies associated with adopting LSS in BIM-driven construction projects in Malaysia. Initially, a thorough literature review was conducted to identify the barriers and strategies related to adopting LSS in projects involving BIM. Relevant keywords were developed based on the research scope, such as BIM challenges/barriers, LSS challenges/barriers, strategies for LSS implementation, and quality management in BIM-related projects. These keywords were used to identify the relevant research articles from the academic databases.

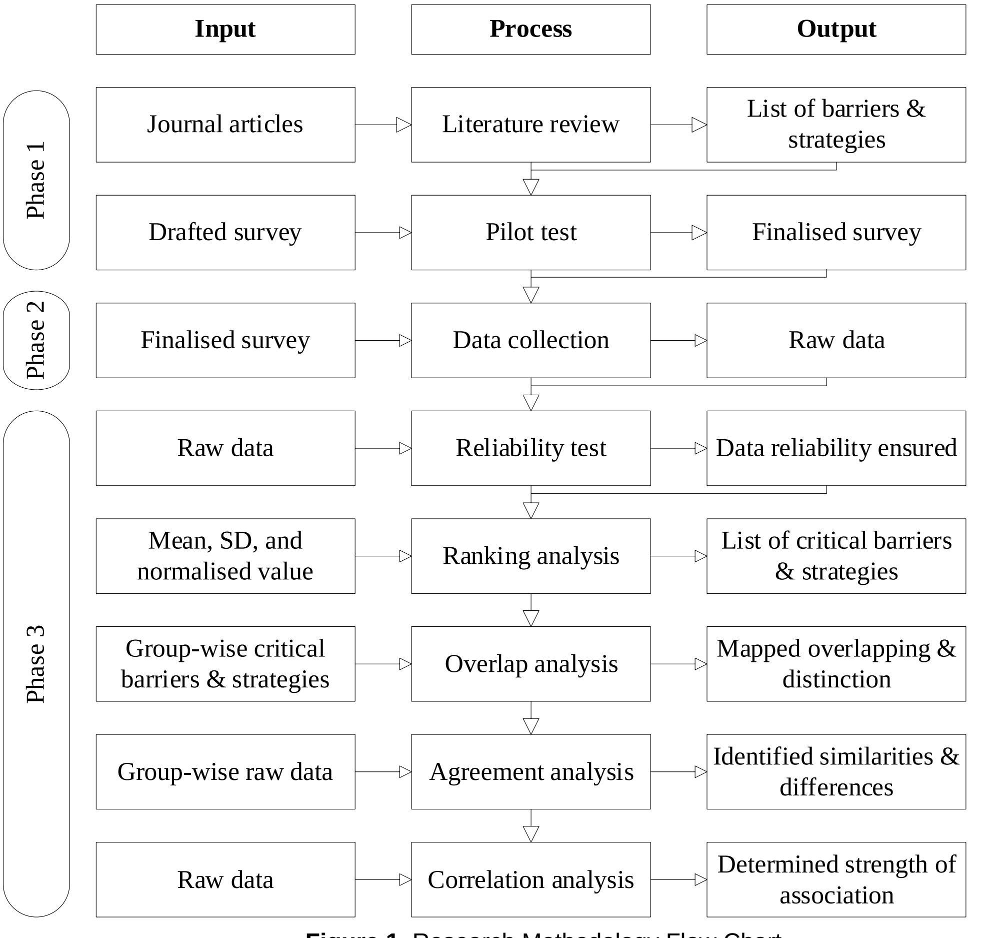


Figure 1. Research Methodology Flow Chart

Table 1 outlines the fifteen barriers and ten strategies for LSS adoption in BIM-integrated construction projects derived from prior research.

Table 1. Barriers and Strategies Identified from Prior Research

ID	Barriers	Prior Research
B1	Lack of active engagement from top management	1, 2, 3, 4, 5
B2	Inadequate specialised training in LSS	2, 3, 6, 7, 8, 9, 5
B3	Lack of resources	2, 3, 10, 6, 8
B4	Lack of awareness regarding the needs and benefits of LSS	2, 10, 9, 5
B5	Cultural and organisational resistance	2, 3, 9, 5
B6	Limited time available for implementing new quality management methods	1, 3, 9, 5
B7	Satisfaction with the existing quality management system	3, 6, 8
B8	Ineffective communication between management and employees	1, 8, 5
B9	Insufficient consultants	3, 10, 9
B10	Poor project selection and prioritisation	10, 4, 5
B11	Unsatisfactory performance in previous projects	10, 4
B12	Poor organisational structure	1, 10
B13	Risk of failing to achieve the expected benefits of improvement	1, 7
B14	Poor employee relationships	10, 4
B15	Risk of interrupting current operations	1, 3

ID	Strategies	Prior Research
S1	Establish a reward and recognition system	11, 3, 5
S2	Obtain effective support from top management	12, 3, 13, 14
S3	Allocate extra funds for LSS implementation	11, 3, 15, 5
S4	Implement an effective LSS training program	12, 16, 5
S5	Hire LSS experts for projects	11, 12, 15, 5
S6	Select Lean Six Sigma tools and techniques precisely	12, 3
S7	Form a strategic planning committee	3, 15, 13
S8	Select staff appropriately for effective LSS training	3, 6, 16
S9	Leverage government support available for construction companies	16, 17
S10	Implement leadership and management training	16, 17

Source - [1]Albliwi, 2017; [2]Fernando, 2017; [3]Gaikwad et al., 2020, [4]Singh et al., 2019; [5] Yadav et al., 2018; [6]Lande et al., 2016; [7]Mustapha et al., 2019; [8]Raghunath & Jayathirtha, 2013; [9]Singh & Rathi, 2019; [10]Hussain et al., 2019; [11]Antony et al., 2012; [12]Bakar et al., 2015; [13]Laureani & Antony, 2018; [14]Sahoo & Yadav, 2018; [15]Jayaraman et al., 2012; [16]Linde and Philippov, 2020; [17]Ranadewa et al., 2018

This study used a survey to collect primary data on the barriers and strategies for LSS adoption in construction projects that involve BIM. According to Kothari (2004), a survey is an effective technique for collecting responses with a larger sample size, making it ideal for quantitative research. Besides, it can effectively achieve the required sample size (Pallant, 2007). The use of surveys simplifies data collection, testing, and analysis, making it a cost-effective method for gathering stakeholder responses (Bihu, 2023).

The initial survey was created based on the barriers and strategies derived from a thorough literature review and included four sections. The first section included an invitation letter outlining the study's purpose, objectives, and other general information. The second section focused on collecting demographic details of the survey participants, with questions aimed at capturing details such as gender, academic qualifications, work experience details in general and BIM-related projects in particular, and the types of organisations they attached to. The third section focused on evaluating the criticality of the barriers, utilising a Likert scale with five points (Not Critical - 1 to Extremely Critical - 5). The last section examined the effectiveness of the strategies, also using the same Likert scale (Not Effective - 1 to Highly Effective - 5). Albaum (1997) noted that the Likert scale is an effective tool for capturing the opinions of survey participants. Armstrong (1987) also endorsed the use of the five-point Likert scale, highlighting its effectiveness in improving data reliability and minimising bias.

A pilot test was conducted with 20 senior Malaysian construction professionals with extensive experience in BIM-oriented projects. A pilot test is commonly conducted in research using surveys to evaluate the suitability of a survey, particularly when it is newly developed (Bujang et al., 2024). A typical pilot survey involves 10 to 30 participants (Sekaran, 2003). The pilot test in this research sought to evaluate the survey for clarity, completeness, the relevance of the terminology used for the variables, and the accuracy of the identified barriers and strategies. Consequently, the pilot test feedback ensured the researchers improved the survey by making the questions more precise, the terminology more accurate, and the barriers and strategies more relevant to the study context.

Data Collection

The data collection process for this study focused on construction professionals in Malaysia, specifically those with experience in working with BIM technologies. Therefore, the study employs purposive sampling. The criteria for choosing study participants in this study are the availability of respondents with relevant experience in BIM-related construction projects, their willingness to participate, and their ability to provide clear, expressive, and reflective responses (Bernard, 2006). As stated by Isya et al. (2019), this approach is widely adopted in construction management for data collection.

The respondents were initially contacted by email. Respondents who could not be contacted through email were reached via LinkedIn. LinkedIn social platform is widely used in prior research (Munianday et al., 2022). Finally, the survey yielded 106 valid responses from construction professionals with relevant experience. The sample size for this study was determined based on Roscoe's (1975) guidelines, which suggest that a sample size between 30-500 is generally adequate for most research (Sekaran, 2003). Hence, the sample size in this study can provide a complete representation of the diverse experiences and perspectives of construction professionals in Malaysia involved in BIM-related construction projects. The survey respondents' representation, in terms of the organisation's core business, was primarily from constructor/builder and professional consultancy types.

Data Analysis

Reliability Test

The first stage of the data analysis process ensures the readiness and reliability of the collected data before proceeding to the rest of the analysis. At this stage, data reliability and the identification of outliers are vital. First, Cronbach's alpha measured the reliability and consistency of the survey responses. A Cronbach's alpha value of 0.7 or higher indicates that the data is acceptable for further analysis (Amirrudin et al., 2020). Second, the two-standard deviation (SD) method was applied to eliminate any data points from the data set that could compromise the findings of the study.

Mean Score Ranking

Mean score ranking was used to rank the barriers and strategies included in the survey. This technique considers both the accuracy of the mean and the variation in responses, with a lower standard deviation indicating a higher ranking (Staplehurst & Ragsdell, 2010). Meanwhile, the normalised value (NV) technique was used to identify the critical variables. The NV provides a more profound interpretation when ranking factors, particularly when identifying critical ones. This technique calculates the NV for each factor by using the minimum and maximum mean values. It then computes the mean values for all factors and normalises them on a scale ranging from 0.000 to 1.000. Factors with the highest mean values are assigned a score of 1.000, while those with the lowest score 0.000. This study applied a benchmark of $NV \geq 0.500$ to identify critical barriers and strategies. This is consistent with prior research practices (Omer et al., 2024). These analytical techniques ensured a systematic and accurate identification of key barriers and strategies for LSS adoption.

Overlap Analysis

Overlap analysis identified the similarities and differences between the barriers and strategies across two distinct groups in this study, namely, contractor/builder and professional consultancies. Overlap analysis is applied to identify similarities and differences between two or more groups. (Moyo et al., 2024). This technique interprets the results by comparing the obtained values through mean ranking or NV. The barriers and strategies with an NV ≥ 0.500 were identified as critical and included in the overlap analysis (Omer et al., 2024). This approach provided insight into how different organisational groups perceive critical barriers and strategies for LSS adoption.

Agreement Analysis

The study employed the Mann-Whitney U Test to investigate the differences between the two core business types of organisations (contractors/builders and professional consultancy) regarding the barriers and strategies to LSS adoption in BIM-related construction projects. Mann-Whitney U Test investigates the potential differences between two distinct groups with two different hypotheses (Love et al., 2004). The null hypothesis states no significant differences exist in the mean values of barriers and strategies between contractor/builder and professional consultancies. In contrast, the alternative hypothesis theorised significant differences in the mean values of barriers and strategies between contractor/builder and professional consultancies. This statistical analysis enabled a deeper understanding of group-specific perceptions regarding barriers and strategies for LSS adoption.

Correlation Analysis

The Spearman correlation analysis examined the relationship between the barriers and strategies for adopting LSS in BIM-related construction projects. This technique evaluates the strength and direction of the relationship between two variables. Asuero et al. (2006) measure correlation as: 0.00–0.29 (very low), 0.30–0.49 (low), 0.50–0.69 (moderate), 0.70–0.89 (high), and 0.90–1.00 (very high).

RESULTS AND DISCUSSION

Respondent Profile

Table 2 presents the details of the respondents' profiles, with 106 responses collected from industry practitioners in the Malaysian construction industry.

The respondent profile primarily consists of a young workforce, with most participants aged between 25 and 29. The sample is predominantly male and reflects a well-educated background, with the majority holding a Bachelor's degree. A significant portion of respondents has experience in BIM projects, with many possessing up to five years of relevant experience. The participants represent diverse organisational backgrounds, including contracting firms and professional consultancy organisations. The sample represents a diverse and experienced group of industry practitioners, which makes it appropriate for this study.

Reliability Test

The internal consistency of the survey was assessed using the Cronbach's alpha coefficient. This coefficient shows how closely related a group of items is, indicating the reliability of the scale (Mohsen & Reg, 2011). The reliability test results showed that both datasets are highly reliable, with Cronbach's alpha values of 0.853 and 0.941 for barriers and strategies, respectively. These values exceed the generally accepted threshold of 0.7, confirming the robustness of the data. The high value suggests that the items in the survey are strongly correlated and consistently measure the same construct. Acceptable internal consistency is indicated by Cronbach's alpha values of 0.7 or higher (Taber, 2018). For outliers, they were identified by calculating the mean and SD of the criticality of each variable (Kwak & Kim, 2017). Consequently, barriers B11 and B14 were eliminated, and the rest of the variables were accepted for subsequent data analysis.

Table 2. Respondent Profile

Demographic	Category	Count	Percentage (%)
Age Range	24 years old and below	16	15.09
	25 - 29	54	50.94
	30 - 34	18	16.98
	35 - 39	11	10.38
	40 - 44	05	4.72
	45 - 49	02	1.89
Gender Distribution	Male	80	75.47
	Female	26	24.53
Education Level	High School	06	5.66
	Technical Diploma	01	0.94
	Diploma	04	3.77
	B.Tech. / HND	01	0.94
	Bachelor's Degree	86	81.13
	Master's Degree	06	5.66
	Doctorate	02	1.89
Experience in Construction	Below 2 years	33	31.13
	2 - 5	43	40.57
	6 - 10	16	15.09
	11 -15	08	7.55
	16 - 20	03	2.83
	More than 20 years	03	2.83
Experience in BIM Projects	No experience	08	7.55
	Below 2 years	42	39.62
	2 - 5	38	35.85
	6 - 10	15	14.15
	11 - 15	03	2.83
Organisation Type	Contractor/Builder	70	66.04
	Consultancy	36	33.96

Mean Score Ranking

Barriers (Overall)

Table 3 shows the ranking of the barriers based on mean scores, standard deviations (SD), normalisation (NV), and the rankings derived from the survey responses.

Table 3. Overall Ranking of The Barriers

Code	Mean	SD	NV	Rank
B4	3.528	1.131	1.000	1
B6	3.387	1.038	0.712	2
B2	3.368	1.107	0.673	3
B1	3.349	0.947	0.635	4
B7	3.311	0.866	0.558	5
B9	3.208	0.993	0.346	6
B3	3.189	0.947	0.308	7
B5	3.189	1.025	0.308	8
B8	3.085	0.977	0.096	9
B13	3.085	0.996	0.096	10
B10	3.075	0.943	0.077	11
B12	3.038	1.013	0.000	12
B15	3.038	1.059	0.000	13

The most critical barrier is B4, with the highest mean score of 3.528, followed by B6 and B2, with mean scores of 3.387 and 3.368, respectively. These findings highlight the need for greater awareness, time allocation, and specialised training programs to address key barriers. Moderate barriers, such as B1 and B7, suggest that organisational support and resistance to change also play significant roles. Additionally, barriers like B12 and B15 rank the lowest, indicating that the organisation structure and risk of interrupting current operations are relatively less concerning.

Since the factors with normalisation values greater than 0.500 are assessed to be critical (King et al., 2022), five barriers were identified as critical based on their normalised values. Among these, B4 has the highest mean score ranking. Other significantly critical barriers are B6, B2, B1, and B7. These barriers represent key challenges that must be addressed to facilitate the successful adoption of LSS in BIM-related construction projects.

Barriers (According to Organisation Types)

As shown in Table 4, the perceptions of the barriers to LSS adoption in BIM-related construction projects in Malaysia vary between contractors/builders and professional consultancies. For contractors/builders, the critical barriers are B4, B2, B1, B7, and B6, with normalisation values greater than 0.5. For professional consultancies, B6 and B4 are identified as critical, with normalisation values greater than 0.5. Despite these differences, both groups emphasise the need to address awareness, and the insufficient time required to execute new quality management methods to ensure successful LSS adoption in BIM construction projects.

Table 4. Ranking for Barriers by Organisation Types

Contractor/Builder					Professional Consultancy				
Code	**Mean**	**STD**	**NV**	**Rank**	**Code**	**Mean**	**STD**	**NV**	**Rank**
B4	3.700	1.026	1.000	1	B6	3.306	1.167	1.000	1
B2	3.543	0.973	0.744	2	B4	3.194	1.261	0.778	2
B1	3.514	0.864	0.698	3	B7	3.028	0.774	0.444	3
B7	3.457	0.879	0.605	4	B1	3.028	1.028	0.444	4
B6	3.429	0.972	0.558	5	B2	3.028	1.276	0.444	5
B3	3.386	0.906	0.488	6	B5	3.000	1.069	0.389	6
B9	3.329	0.974	0.395	7	B9	2.972	1.000	0.333	7
B5	3.286	0.995	0.326	8	B8	2.944	0.924	0.278	8
B10	3.186	0.937	0.163	9	B13	2.944	0.984	0.278	9
B8	3.157	1.002	0.116	10	B12	2.944	1.145	0.278	10
B13	3.157	1.002	0.116	11	B15	2.889	1.063	0.167	11
B15	3.114	1.057	0.047	12	B10	2.861	0.931	0.111	12
B12	3.086	0.944	0.000	13	B3	2.806	0.920	0.000	13

Strategies (Overall)

Table 5 shows that the strategies with the highest mean score include S10, which ranks first with a mean of 3.774, followed by S2 (3.708). These strategies highlight the importance of strong leadership and top management involvement in LSS adoption. Other notable strategies are S7 and S3, which emphasise the necessity of strategic planning and securing resources for successful implementation. Strategies such as S5 and S9 also receive moderate ratings, indicating their relevance but slightly less priority. Finally, strategies like S8 and S6 have lower mean scores, suggesting they are still valuable but may require additional attention or customisation in specific contexts.

Table 5. Overall Ranking of The Strategies

Code	Mean	STD	NV	Rank
S10	3.774	0.897	1.000	1
S2	3.708	0.995	0.811	2
S7	3.585	0.914	0.459	3
S3	3.547	0.987	0.351	4
S4	3.547	1.114	0.351	4
S5	3.528	1.071	0.297	6
S9	3.472	1.025	0.135	7
S8	3.462	1.071	0.108	8
S1	3.443	0.863	0.054	9
S6	3.425	1.032	0.000	10

Strategies (According to Organisation Types)

As shown in Table 6, the critical (most effective) strategies for LSS adoption in BIM-based construction projects in Malaysia, with normalisation values above 0.5, highlight key areas essential for successful implementation. For contractors/builders, the most effective strategies include S10, S2, S3, S7, S4, and S5. Similarly, the critical strategies for professional consultancies are S10 and S2. Despite slight variations between the two groups, contractors/builders and professional consultancies agree on the importance of S2 and S10 as the strategies that can result in the most successful outcomes for LSS adoption in BIM-based construction projects in Malaysia.

Table 6. Ranking of Strategies by Organisation Types

Contractor/Builder					Professional Consultancy				
Code	Mean	STD	NV	Rank	Code	MEAN	STD	NV	Rank
S10	3.700	0.874	1.000	1	S10	3.917	0.937	1.000	1
S2	3.657	1.020	0.857	2	S2	3.806	0.951	0.789	2
S3	3.629	0.920	0.762	3	S7	3.611	0.994	0.421	3
S7	3.571	0.878	0.571	4	S1	3.528	0.910	0.263	4
S4	3.571	1.015	0.571	5	S9	3.528	0.971	0.263	5
S5	3.557	1.016	0.524	6	S4	3.500	1.298	0.211	6
S8	3.471	1.059	0.238	7	S5	3.472	1.183	0.158	7
S9	3.443	1.058	0.143	8	S8	3.444	1.107	0.105	8
S6	3.429	0.972	0.095	9	S6	3.417	1.156	0.053	9
S1	3.400	0.841	0.000	10	S3	3.389	1.103	0.000	10

Overlap Analysis

Barriers

The overlap analysis in Figure 2 depicts the critical barriers to LSS adoption identified by contractors/builders and professional consultancies. Contractors/builders face unique critical barriers such as B1, B2, and B7. However, professional consultancies do not share these barriers exclusively. Both parties' views are in unison regarding two common critical barriers: B4 and B6. This overlap suggests shared areas of concern while also highlighting distinct organisational challenges in implementing LSS in construction projects in Malaysia, where BIM is integrated.

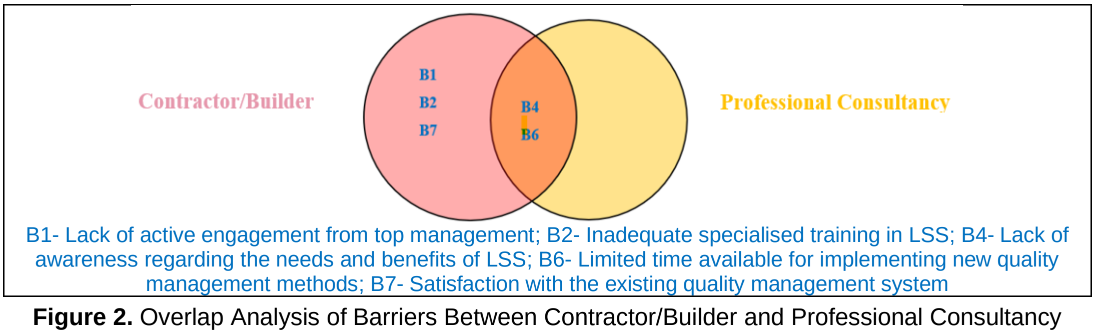
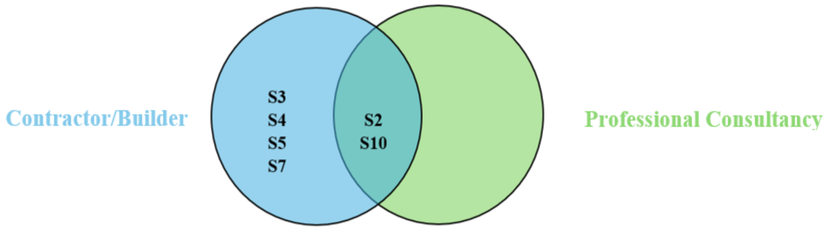


Figure 2. Overlap Analysis of Barriers Between Contractor/Builder and Professional Consultancy

Strategies

The overlap analysis of critical strategies between contractors/builders and professional consultancy organisations, as shown in Figure 3, highlights both unique and shared strategies for LSS adoption in BIM-based construction projects. Contractors/builders prioritise strategies such as S3, S4, S5, and S7. Inversely, professional consultancies give importance to S10 and S2. However, both groups reached a consensus on the importance of S2 and S10 as common critical strategies for the successful implementation of LSS in BIM.



S2- Obtain effective support from top management; S3- Allocate extra funds for LSS implementation; S4- Implement an effective LSS training program; S5- Hire LSS experts for projects; S7- Form a strategic planning committee; S10- Implement leadership and management training

Figure 3. Overlap Analysis of The Critical Strategies Between Contractor/Builder and Professional Consultancy

Agreement Analysis

Table 7 details the agreement analysis results, using the Mann-Whitney U Test, between the two core business types of organisations for the barriers to LSS adoption in BIM-based construction projects. The analysis reveals that three barriers (B2-inadequate specialised training in LSS, B3-lack of resources, and B4-lack of awareness regarding the needs and benefits of LSS) have P-values less than 0.05, indicating statistically significant differences between the two groups, contractor/builder and professional consultancy.

Table 7. Results of Agreement Analysis (Barriers)

	Contractor/Builder			Consultancy			Overall			p-value
Code	Mean	STD	Rank	Mean	STD	Rank	Mean	STD	Rank	
B1	3.514	0.864	3	3.028	1.028	4	3.349	0.947	4	0.052
B2	3.543	0.973	2	3.028	1.276	5	3.368	1.107	3	***0.003***
B3	3.386	0.906	6	2.806	0.920	13	3.189	0.947	7	***0.013***
B4	3.700	1.026	1	3.194	1.261	2	3.528	1.131	1	***0.021***
B5	3.286	0.995	8	3.000	1.069	6	3.189	1.025	8	0.354
B6	3.429	0.972	5	3.306	1.167	1	3.387	1.038	2	0.060
B7	3.457	0.879	4	3.028	0.774	3	3.311	0.866	5	0.285
B8	3.157	1.002	10	2.944	0.924	8	3.085	0.977	9	0.053
B9	3.329	0.974	7	2.972	1.000	7	3.208	0.993	6	0.753
B10	3.186	0.937	9	2.861	0.931	12	3.075	0.943	11	0.499
B12	3.086	0.944	13	2.944	1.145	10	3.038	1.013	12	0.344
B13	3.157	1.002	11	2.944	0.984	9	3.085	0.996	10	0.160
B15	3.114	1.057	12	2.889	1.063	11	3.038	1.059	13	0.256

Table 8 displays the agreement analysis results for the strategies. The results show that all strategies have p-values greater than 0.05 and, therefore, suggest that there are no statistically significant differences in opinions between contractors/builders and professional consultancies for the strategies. Except for S6 (0.236) and S7 (0.277), other strategies exhibit higher p-values, indicating a stronger likelihood that their distributions are similar across the groups, with no significant differences. This indicates a consensus on the effectiveness of the identified strategies across both groups.

Table 8. Results of Agreement Analysis (Strategies)

	Contractor/Builder			Consultancy			Overall			p-value
Code	**Mean**	**STD**	**Rank**	**Mean**	**STD**	**Rank**	**Mean**	**STD**	**Rank**	
S1	3.400	0.841	10	3.528	0.910	4	3.443	0.863	9	0.707
S2	3.657	1.020	2	3.806	0.951	2	3.708	0.995	2	0.627
S3	3.629	0.920	3	3.389	1.103	10	3.547	0.987	4	0.895
S4	3.571	1.015	5	3.500	1.298	6	3.547	1.114	4	0.743
S5	3.557	1.016	6	3.472	1.183	7	3.528	1.071	6	0.889
S6	3.429	0.972	9	3.417	1.156	9	3.425	1.032	10	0.236
S7	3.571	0.878	4	3.611	0.994	3	3.585	0.914	3	0.277
S8	3.471	1.059	7	3.444	1.107	8	3.462	1.071	8	0.858
S9	3.443	1.058	8	3.528	0.971	5	3.472	1.025	7	0.923
S10	3.700	0.874	1	3.917	0.937	1	3.774	0.897	1	0.395

Spearman Correlation Analysis

Barriers

Figure 4 shows the Spearman correlation heatmap for the barriers to LSS adoption in BIM-based construction projects in Malaysia. Correlation coefficients are interpreted as follows: 0.00–0.29 (very low), 0.30–0.49 (low), 0.50–0.69 (moderate), 0.70–0.89 (high), and 0.90–1.00 (very high). Accordingly, the colour gradient in the heat map represents the strength of the correlations, with darker red indicating a stronger positive correlation and blue indicating a weaker or negative correlation.

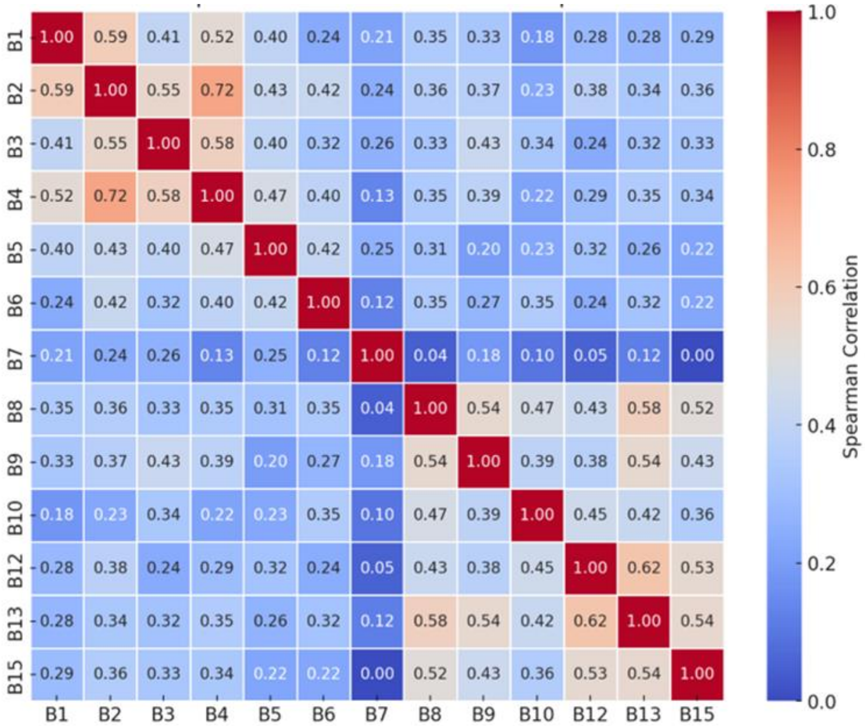


Figure 4. Spearman Correlation Heat Map (Barriers)

The strongest correlation among barriers is between B2 and B4 (0.72), indicating the co-occurrence of these two barriers and suggesting that they may have shared underlying causes. B12 and B13 (0.62) exhibit a strong association, suggesting a potential link between their impacts on projects. Moderate correlations exist between barriers such as B3 and B4, B3 and B2, and B9 and B12, with correlation coefficients of 0.58, 0.55, and 0.45, respectively. This can imply that while these barriers are associated, they do not always appear together. Conversely, some barriers, such as B6 and B7 (0.12), B10 and B7 (0.10), and B12 and B7 (0.05), exhibit weaker correlations, possibly implying their independent nature in occurrence. The findings suggest that barriers with stronger correlations require coordinated efforts to be effectively mitigated with potential strategies, while barriers with weaker correlations may need distinct mitigation measures.

Strategies

Figure 5 shows the Spearman correlation heatmap for the strategies for the adoption of LSS in BIM-based construction projects in Malaysia. Among the strategies, S3 and S4 (0.75), S4 and S6 (0.75) and S4 and S5 (0.74) exhibit a strong correlation, suggesting a high level of interconnectivity. This indicates that they can contribute to the same objectives in mitigating barriers. Other significantly stronger correlations are observed between S7 and S8 (0.73), S2 and S10 (0.70), and S6 and S8 (0.70), which further supports the idea that launching multiple strategies together can yield better results. Conversely, slightly weaker correlations are observed between specific strategies, such as S6 and S9 (0.44) and S5 and S9 (0.46). This suggests these strategies may work independently, targeting different aspects of LSS adoption. However, the overall trend among correlations shows positive associations, indicating that the combined implementation of these strategies can enhance their effectiveness.

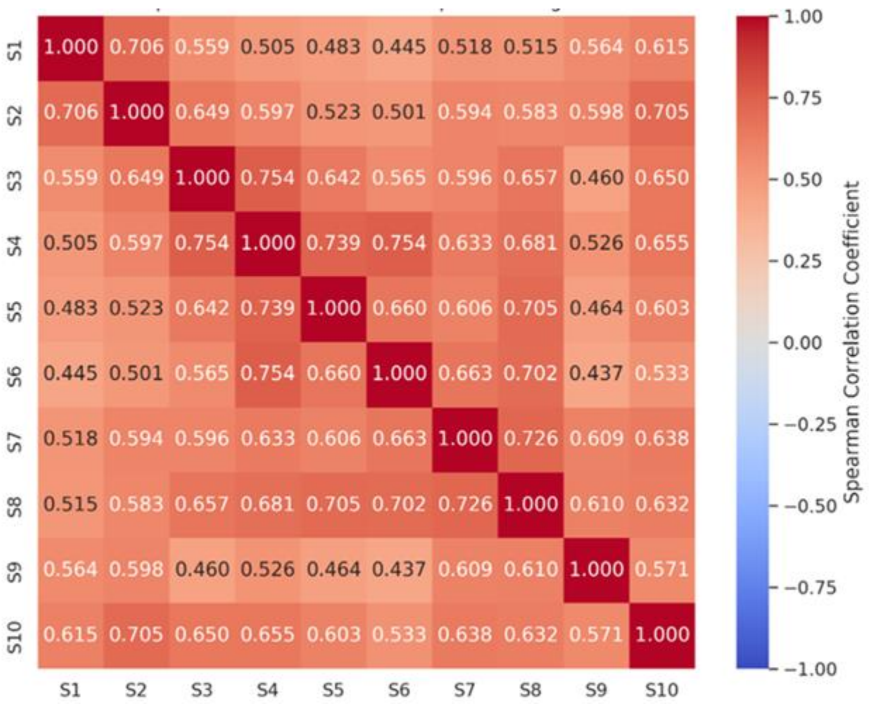


Figure 5. Spearman Correlation Heat Map (Strategies)

CONCLUSIONS

This study provides a comprehensive analysis of the barriers and strategies for the adoption of LSS in BIM-based construction projects in Malaysia. A quantitative research approach used a general literature review and a survey. Data were collected from 106 professionals with experience in BIM-based construction projects in Malaysia. The study identifies five critical barriers: lack of awareness regarding the needs and benefits of LSS, inadequate specialised training in LSS, limited time available for implementing new quality management methods, lack of active engagement from top management, and satisfaction with the existing quality management system. The most effective strategies for LSS adoption include obtaining effective support from top management and implementing leadership and management training. This study has several implications for both the construction industry and academia. For industry practitioners, the results offer a clear framework for addressing the barriers to LSS adoption in BIM-based construction projects while suggesting action-oriented strategies for effective implementation. For academia, this study lays the foundation for further research. This can include examining the interplay between specific barriers and strategies within varying organisational contexts and regions. Further, future research could explore longitudinal studies to assess the long-term impact of LSS in BIM-based projects and compare barriers and strategies across various construction projects using BIM technology. In summary, this study contributes to the body of knowledge on LSS adoption in BIM-based construction projects, providing valuable guidance for enhancing the quality of construction processes in Malaysia and beyond. With the proposed strategies to overcome the identified barriers, construction organisations can improve their ability to integrate LSS with BIM, aiming to achieve better project performance and more sustainable outcomes.

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SYNERGISTIC INTEGRATION OF BIM AND IBS FOR WASTE MINIMISATION AND SAFETY ENHANCEMENT IN CONSTRUCTION PROJECTS

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Abstract
The integration between BIM and IBS remains under-researched. This research investigates how construction waste and safety can be minimised by using BIM and IBS. The relationship between construction waste, safety, BIM and IBS was analysed using PLS-SEM. The result from the path from BIM implementation to CW minimisation coefficient of 0.425 indicated a positive influence with a highly significant p-value (0.0000) and a T statistic of 6.513. This research found a strong relation between the detection of clashes and the optimisation of BIM's material optimisation. There was also synergy between IBS and BIM, which gave the solutions for the reduction of construction waste and enhanced the projects towards more cost-effectiveness and safety. This research concluded that significant minimisation of waste and safety can be ascertained by integrating BIM and IBS.

Keywords: *Construction; Waste; Minimisation; BIM; IBS*

INTRODUCTION

Construction waste contributed significantly to the degradation of the environment by about 30-40%. This situation seriously increased the emission of carbon and pollution (Kibert, 2016). The activities in the construction industry are not conducive to safety and health because most of them often take place outdoors, and the sites are dangerous places for the public and workers (Kamar et al., 2024). As such, reducing waste is a challenging issue for industry professionals to implement sustainable practices. Therefore, BIM integrating with IBS becomes a solution that can solve this issue, whereby BIM as the digital tool can effectively collaborate during the lifecycle of the projects (Eastman et al., 2011). BIM is able to detect clashes in the design and optimise the usage of construction materials (Azhar, 2011). IBS enhances improvement in quality control and reduces the time completion (Kamar et al., 2010). Moreover, on-site errors which impact construction wastes can be reduced by using prefabricated components (Nawi et al., 2011).

Optimisation towards waste of materials, delay in completion, and inefficiencies usage of labour can be achieved by the synergy between IBS's prefabrication and capabilities of IBS (Won & Cheng, 2017). Objectives of the research are as follows: -

- To assess the impact on construction waste minimisation by integrating IBS and BIM.
- To investigate how waste can be reduced by utilising IBS in construction projects.

This research assesses insights practice, which is beneficial for industry professionals in reducing construction waste.

LITERATURE REVIEW

Impact on Environment Due to Waste from Construction Projects

During the demolition, renovation and construction phases, many materials such as plastics, wood, concrete and metals contribute to construction waste, which causes significant degradation of the environment and safety (Tam, 2011). 40% of waste was generated from construction activities such as landfills and gas emissions of greenhouse (UNEP, 2014). Therefore, in order to promote sustainability, proper management of waste is vital in reducing the footprint of activities from construction projects.

Minimisation of Waste and BIM

Effective usage of materials, design clashes and errors can be reduced by using BIM, which enables the collaboration of multiple stakeholders (Eastman et al., 2011). BIM has an advantage in integrating various aspects of the project, such as analysis of environmental issues and project planning, which enhances the decision-making process (S. Azhar, 2011). BIM assists in reducing rework, which is the main contributor to construction waste, through proper design and planning (Won & Cheng, 2017). In addition, BIM optimises material utilisation by giving accurate numbers of materials and avoiding over-ordering (Osmani et al., 2008). Ajayi et al. (2015) found that BIM construction waste can be reduced by up to 45% by utilising BIM.

Minimisation of Waste and IBS

The ability of IBS, such as minimising errors on-site, has been known as an effective method in minimising waste in construction (Kamar et al., 2010). IBS enhances the handling of material much better, which can reduce waste, mainly from transporting materials at sites. The manufacturing component of IBS in a controlled environment contributes to waste reduction due to accurate measurements and enabling off-cut recycling. The reuse of materials in the system of IBS allows components to be redesigned for usage in future projects (Gibb & Isack, 2003). The usage of IBS minimises rework and reduces wastage of material wastage (Mydin et al., 2014).

The Synergising Between IBS and BIM in Minimisation of Waste

The synergising between IBS and BIM improved efficiency and precision in planning, design and construction. BIM is able to provide a class-free precise design which aligns with the components of prefabricated specifications (Liu et al., 2017). This integration improved construction activities with fewer errors and rework and reduced wastage of material (Azhar et al., 2012). The utilisation of simulations through BIM for virtual can identify design clashes in design at the early stage beginning before manufacturing the components, thus avoiding errors and material wastage. IBS's integration with BIM can optimise on-site logistics and can implementing just-in-time which can reduce the need for storage on-site and reduce wastage of material (Rocha et al., 2022). IBS and BIM also facilitate the implementation of lean construction, where waste can be minimised by using streamlined processes (Abanda et al., 2017).

Literature Gap

There is limited evidence of empirical on the impact of integration between IBS and BIM for construction waste minimisation and safety. There is a lack of analyses on the benefits of combining BIM and IBS that examine their impact on the reduction of waste. Therefore, more study is needed to study how BIM and IBS can be integrated effectively for construction projects where these technologies remain low in terms of adoption. This research aims to close the gaps by assessing the combined impact of BIM and IBS on wastage in construction projects.

METHODOLOGY

Design of Research

The design of the research focuses on investigating the relationship between the implementation of IBS and BIM and the impact on the minimisation of waste in construction projects. Data analysis is carried out using PLS-SEM. PLS-SEM is relevant to this research because the smaller sizes of samples can also be analysed in order to model the complex relationships of latent variables (Hair, 2022). The framework of the research comprises multiple variables, including the implementation of BIM and IBS and the minimisation of waste in construction.

Population and Sampling

The population includes professionals having experience with BIM and IBS in their projects, comprising engineers, architects, contractors, BIM coordinators and project managers for public and private sector projects. The selection of participants is made using a purposive sampling technique, which is relevant to the objectives of the research (Palinkas et al., 2015). The sample size is determined based on the guidelines for PLS-SEM used in the outer model is used to determine sample size which states that the sample size is 10 times the largest number of indicators (Hair, 2022). Therefore, 325 respondents are taken for analysis of PLS-SEM.

Data Collection

A structured questionnaire was sent in person and online to construction professionals in construction for data collection. The questionnaire provides four sections: Section A (demographic information) items related to education, gender, years of experience in construction, and familiarity with IBS and IBS; Section B (implementation of BIM) measures the adoption of BIM in key aspects like integration of design at the beginning stage, simulation of virtual construction and optimisation of materials. Section C (implementation of IBS) assesses practices of IBS such as control of quality, modularisation and prefabrication. Section D (minimisation of waste in construction) assesses strategies for minimising waste in construction, including practices of sustainability, including lean construction and recycling, as per Table 1.

Table 1. Variables for The Analysis

Section B	**Factors for Implementation of BIM on Waste in Construction and Safety**
B1	Integration of design at early stage
B2	Simulation for virtual construction
B3	Modularisation and standardisation
B4	Optimisation of material
B5	Disassembly design
B6	Control of quality
B7	Optimisation of cost
B8	Workforce with skill
B9	Communication and collaboration
B10	Principles of lean
Section C	Factors for implementation IBS on minimisation waste of construction:
C1	Modularisation and prefabrication
C2	Environmental control
C3	Manufacture design
C4	Material optimisation of material
C5	Quality control of quality
C6	JIT
C7	Measures of safety
Section D	Factors of minimisation waste in construction
D1	Efficiency of material
D2	Deconstruction design
D3	Recycling and segregation on-site
D4	Lean of construction
D5	Practices for sustainability
D6	Education and training
D7	Adoption of technology

Data Analysis

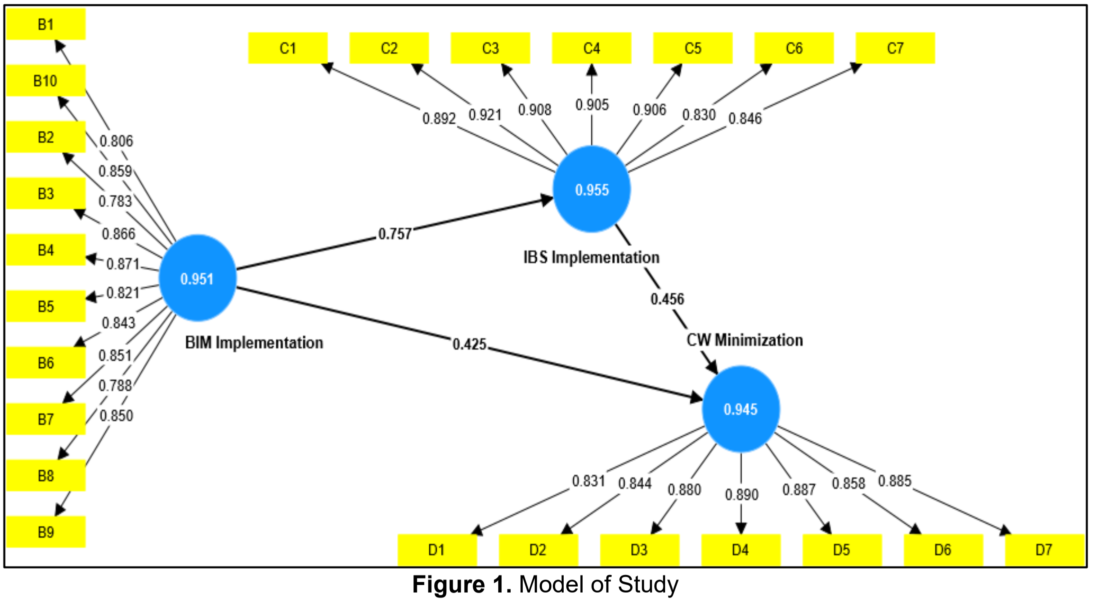

Figure 1. Model of Study

Indicator reliability is mentioned in Figure 1, where a value of 0.7 loading items was considered reliable. Items with values of 0.5 and 0.7 were used if they could fit the model. Composite reliability (CR) was used to verify the reliability of internal consistency. 0.7 of value considered reliability in good status. While 0.5 value means that variables of latent experienced a variance of indicator more than 50%. (Fornell & Larcker, 1981). Each variable of latent was considered distinct by using discriminant validity (Henseler et al., 2015). In the second stage, relationships between variables of latent were analysed by using path coefficients to establish their relationships with bootstrapping, which were utilised to check significance. The R^2 value was used to determine the variance by independent variables. The effect size was assessed, with values of 0.02, 0.15 and 0.35 values representing small, medium and large effects used in order to determine effect size (f^2) (Cohen, 1988).

RESULTS AND DISCUSSION

Assessment for Model of Measurement

Results for Outer Loading

The results for outer loadings, as shown in Table 2, mention that the implementation of BIM constructs a high level of reliability with the implementation of IBS and minimisation of construction waste (CW). There are strong construct associations for the implementation of BIM, with the loading values being from 0.783 to 0.871. Also, the IBS implementation showed that the loading was very high, between 0.830 and 0.921, establishing a strong construct. Minimisation of CW also shows high loadings from 0.831 to 0.890, indicating that each item variable of latent reflects effectively. The measurement model is reliable, as shown by the strong loadings of the outer across all constructs, ensuring the analysis is valid.

Table 2. Result of Outer Loadings

Variables of Latent	Outer Loadings
B1 <- Implementation of BIM	0.806
B10 <- Implementation of BIM	0.859
B2 <- Implementation of BIM	0.783
B3 <- Implementation of BIM	0.866
B4 <- Implementation of BIM	0.871
B5 <- Implementation of BIM	0.821
B6 <- Implementation of BIM	0.843
B7 <- Implementation of BIM	0.851
B8 <- Implementation of BIM	0.788
B9 <- Implementation of BIM	0.850
C1 <- Implementation of IBS	0.892
C2 <- Implementation of IBS	0.921
C3 <- Implementation of IBS	0.908
C4 <- Implementation of IBS	0.905
C5 <- Implementation of IBS	0.906
C6 <- Implementation of IBS	0.830
C7 <- Implementation of IBS	0.846
D1 <- Minimisation of CW	0.831
D2 <- Minimisation of CW	0.844
D3 <- Minimisation of CW	0.880

Variables of Latent	Outer Loadings
D4 <- Minimisation of CW	0.890
D5 <- Minimisation of CW	0.887
D6 <- Minimisation of CW	0.858
D7 <- Minimisation of CW	0.885

Reliability and Validity

There is strong validity of the construct for the implementation of BIM, minimisation of CW and implementation of IBS, as shown in Table 3. Cronbach's alpha showed a level of consistency at a very high level with values of 0.951, 0.945 and 0.955. Values of composite reliability of 0.955 to 0.963 are also very high, establishing that each construct is reliable. Moreover, the validity is adequate because all constructs are more than 0.5. The model of measurement is reliable and valid with the robustness of the constructs in respective concepts.

Table 3. Result of Validity and Reliability

Validity and Reliability Construct				
Variables of Latent	**Cronbach's Alpha**	**Reliability of Composite (rho_a)**	**Reliability of Composite (rho_c)**	**Average of Variance (AVE)**
Implementation of BIM	0.951	0.953	0.958	0.696
Minimisation of CW	0.945	0.946	0.955	0.754
Implementation of IBS	0.955	0.956	0.963	0.787

Validity of Discriminant

Discriminant is valid, as shown in Table 4, for all constructs. Each construct AVE values along 0.834, 0.868 and 0.887 are more than values of correlation between constructs. This established that each construct fulfilling the criterion for Fornell-Larcker is valid with more variance shared with its own indicators compared to others. This result established that distinct constructs enhance the model's reliability for measuring BIM implementation of BIM, minimisation of CW, and implementation of IBS.

Table 4. Validity of Discriminant

Validity of Discriminant - Fornell-Larker Criterion			
	Implementation of BIM	**Minimisation of BIM**	**Implementation of IBS**
Implementation of BIM	0.834		
Minimisation of CW	0.770	0.868	
Implementation of IBS	0.757	0.778	0.887

The measurement model is valid and reliable, aligning with the hypotheses on the implementation of BIM, implementation of IBS, and minimisation of CW, as shown in Tables 2,3 and 4. Outer loadings are strong for all indicators, establishing that the indicator is reliable in its construct, as shown in Table 2. Values for Cronbach's alpha, reliability of composite and AVE, as shown in Table 3, are very high, indicating the consistency for internal is robust and valid, establishing the reliable constructs for measurement of the implementation of BIM, implementation of IBS and minimisation of CW. As such, these valid results support the assessment of the impact of waste reduction.

Evaluation of Structural Model

Results of Path Coefficient

The path for the implementation of BIM to minimisation of CW shows a 0.425 coefficient value with a high p-value (0.0000) and T statistic (6.513), suggesting that the implementation of BIM influences the minimisation of CW in a very positive manner. The path from the implementation of BIM to the implementation of IBS shows a coefficient of 0.757, p-value of 0.0000 and T statistic of 21.561, indicating that the implementation of BIM supports the implementation of IBS significantly. Furthermore, IBS implementation has a direct positive impact on CW minimisation, with a path coefficient of 0.456, T statistic of 6.693 and p-value of 0.0000, indicating that implementation of IBS has a direct positive impact on the minimisation of CW.

Table 5. Result for Path Coefficient

	Path Coefficients	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Implementation of BIM −> Minimisation of CW	0.425	0.425	0.427	0.065	6.513	0.0000
Implementation of BIM −> Implementation of IBS	0.757	0.757	0.756	0.035	21.561	0.0000
Implementation of IBS −> Minimisation of CW	0.456	0.456	0.454	0.068	6.693	0.0000

Values of R-Square

The variance for CW minimisation and IBS implementation is substantially represented by the value of R-square in Table 6. The minimisation of CW's R-square value is 0.682 (adjusted R-square = 0.680), indicating that 68.2% of the variance in the minimisation of CW is shown by the model's predictors of implementation of BIM and implementation of IBS. This establishes a strong power of explanatory for the model in predicting the minimisation of construction waste. The R-square for the implementation of IBS is 0.573 (adjusted R-Square = 0.572), indicating that BIM Implementation of BIM explains 57.3% of the Implementation of IBS in terms of variance. These high values of R-square establish a model is fit.

Table 6. Values of R-Square

	R-Square	Adjusted R-Square
Minimisation of CW	0.682	0.680
Implementation of IBS	0.573	0.572

Values of F-Square

Values of 0.35, 0.15 and 0.02 indicate large, medium and small sizes of effect, as mentioned by Cohen (1988). The size of the effect of BIM implementation of BIM on the minimisation of CW is 0.243, indicating a medium-to-large effect, establishing that the implementation of BIM contributes significantly to waste minimisation of waste. The effect of BIM implementation on IBS implementation is 1.342, indicating there is a very large size of the effect of the implementation of BIM on the implementation of IBS in enhancing the practices of IBS, which is very substantial. The size of effect 0.279 for the implementation of IBS on CW minimisation also represents a medium-to-large effect, which establishes the implementation of IBS's impact on minimising waste in construction projects.

Table 7. Value of F-Square

	F-Square
Implementation of BIM –> Minimisation of CW	0.243
Implementation of BIM –> Implementation of IBS	1.342
Implementation of IBS –> Minimisation of CW and safety	0.279

Path coefficient of 0.425, p-value (0.0000) and T statistic (6.513) establish a relationship between the implementation of BIM is very positive and significant with minimisation of CW. BIM implementation positively influences IBS implementation and shows strong support with a substantial path coefficient of 0.757, a p-value of 0.0000 and a T statistic of 21.561, indicating a strong predictor with BIM towards IBS Implementation of IBS. A path coefficient of 0.456, p-value of 0.0000 and T statistic of 6.693 suggest an impact is very positive and significant. Overall, these results show that the implementation of BIM improves both IBS implementation of IBS and CW minimisation of CW effectively. In contrast, IBS implementation of IBS enhances the reduction of waste in construction.

BIM and IBS play significant roles in improving sustainability in construction projects based on the identification of relationships between IBS, BIM, minimisation of construction waste and safety. The findings show that BIM implementation of BIM also supports practices of IBS strongly together with reducing waste from the construction. The finding concurs with studies previously done by Won and Cheng (2017), also mentioning that improving the planning of the projects and optimisation of materials can minimise construction waste together with utilising IBS and BIM. However, the present research furthers the study on the integration of BIM with IBS, which has a significant impact, especially in the reduction of construction waste. This integration concurs with Gibb and Isack's (2003) finding that project planning together with prefabrication, can reduce waste and optimise project efficiency.

A STUDY ON THE MATERIAL WASTE QUANTIFICATION AND MITIGATION IN CONSTRUCTION PROJECTS

By combining the advantages in terms of optimisation of material, detection of clashes and collaboration of projects, the integration of BIM and IBS can improve the issue of waste minimisation at construction sites. When combined with IBS's prefabrication techniques, materials can prepare to correct specifications in the quality environments, further optimising waste according to adjustment on-site. Project collaboration can also be improved as BIM uses a centralised system for model sharing in real-time, which can ensure that designers and contractors refer to the same detailed design. Thus, errors can be reduced to a minimum. This is also very effective with IBS integration; any errors or clashes can be rectified immediately before components are prefabricated, thus reducing waste in material, delay and avoiding alterations on-site.

CONCLUSIONS

The research identified that integrating BIM and IBS has a very significant impact on minimising waste in construction. Therefore, enhancing towards more safety and sustainable practices in construction projects. The findings establish that BIM and IBS encourage the reduction of waste. Moreover, the integration provides benefits such as optimising material usage, facilitating collaboration, and enabling the detection of clashes. This integration improves the efficiency of projects and alignment with teams in construction projects. By establishing the effectiveness of the integration of BIM and IBS, this study provides valuable insights into sustainable practices for construction projects. Furthermore, encouraging the integration of BIM and IBS can improve the minimisation of waste substantially and meet the sustainable practices in the construction industry.

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SUSTAINABLE DESIGN CRITERIA FOR GREEN OFFICE BUILDINGS

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Abstract
Cities serve as home to over 50% of the global population and are crucial to many of a nation's major economic endeavours. Significant rises in carbon dioxide emissions brought about by human activity have made the discrepancy between actual emissions and the target of reducing global warming even more pronounced. Office buildings are a major contributor to climate change; in response to this, there is an increase in demand for green office buildings. Therefore, this paper aims to report a study that explores the key sustainable design concepts that are incorporated into the designing stage of green office building projects. 143 construction stakeholders responded to the questionnaires, which were used as the data collection method. From the data analysis, it was found that energy efficiency is the fundamental design criterion used in designing green office buildings, followed by renewable energy integration, usage of sustainable materials, waste conversation, indoor air quality improvement, waste reduction, and biodiversity enhancement. All the parties involved in the construction process need to work together to accomplish the primary goals of green buildings, which are reducing energy use, avoiding or minimising greenhouse gas emissions, and protecting biodiversity and ecosystems. Much empirical research is needed to identify the obstacles that building owners must overcome to make their buildings sustainable to highlight the significance of lowering carbon footprints for Malaysia to become a low-carbon city by 2030.

Keywords: *Carbon Footprint; Energy Efficiency; Green Office; Well-Being; Workplace*

INTRODUCTION

Sustainable architecture is a key objective in modern design, emphasising a transition toward greener practices. Green design benefits the environment by reducing pollution, conserving resources, and minimising environmental harm. It also enhances occupant productivity while lowering energy and water costs (Asman, Kissi, Agyekum, Baiden, & Badu, 2019). Buildings impact both health and the environment, leading to the rise of "green building," which integrates resource efficiency, building performance, and occupant well-being throughout a structure's lifecycle (Ashmawy, Ragheb, Ragheb, & Marouf, 2024; Ayarkwa, Opoku, Antwi-Afari, & Li, 2022).

Liu et al. (2022) reported a more than 20-fold increase in global temperature, with projections indicating a rise of over 4°C by 2100, following an increase of over 1°C between 1880 and 2000. This raises concerns about ecosystems' ability to adapt. A major contributor to global warming is the greenhouse effect caused by industrial pollution, which increases atmospheric gas concentrations (Zhuan, Abidin, Mohd, & Darus, 2023). Reducing greenhouse gas (GHG) emissions is essential to mitigating climate change. Building design professionals are adopting sustainable strategies to conserve resources, prevent land contamination, and reduce energy consumption. Green building practices have become a key approach to minimising construction's environmental impact (Kamath et al., 2019; Lakhiar et al., 2024a).

Lakhiar et al. (2024b) and Sanmargaraja et al. (2023) highlighted that "green building" aims to reduce environmental impacts throughout a building's life cycle. These buildings offer lower carbon emissions, energy savings, and greater economic benefits, making them more commercially valuable than conventional structures. As a result, green building may become essential in future urban architecture. Climate-resilient buildings use locally available recyclable materials and energy-efficient technologies to reduce costs and environmental effects. Green refurbishments also provide significant energy and carbon dioxide savings (Ayarkwa et al., 2022; Lakhiar et al., 2023).

Green construction principles benefit both new and refurbished buildings, but tenants in multi-tenant office buildings may face challenges in implementing major retrofits (Gou, 2016). Additionally, research on green office building design criteria remains limited (Liu et al., 2022). In Malaysia, sustainable development has been promoted since the Ninth Malaysia Plan (2006–2010) and continued through the 11th Malaysia Plan (2016–2020). However, construction stakeholders have been less willing to adopt green practices, necessitating further research in this area (Saharuddin et al., 2023; Zainordin, Ismail, Toh, & Omar, 2023). This study investigates key design criteria to provide insights for developers, policymakers, and stakeholders in advancing green office buildings in Malaysia.

The World Green Building Council (2022) defines Green Building Rating Tools (GBRTs) as assessment systems that evaluate buildings' compliance with environmental sustainability standards. Various countries have developed their rating systems, such as LEED (U.S.), GBCC (Korea), BREEAM (U.K.), and Green Mark (Singapore). In Malaysia, available GBRTs include the Green Building Index (GBI), Green Real Estate (GreenRE), Green Mark, Green Star, MyCREST, and the Low Carbon City Framework (LCCF). These tools assist architects, engineers, and developers in designing energy-efficient buildings that reduce greenhouse gas emissions and protect biodiversity. However, Malaysia's green building movement is still in its early stages, requiring more incentives and awareness to promote sustainable practices (Lam, Wong, Tan, & Yap, 2024).

LITERATURE REVIEW

Olanrewaju, Sanmargaraja, Tan, and Chu (2024) outline seven key design principles for green office buildings: energy efficiency, sustainable materials, water conservation, waste reduction, indoor air quality improvement, renewable energy integration, and biodiversity enhancement. Achieving sustainability in the building industry requires a multi-disciplinary approach, focusing on energy efficiency, material optimisation, waste reduction, and pollution control (Akadiri, Chinyio, & Olomolaiye, 2012; Ardiani & Shateri, 2018). Enhancing current building practices can reduce environmental harm while maintaining functionality. A sustainable building design framework is shaped by three main objectives: resource conservation through efficient material and energy use, cost efficiency by balancing initial investments with long-term savings, and human-centred design that ensures comfort, resilience, and alignment with social, environmental, and economic sustainability principles.

Energy Efficiency

As the global population grows, so does energy demand, with buildings being a major contributor to energy consumption. Many existing structures worldwide, including in Malaysia, are not energy efficient. Additionally, Malaysia's reliance on fossil fuels for energy production contributes to greenhouse gas emissions and global warming (Goh, Zainordin, & Khoo, 2024). Energy efficiency is crucial in green building, as it helps minimise environmental, economic, and social impacts. Key strategies for sustainable buildings include building-integrated photovoltaic (BIPV) façades, PV installations, efficient lighting, resource-conscious building envelopes, wind turbine integration, energy-saving techniques, multi-objective search approaches, energy modelling, overall thermal transfer value calculations, innovative energy concepts (Hafez et al., 2023).

Improving energy performance in office spaces can begin with energy-efficient lighting. Indirect ambient lighting can replace direct lighting for better comfort, while sensors and control systems can automatically switch off electrical lights when sufficient daylight is available. Additionally, HVAC systems with automatic speed and pump controls can enhance efficiency, potentially reducing overall energy consumption by up to 40% (Pauzi, Yeow, Go, & Hadibarata, 2021). Energy efficiency also includes low-energy fixtures and renewable energy sources such as geothermal, hydropower, wind, and biomass, all of which contribute to sustainable building practices (Bashir, Ahmad, Sale, Abdullahi, & Aminu, 2016).

Use of Sustainable Materials

Natural architecture is inherently sustainable as it minimises reliance on modern energy-dependent technologies. Achieving optimal architectural performance in terms of cost, efficiency, and environmental impact requires thoughtful design, appropriate building materials, and viable construction techniques. Green building materials play a crucial role in sustainable architecture, especially given the construction sector’s high consumption of natural resources. In the U.S., 60% of raw materials used in construction come from surplus and non-hazardous solid waste (Alhalabi, 2018; Neyastani, 2017). Utilising green materials such as reusable, recyclable, and energy-efficient ones helps to reduce energy waste in buildings. Additionally, recycling and reclaiming construction materials lower carbon dioxide emissions and energy consumption by minimising the need for raw material extraction, processing, and long-distance transportation (Altuhaf, Mahmoud, & Alaane, 2023).

Efficient engineering design and the use of waste materials should replace non-renewable building materials. Preference should be given to materials with minimal environmental impact, such as recycled content materials and engineered composite materials. These modern materials, including insulated concrete and composites, offer superior strength and durability compared to conventional materials. Additionally, high-recycled-content materials like recycled concrete aggregate, fly ash, and slag can be incorporated into construction. Reconditioned office furniture and chairs made from recycled materials also contribute to sustainability (Sitanggang & Susanto, 2017).

Water Conservation

Global water consumption is exceeding sustainable limits at an increasing rate, necessitating conservation efforts in workplaces through green office policies. Water can be collected, saved, filtered, and reused, making it a vital resource in green building design. Implementing dual plumbing systems to recycle water for toilet flushing or car washing can help conserve water throughout a building's lifespan. Additionally, emphasising the recycling and reuse of stormwater, greywater, and rainwater reduces unnecessary potable water consumption. Efficient stormwater management systems should align with natural hydrological processes, preserving stormwater retention, recharge systems, and water infiltration (Aroonsrimorakot, Laiphrakpam, & Korattana, 2019). A thorough analysis is required to identify cost-effective, time-efficient, and environmentally beneficial designs. Furthermore, preserving mature vegetation is crucial, as plants contribute to evapotranspiration, absorbing and redistributing up to 30% of precipitation on-site (Pauzi, Yeow, Go, & Hadibarata, 2021).

Waste Reduction

Reducing wastewater production in the workplace helps conserve natural resources and mitigate environmental pollution. Efforts to minimise office waste should include visible recycling centres, such as those in Singapore, and promoting reuse and recycling among employees. Educational materials like graphics, posters, and photographs on office walls or notice boards can help staff identify and sort waste correctly. Additionally, emails can be used to inform employees about recycling procedures. Contractors responsible for recycling should determine which plastic types are suitable for reprocessing (Aroonsrimorakot et al., 2019; Yuan & Tang, 2021).

Designers play a crucial role in minimising construction waste by implementing material standardisation, component prefabrication, and emerging BIM technology. Effective waste management begins with designing to minimise waste, while builders should consider material life cycles to optimise usage, longevity, demand, and cost. Reusing and recycling materials are cost-effective and sustainable strategies applicable to all economies and communities (Amaral et al., 2020). Plastics pose a significant challenge to sustainability, yet their affordability, versatility, and durability make them essential for industries like packaging. Despite being produced for over 60 years, plastic production has surged, reaching 8.3 billion metric tonnes, most of which are disposable and end up as waste (Nandy, Fortunato, & Martins, 2022).

Indoor Air Quality Improvement

Indoor environmental quality (IEQ) is essential for occupant health and productivity. Green buildings improve indoor air quality (IAQ), reducing sick building syndrome (SBS) caused by poor ventilation, high temperatures, and pollution. Good IEQ enhances decision-making and workplace comfort, ensuring no harmful pollutants are present (Felgueiras et al., 2023). However, balancing energy efficiency and maintaining optimal indoor conditions remains a challenge in green building design (Altomonte et al., 2019).

Buildings should incorporate ample windows and natural ventilation to enhance airflow. Thoughtfully placed ventilation systems ensure efficient heating, cooling, and pollutant filtration, providing clean air for occupants. Since air conditioning and ventilation account for over half of a building's energy use, an integrated control system is essential (Pauzi et al., 2021). Sustainable materials like low-VOC paints, recycled materials, and responsibly sourced timber further reduce environmental impact and improve indoor air quality (Khan et al., 2023).

Renewable Energy Integration

The ASEAN region receives 2000–2600 hours of sunlight annually, making solar energy a widely available renewable resource (Pauzi et al., 2021). Solar air conditioning, water heaters, and cells are common in green buildings, though low energy conversion rates remain a challenge. Further research is needed to enhance efficiency and expand integration with other green technologies (Pauzi et al., 2021). Additionally, renewable energy sources like wind, hydro, biomass, and geothermal are gaining attention for their environmental benefits and cost-saving potential in electricity generation (Ang et al., 2022).

Biodiversity Enhancement

Enhancing biodiversity through green building design is vital for sustainable urban development. Green roofs and walls provide habitats for urban wildlife, promoting ecological connectivity (Mayrand & Clergeau, 2018). Integrating nature-based solutions, such as urban green spaces, rain gardens, and vegetated facades, enhances urban resilience while supporting biodiversity (Francesco, 2024). Using native plants in green buildings benefits local ecosystems, strengthening the relationship between human settlements and nature for long-term sustainability (Francesco, 2024).

METHODOLOGY

This study gathered data from the International Architecture, Interior Design, and Building Exhibition (ARCHIDEX) 2024, held at the Kuala Lumpur Convention Centre (KLCC) from July 2–5. As Malaysia's largest architectural exhibition, ARCHIDEX 2024 spanned 26,000 square meters, hosting 700 local and international exhibitors across 1,500 booths. The event attracted approximately 40,000 visitors from over 100 countries, serving as a platform for industry professionals to explore emerging trends and innovations in architecture and design.

The study employed a purposive sampling technique to distribute the questionnaire, as described by Olanrewaju, Idrus, and Khamidi (2011), which is effective when researchers aim to select participants with specific characteristics. The questionnaire focused on key sustainable design aspects, including energy efficiency, biodiversity enhancement, indoor air quality, water conservation, sustainable materials, waste reduction, and site sustainability. The survey targeted ARCHIDEX participants from various sectors, including architecture, engineering, quantity surveying, contracting, material supply, government agencies, private companies, and property development. A total of 143 participants responded, and Kuder-Richardson reliability analysis was conducted to ensure data consistency.

FINDINGS AND DISCUSSION

findings and discussion session are divided into two sections which are the respondents' demography and sustainable design principles for green office buildings.

Respondents' Demography

Figure 1 indicates that most survey participants are from Malaysia, Pakistan, the United Arab Emirates, Taiwan, Singapore, Hong Kong, Australia, Indonesia, and the United States of America, following in order of participation. In addition, the results also show that 74.1% of respondents are from Southeast Asia, with 12.6% coming from South Asia, 7% from the Middle East, 4.9% from Eastern Asia, and roughly 1.4% from the Western Region.

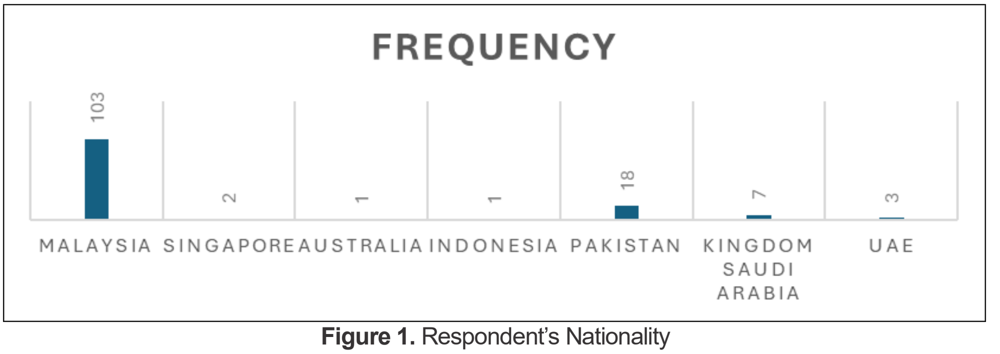

Figure 1. Respondent's Nationality

Table 1 shows that almost 49.7% of the overall respondent population has an engineering background, followed by 16.8% with an architecture background, 32.9% with a construction background, and roughly 0.7% with a background in another discipline.

Table 1. Respondent's Academic Background

Background	Frequency
Quantity surveying	9
Construction management	10
Architecture	24
Engineering	69
Facility management	5
Building surveying	13
Building technology	9
Fresh graduate in civil engineering	1
Bachelor of arts	1
Environmental engineer	1
Others	1

More than 34% of the respondents have 5 to 10 years of work experience, followed by 24.5% who have less than 5 years, 24.5% who have 11 to 15 years, 11.2% who have 16 to 20 years, and 5.6% who have more than 20 years (Figure 2).

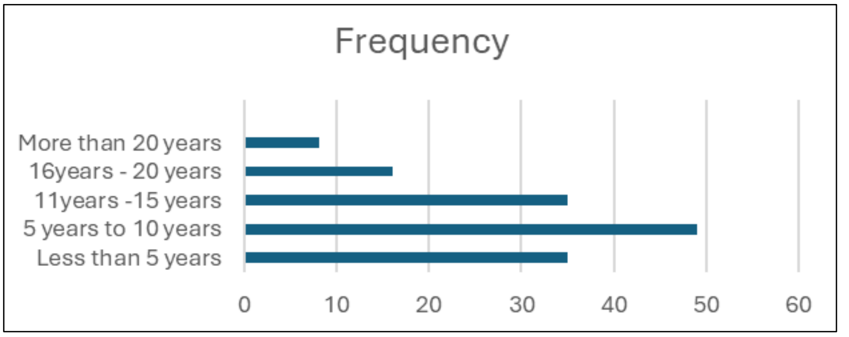

Figure 2. Respondent's Work Experience (Years) in The Construction Industry

Most (45.5%) of the respondents are from consulting firms, 9.1% are contractors, 13.3% are suppliers of materials, and 32.1% are from other organisations (Table 2).

Sustainable Design Principles for Green Office Buildings

The results demonstrate a strong level of internal consistency among the seven items in Table 3 and Table 4, with a Cronbach's Alpha of 0.7 or higher, which is considered acceptable for measuring the design criteria for green buildings. Water Conservation and Waste Reduction contribute significantly to scale reliability, whereas Energy Efficiency and Renewable Energy Integration have lower contributions but remain within acceptable limits. Notably, removing Waste Reduction would decrease Cronbach's Alpha to 0.688, highlighting its critical role in maintaining scale reliability.

Table 2. Respondent's Type of Organisation

Organisation	Frequency
Consulting architecture firm	39
Consulting engineering firm	22
Consulting quantity surveying firm	3
Contractors	13
Material suppliers	19
Public- government	3
Private company	31
Property developer	2
Teaching and research	1
Software developer	1
Sustainability consulting	1
Others	8

Removing items such as Energy Efficiency or Renewable Energy Integration would only slightly improve reliability, justifying their inclusion for comprehensive content coverage. The Intraclass Correlation Coefficient (ICC) indicates moderate reliability for individual items, suggesting some variability in single-item ratings, which is expected in multi-item scales.

The average ICC measure of 0.760 indicates good reliability, aligning with Cronbach's Alpha and confirming the consistency of the green building design criteria. The significant F-test validates that the observed ICC is not random but reflects true consistency. Overall, the scale reliably assesses the perceived importance of design criteria, with Waste Reduction and Water Conservation emerging as the strongest indicators.

Table 3. Item-Total Statistics

	Scale Mean If Item Deleted	Scale Variance If Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha If Item Deleted
Energy efficiency	3.504	3.717	0.367	0.752
Water conservation	3.636	3.275	0.557	0.714
Use of sustainable materials	3.6084	3.451	0.459	0.735
Waste reduction	3.769	3.052	0.662	0.688
Indoor air quality improvement	3.734	3.380	0.456	0.736
Renewable energy integration	3.587	3.582	0.388	0.749
Biodiversity enhancement	3.923	3.410	0.457	0.736

Table 4. Intraclass Correlation Coefficient

	Intraclass Correlation	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single measures	0.312a	0.246	0.388	4.173	142	852	0.000
Average measures	0.760c	0.695	0.816	4.173	142	852	0.000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent because it is not estimable otherwise.

Table 5 indicates that 18.4% of respondents consider energy efficiency the most critical sustainable design criterion for green office buildings. Energy efficiency reduces energy demand for services like lighting and HVAC, reinforcing sustainability efforts. Chen and Abu al-Rejal (2015) highlight energy efficiency as a key strategy for lowering greenhouse gas emissions. Historical examples include U.S. energy-saving measures introduced during the 1970s energy crises and Nigeria's initiatives to promote efficiency in housing, transportation, and industrial sectors through collaboration with research institutions (Chen & Abu al-Rejal, 2015).

Table 5. Sustainable Design Principles for Green Office Building Projects During the Design Phase

Principle	Frequency
Energy efficiency	113
Renewable energy integration	101
Use of sustainable materials	98
Water conservation	94
Waste reduction	75
Biodiversity enhancement	53

The International Energy Agency (IEA) projects that global building energy consumption will rise from 33% in 2017 to 55% by 2050. Implementing simple design, construction, and operational strategies can enhance energy performance. However, in many emerging nations, sustainability goals are often overlooked, leading to increased energy consumption. Reducing electricity use can also lower CO_2 emissions from power generation. Stakeholders in the building sector increasingly acknowledge that monitoring sustainability criteria can significantly mitigate climate change impacts (Nkini, Nuyts, Kassenga, Swai, & Verbeeck, 2023).

The data indicate that 16.5% of respondents consider renewable energy integration the second most important sustainable design feature for green office buildings. Incorporating renewable sources like solar, wind, geothermal, and biomass into a building's lifecycle can reduce reliance on fossil fuels and enhance environmental sustainability (Chen et al., 2024). Historically, passive solar design influenced building orientation by optimising natural ventilation and sunlight.

Smart buildings utilise advanced sensors, controls, and systems to dynamically adapt to their environment and occupants' needs, enhancing energy efficiency (Orikpete, Ikemba, & Ewim, 2023). This integration of technology, architecture, and energy management reduces waste and allows excess energy to be returned to the grid. Energy efficiency is not just about consuming less energy but using it optimally to minimise waste and maximise utility.

Survey results indicate that respondents ranked the use of sustainable materials as the third most important factor in green office building design. Sustainable materials enhance building performance, improve occupant comfort, and support better health outcomes (Sheth, 2016). Green buildings can reduce indoor temperatures by 5°C in summer and remain 2°C warmer in winter, leading to a 30% reduction in energy consumption compared to conventional buildings (Patel & Patel, 2021).

Survey respondents ranked water conservation as the fourth most important factor in green office building design. With the rising global population, freshwater demand is increasing, and the United Nations projects that by 2050, up to 5 billion people could face water shortages. To address this, it is crucial to protect water resources and prevent pollution (Das, Bera & Moulick, 2015; Basil, Agu & Agbo, 2022). Water conservation strategies include using water-efficient fixtures such as ultra-low flushing toilets, bidets, and low-flow showerheads, as well as dual plumbing systems that recycle water. Other methods include rainwater harvesting and greywater recycling (Das, Bera & Moulick, 2015; Basil, Agu & Agbo, 2022).

Indoor air quality (IAQ) improvement was ranked as the next important design principle by 13.0% of respondents. Senitkova (2017) highlighted the growing recognition of IAQ as a key factor affecting occupants' health and well-being. Proper ventilation is essential, as poorly ventilated buildings are more prone to indoor air quality issues. Ensuring sufficient outdoor air supply can help reduce indoor pollutant exposure. Wu et al. (2021) noted that thermal environment and air quality significantly influence human responses, yet post-assessments of IAQ in office buildings, particularly green office buildings, remain limited.

Waste reduction was identified as an important design principle by 12.2% of respondents. Akdağ and Beldek (2017) emphasised that managing construction waste alone is insufficient; material design should also be considered during the design phase to optimise energy savings. Green building design can lead to significant reductions, including 30% energy savings, 35% carbon savings, 30–50% water savings, and 50–90% cost savings. Omeje and Okanya (2024) highlighted the need to replace the traditional cradle-to-grave approach with a cradle-to-cradle system, allowing materials to be repurposed rather than discarded after a single use.

Biodiversity enhancement was the least prioritised design principle, selected by 8.6% of respondents. Incorporating green building elements, such as vegetation, improves indoor air quality, reduces carbon emissions, and enhances occupant satisfaction. Green building assessment tools help developers and consultants create sustainable buildings that conserve energy, mitigate greenhouse gas emissions, and protect biodiversity (Lam et al., 2024). Additionally, other important design principles include natural lighting, ventilation, green roofs, smart building technologies, and transportation alternatives (Ashmawy et al., 2024).

CONCLUSIONS

This study explored key sustainable design concepts in green office building projects, highlighting energy efficiency as the top priority due to high electricity consumption during operations. Renewable energy integration and sustainable materials ranked next, while waste reduction and biodiversity enhancement received less emphasis. Achieving green building goals by reducing energy use, lowering greenhouse gas emissions, and preserving ecosystems requires collaboration among designers, contractors, developers, policymakers, and government authorities.

Designers should implement holistic strategies, integrating passive and active design techniques, renewable energy, and climate-responsive solutions to reduce energy consumption, particularly in air conditioning. Policymakers must enforce energy efficiency regulations and offer incentives, such as tax waivers, to encourage sustainable practices. Despite challenges like stakeholder reluctance during data collection, further research is needed to overcome barriers and support Malaysia's goal of achieving low-carbon city status by 2030. Future studies should focus on interviews with Green Building Certified building owners to understand certification challenges.

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GUIDE TO AUTHORS

Aims and Scope:

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

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CODIFICATION AND APPLICATION OF SEMI-LOOF ELEMENTS FOR COMPLEX STRUCTURES

(FULL NAME) Ahmad Abd Rahman[1,2], Maria Diyana Musa[2] and Sumiana Yusoff[2]
[1]*Department of Quantity Surveying, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Sarawak, Malaysia*
[2]*Institute of Ocean and Earth Sciences (IOES), University of Malaya, Malaysia*

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

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

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

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

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

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

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

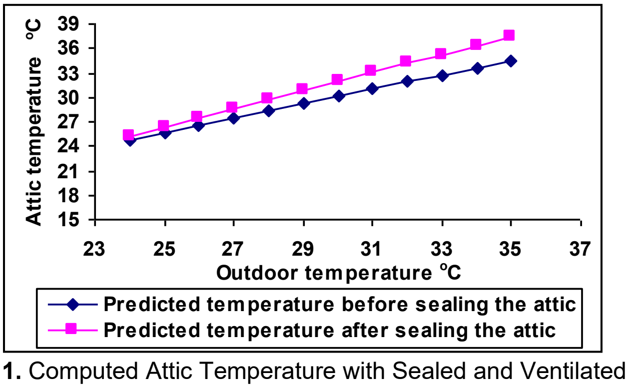

Figure 1. Computed Attic Temperature with Sealed and Ventilated Attic

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

Table caption: Arial Bold + Arial, 9pt. + Capitalize Each Word. Captions should be written above the table.

Table Line: 0.5pt.

Table 1. Recommended/Acceptable Physical Water Quality Criteria

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

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

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

Citation:

Passage Type	First Reference in Text	Next Reference in Text	Bracket Format, First Reference in Text	Bracket Format, Next Reference Marker in Text
One author	Walker (2007)	(Walker, 2007)	(Walker, 2007)	(Walker, 2007)
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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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Johan, R. (1999) Fire Management Plan for The Peat Swamp Forest Reserve of North Selangor and Pahang. In Chin T.Y. and Havmoller, P. (eds) Sustainable Management of Peat Swamp Forests in Peninsular Malaysia Vol II: Impacts. Kuala Lumpur: Forestry Department Malaysia, 81-147.

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

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